Pontificia Universidad
JAVERIANA
Cali

DESIGN OF THE SPATIAL DISTRIBUTION OF THE ROUTES OF THE MIO SYSTEM ACCORDING TO THE QUALITY OF SERVICE PERCEIVED IN THE COMMUNE 18.

PRESENTED BY:

DAVID ALEJANDRO RAMIREZ CAJIGAS

PONTIFICAL UNIVERSITY JAVERIANA CALI

FACULTY OF ENGINEERING

CIVIL ENGINEERING

SANTIAGO FROM CALI

FEBRUARY 2018

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DEGREE PROJECT TO APPLY FOR THE DEGREE OF

CIVIL ENGINEER

DIRECTOR

MARIA FERNANDA GARCIA ALADIN

CIVIL ENGINEERING

FACULTY OF ENGINEERING

SANTIAGO FROM CALI

FEBRUARY 201

Pontificia Universidad JAVERIANA Cali

Facultad de Ingeniería
Secretaría de la Facultad

Acta de Correcciones al Proyecto de Grado
Ingeniería Civil

Fecha: febrero 21-2018

Autores: David Alejandro Ramirez Cajigas

Nombre del Proyecto de Grado: Diseño de la distribución espacial de las rutas del sistema MIO de acuerdo con la calidad del servicio percibido en la Comuna 18

Director: Maria Fernanda García Aladín

Como indica el artículo 2.27 de las Directrices de Trabajo de Grado, he verificado que los estudiantes indicados arriba han implementado todas las correcciones que los Jurados del Proyecto de Grado definieron que se efectuaran, como consta en el Acta de Calificación correspondiente.

Ada García

Firma de Director(a) del Proyecto de Grado

Nota de Aceptación

Aprobado por el Comité de Trabajo de Grado en cumplimiento de los requisitos exigidos por la Pontificia Universidad Javeriana para optar el título de Ingeniero Civil.

Dr. Jaime Aguilar Zambrano
Decano de la Facultad de Ingeniería

Dr. Iván Fernando Otálvaro Calle
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Ing. Luis Fernando Macea Mercado
Jurado 1

Ing. Javier Alexander Pérez Caicedo
Jurado 2

Santiago de Cali, 12 febrero de 2018

Doctor
Iván Fernando Otálvaro
Director de Carrera de Ingeniería civil.
PONTIFICIA UNIVERSIDAD JAVERIANA CALI

Cordial Saludo,

La presente es para comunicarle que como directora de Trabajo de Grado del estudiante DAVID ALEJANDRO RAMIREZ CAJIGAS con código EMPLID 0200379, puedo confirmar que el proyecto "**DISEÑO DE LA DISTRIBUCIÓN ESPACIAL DE LAS RUTAS DEL SISTEMA MIO DE ACUERDO CON LA CALIDAD DEL SERVICIO PERCIBIDO EN LA COMUNA 18.**" ha sido culminado y se encuentra listo para ser sustentado.

Atentamente,

MARIA FERNANDA GARCIA ALADIN
Directora de Trabajo de grado.

Santiago de Cali, 12 febrero de 2018

Doctor
Iván Fernando Otálvaro
Director de Carrera de Ingenieria civil.
PONTIFICIA UNIVERSIDAD JAVERIANA CALI

Cordial Saludo.

Mediante esta carta me permito presentar la corrección del Trabajo de Grado titulado **"DISEÑO DE LA DISTRIBUCIÓN ESPACIAL DE LAS RUTAS DEL SISTEMA MIO DE ACUERDO CON LA CALIDAD DEL SERVICIO PERCIBIDO EN LA COMUNA 18."** el cual se ha culminado exitosamente y está listo para ser sustentado.

Esto con el fin de cumplir con los requisitos exigidos por la Universidad para optar por el título de Ingeniero civil

Atentamente.

David Alejandro Ramirez Cajigas
C.C. 1.144.073.340 de Cali
Código **EMPLID: 0200379**

ACTA

TIPO DE ACTA: **Reunión**
LUGAR: **Oficina MetroCali**
FECHA: **noviembre 23 de 2017**
HORA: **9:00 AM**

ASISTENTES	CARGO
1. Luis Felipe García	Director de Operaciones de MetroCali
2. María Fernanda García	Profesora Pontificia Universidad Javeriana Cali
3. David Alejandro Ramírez	Alumno Pontifica Universidad Javeriana Cali

ORDEN DEL DÍA

1. Presentación del tema de investigación del alumno David A Ramirez C, titulado DISEÑO DE LA DISTRIBUCIÓN ESPACIAL DE LAS RUTAS DEL SISTEMA MIO DE ACUERDO CON LA CALIDAD DEL SERVICIO PERCIBIDO EN LA COMUNA 18.
2. Identificar la información de la Operación de MIO en la comuna 18 que se requiere para el desarrollo del Trabajo de Grado
3. Discusión de la investigación con los expertos

DESARROLLO DE LA REUNIÓN

1. Se realizará un análisis del transporte público en la Comuna 18 con los indicadores topológicos de accesibilidad, los cuales se aplicarán a las rutas internas. Esta investigación está motivada en el hecho de que actualmente la comuna presenta una distribución de paradas muy inferiores a los 300 m y, en general, largos tiempos de viaje. Los usuarios manifiestan complacencia ante el servicio puerta a puerta, pero a su vez el tiempo de viaje es una fuente del descontento de los usuarios con respecto al servicio. Se propone que las paradas de los buses en todo sistema de transporte publico deben planificarse dentro de una distancia adecuada (máximo 300 metros de caminata hasta la estación por parte del usuario) entre una y otra que evite lentitud en el desplazamiento de los vehículos, por lo cual el presente trabajo plantea reubicar los paraderos a una distancia típica de 300 m y además con un radio de cubrimiento de sitios de atracción o concentración de los ciudadanos, que les evite largos y fatigosos desplazamientos entre las paradas y el lugar de destino, pero disminuya el tiempo de viaje, entre otros factores.

2. Debido a la necesidad de realizar la investigación basada en datos reales, que den validez a las conclusiones del trabajo, se realiza la siguiente solicitud de información a Metrocali:

    a. PSO-171107 V3_Rev.xls SIG MIO PSO 171107.kmz, PARADAS.shp y RUTAS.shp, este conjunto de información es la base de datos de todo el sistema de transporte masivo MIO a noviembre de 2017.

    b. La información indicada será procesada solo con fines académicos y seguirá siendo tratada en este mismo contexto.

ACTA

DECISIONES TOMADAS

1. Se le brindo al estudiante de la Pontificia Universidad Javerina Cali, David Alejandro Ramirez Cajigas, los datos correspondientes a las rutas, paraderos y estación existentes a noviembre de 2017, en la comuna 18.

Compromisos		Responsable	Fecha Programada	Fecha Ejecutada
1.	*Realizar la investigación con datos reales suministrados por MetroCali*	*David Alejandro Ramirez C*	*Enero 2018*	*Enero 2018*
2.	MetroCali se comprometió a facilitar la base de datos para ruta y paraderos, de la comuna 2018 a noviembre de 2017	Luis Felipe García A	23 de noviembre de 2017	23 noviembre de 2017

Luis Felipe García

Director de Operaciones MetroCali

David Alejandro Ramírez

Maria Fernanda García

Alumno Pontificia Universidad Javeriana Cali

Profesora Pontificia Universidad Javeriana Cali

Anexos:

Proyecto/ Elaboro:

Original: *(serie: subserie:).*

Copia:

Table of Contents

Index Tables

Index Figure

Image Index

ABSTRACT

In order to propose an adjustment of the spatial distribution of the routes of the MIO system in commune 18 of Cali, to improve the perception of the service by users. I know carried out the present degree work which had as an analysis support the great survey of Mobility 2015, basis of the study that allows issuing the report ¿Cali, how are we doing? Additionally, a pilot test was applied, processed using the IBM SPSS program. Statistics 23, which focused only on commune 18, in order to know in particular the perception of the MIO transport service in the sector. Which together with an informative collection broad and deep, based on primary information provided by MetroCali, such as managing entity of the MIO transport system, and the pertinent secondary information, allowed to reach the indicated objective to which was added the technical evaluation with measures accessibility topologies of existing and proposed routes. Based on this it was concluded that the routes and bus stops should be organized within the commune 18 of Cali, taking care that the users find a whereabouts of the MIO bus within a maximum radius of 300 meters, and that between whereabouts the distance allows the bus driver to reach a greater speed in his displacements, which altogether allows to reduce the travel time to the user, entailing This is so that their perception of the service provided by the transport system can be better. In This work improves the travel times en route without altering the waiting times in the whereabouts and guaranteeing good accessibility.

1. INTRODUCTION

The intention of investigating public transport in the city of Santiago de Cali and the effect on the population, part of the premise that transportation is an essential need of citizens, because moving to the interior of a large city, for economic reasons or social is a daily operation that must be supplied with own or public means or with a combination of both.

Transportation has represented a challenge throughout history for the human being, who in the The modern world is not alone in solving such a challenge, because in organized societies current, represented in each city or municipality, have the actions of the local government, regional and national to find a permanent solution to the need for transportation. The responsible governments know how important it is for their citizens to have effective, efficient and effective transport services. Effective for being fast; efficient by function well, and effectively, because they are well grounded in their operational structure. These characteristics allow transport to be perceived as reliable by users.
citizens, who judge the performance of the local government in relation to the performance of the public transport system operating in the city.

Despite being the focus of daily attention, urban public transport systems are in continuous crisis in large Latin American cities, due to coverage problems geographic location of the service, time of frequency of the passage of vehicles, cost of the passage and other factors, such as availability of roads, provision of urban furniture for stops, security of users of the service and the system itself. There are also other factors arising not only from the growth of the number of inhabitants in each city, but, and more importantly, of the increase of the expectations of the people, regarding the use of their personal freedom to move in the city 24 hours a day. All this makes the challenge greater in times modern and will be greater as personal expectations and ambitions increase of each individual.

Colombia in general and Santiago de Cali in particular are in that scenario. Cali has its public transport system, called MIO (Massive Integrated of the West), subjected to that strong pressure of the growth of people's expectations, in which people demand be provided with a public transport that meets all the quality requirements, typical of intelligently managed cities, such as a wide time coverage service, coverage of all areas of the city, low waiting time, affordable cost, comfort in travel conditions (seated passengers, air conditioning, internet, other factors) and all the other conditions of a world made to function in the digital age.

Not guaranteeing the mobility of citizens reduces the chances that they will have economic development and better quality of life, but also reduces the generation capacity of social and economic dynamics of the city, as a social conglomerate, which implies reducing its ability to attract tourism, investment and opportunities for economic action for its population.

The handicap limits access to the activities of life in society, this can reduce the quality of life, the happiness of people, contribute to making decisions that are not suitable for the same and of course contributes to increasing social exclusion among members of the society. (Luke, 2011)

This general problem of Cali can be seen in a focused way by sectors. For this reason the This work focuses on the 18th commune of the city, made up of 20 neighborhoods, some located in the hillside area, which naturally can be more difficult to attend to in terms of public transport service.

A large part of the social group that lives in miserable, disadvantaged conditions and in poverty hillside areas of the city are found, and although this is not a rule, if it is fulfilled in the commune 18 in places like the mines sector.

A mass passenger transport system that is not planned with the aim of improving quality of life for people, over time it can generate a demonstrable disadvantage between the public and private transport users; this being an even bigger problem in the free world, where people are able to acquire credit to get private transportation, as has been showing in the users of the MIO transport, who now choose to buy motorcycle or even car (Steer Davis Gleave, 2015).

It is a mistake, then, to plan public transportation systems for people, thinking of economic restrictions, in the end people will migrate to a more comfortable system, so that involve an economic effort.

Very slow transport systems generate economic stagnation and unhappier people. The engineer in charge of public works must then respond to the needs of the users, in this case to attract more customers to the system that generate the necessary income for your operation.

This Degree Work proposes a redistribution of the routes and the whereabouts of the Commune 18, based on the Origin Destination Survey of Mexico City 2007 (Manuel, 2015). I know knows that 95% of private transport users make trips on foot of a maximum of 5 minutes, while 72% of public transport users spend the same time on their walks. On the other hand, 21% of public transport users walk from 6 to 10 minutes, 5% from 11 to 15 and the remaining 2% walk longer. An average pedestrian can walk at 4 km/h for which in 5 minutes he travels about 0.33 km. At the time of walking must be added the travel time in the mode of motorized transport as such. in big cities it is common for walking distances to exceed 300 m because stops of mass transportation are generally located in places with high travel demand (Manuel, 2015).

In accordance with the previous approach, an analysis of public transport was carried out in the Commune 18 and it was found that it presents internal routes with a much lower distribution of stops at 300 m and, in general, long travel times. Users express satisfaction door-to-door service, but in turn travel time is a source of discontent, for which the present work proposes to locate the whereabouts at a typical distance of 300 m and in addition with a radius of coverage of sites of attraction for citizens, which avoids them long and strenuous commuting between stops and destination, but reduce travel time travel, among other factors.

The study was carried out based on the Mobility surveys of 2015, the survey ¿Cali como Let's go? And a pilot survey carried out by the author, under the modality of *election by convenience* to users of the system who were within the border area of the commune 18, contrasting and correlating this with data provided by Metrocali, which is the entity that controls the mass transportation system in the city of Santiago de Cali.

The results are expected to serve as a reference for the key agents who take decisions related to transportation in the city of Cali, direct their management to the solution to mobility problems and for the benefit of the population.

1.1 Definition of the research problem

Urban public transport is a dynamic social and economic element, as it constitutes a comprehensive system capable of providing solutions to the needs of people moving, which allows them to meet precise objectives, such as work, study, recreation and in general attend to all the commitments that demand leaving and returning home.

However, the problem arises when the public transport service does not meet the need of transport within conditions of efficiency and opportunity, which allow the users feel satisfied with the service. The perception of the quality of the public service of transport in Cali is negative, judging by the common manifestations of users, collected in studies, such as *¿Cali, how are we going?*

That study says "The Mass Transportation System, MIO emerged with the purpose of replacing the traditional Collective Public Transport system (TPC), articulate with other transport systems transport, reduce polluting emissions and discourage the use of private transport. (Cali Chamber of Commerce, Alvaralice Foundation, El País, Autonomous University of West , El Tiempo Publishing House, Corona Foundation , Bogota Chamber of Commerce), objectives that, according to what is proposed, have not been fully met, due to poor service, thus cataloged based on a critical factor: the perception of travel time by passengers. system users.

Indeed, the study presented in 2015, with data to 2014, indicates that among high mobility users, that is, those who must travel to study or work, 54% points out that the displacement in the MIO takes more time, data that grew 9 points between 2013 and 2014. 55% of general users (without high mobility), also perceive that they travel takes longer (Cali Chamber of Commerce, Fundación Alvaralice, El Country, Autonomous University of the West , El Tiempo Publishing House, Corona Foundation , Bogotá Chamber of Commerce, August 2015).

In Cali, in 2014, users in general used these means of transport: MINE 37%; private 30% (car 10% and motorcycle 20%); collective 17% (bus 10% and taxi 7%); human 13% (on foot 6% and bicycle 7%) and informal 3%. Highly mobile users used: MIO 32%; private 43% (car 14% and motorcycle 29%); collective 10% (bus 6% and taxi 4%); human 13% (on foot 5% and bicycle 8%) and informal 1% (Cali Chamber of Commerce, Fundación Alvaralice, El País, Autonomous university of Occident , El Tiempo Publishing House, Corona Foundation , Camera of Commerce of Bogotá, August 2015).

Satisfaction with the MIO service was 24% for all citizens and 21% for for highly mobile users. In general, satisfaction with the key factors was: proximity to stations 22%, route coverage 18% and travel time on routes 16% (Cali Chamber of Commerce, Alvaralice Foundation, El País, Autonomous University of West , El Tiempo Publishing House, Corona Foundation , Bogota Chamber of Commerce, August 2015).

The central reason for this general dissatisfaction may have been the fact that the system required to have 911 buses, between articulated, standard and complementary, but only had with 903, of which only 690 were in circulation, this representing a deficit of 221 buses (comes from 911 – 690), equivalent to 24% (comes from 221/911), meaning that the system lacked almost a quarter of the fleet required to be able to mobilize as effectively it did 471,969 passengers/day, that is, only 55.65% of the goal for 2014 of 848,000 (Cali Chamber of Commerce, Alvaralice Foundation, El País, Autonomous University from the West , El Tiempo Publishing House, Corona Foundation , Bogota Chamber of Commerce, August 2015).

However, it is clear that the deficit of buses in circulation can explain the dissatisfaction *route coverage,* but not *travel time on routes* and less *proximity to stations,* the latter understood as the proximity of the stations or whereabouts of the MIO to the place of origin and destination of the user, epicenter this factor of the present work.

The perception of satisfaction with the MIO for the years 2016 and 2017 by users, had the behavior reflected in the Table of Figure 1.

It stands out as high mobility or frequent users in 2106 and 2017 manifest respectively these low levels of satisfaction with the critical indicators: closeness to stations 38% and 42%, route coverage 26% and 29%; and travel time on routes 26% and 30%. (Cali Chamber of Commerce, Alvaralice Foundation, El País, Autonomous University from the West , El Tiempo Publishing House, Corona Foundation , Bogota Chamber of Commerce, August 2015)

Movilidad Cali

cómovamos

¿Qué tan satisfecho está usted con los siguientes aspectos del MIO?

Movilidad

	Satisfechos					
	Usuarios frecuentes			Usuario no frecuentes		
	2016	2017	Dif.	2016	2017	Dif.
Frecuencia de los buses articulados	19%	23%	4 pp	15%	17%	2 pp
Frecuencia de los buses padrones	22%	25%	3 pp	16%	12%	-4 pp
Frecuencia de los buses alimentadores	22%	18%	-4 pp	15%	11%	-4 pp
Tiempo de Viaje en los recorridos	26%	30%	4 pp	19%	18%	-1 pp
Cobertura de las rutas	26%	29%	3 pp	18%	15%	-3 pp
Cercanía de las estaciones a su lugar de origen y destino	38%	42%	4 pp	23%	25%	2 pp
	Insatisfechos					
	Usuarios frecuentes			Usuario no frecuentes		
	2016	2017	Dif.	2016	2017	Dif.
Frecuencia de los buses articulados	56%	53%	-3,1 pp	55%	54%	-1,4 pp
Frecuencia de los buses padrones	55%	52%	-3,2 pp	53%	57%	3,7 pp
Frecuencia de los buses alimentadores	54%	58%	3,6 pp	54%	60%	6,0 pp
Tiempo de Viaje en los recorridos	54%	51%	-3,0 pp	55%	54%	-1,3 pp
Cobertura de las rutas	50%	48%	-2,2 pp	53%	54%	1,2 pp
Cercanía de las estaciones a su lugar de origen y destino	38%	34%	-3,8 pp	46%	48%	1,7 pp

Figure 1 How satisfied is the MIO user Source: Ipsos. Frank Napoleon. cali how come on, report year 2017.

This multifactorial dissatisfaction has made the objective of the MIO system to "... articulate other transportation systems, reduce polluting emissions and discourage the use of private transport" is not being fulfilled, because as reported by the indicated study, in 2012 the 49% of high mobility users used mass or collective public transport, not including taxi, but in 2015 only 43% used it, when in 2006 59% used it, figures are with tendency to grow in subsequent years, this being perhaps the greatest demonstration statistics of not meeting the objectives of the MIO system.

Identified the failures of the MIO transport service at the level of the entire city, thanks to the perception of the users reported in the cited studies, the research problem of this work is delimited to the commune 18, for being contained in the Responsibility project Social of the Pontificia Universidad Javeriana of the year 2017, and for being representative of the 22 communes of the city, focusing the object of study on the proximity factor to *the stations,* from the observation of the proximity between whereabouts and of these with the place of origin and user's destination, which is a critical variable, profoundly influencing the perception of the quality of the service, by influencing the definitive *travel time factor in the routes,* since whereabouts without strategic location in relation to the epicenters of human concentration, to the time that, too far from each other, force the user to walk more, while the whereabouts located very close to each other cause more stops, increasing the time it takes for the bus to cover a route, and all this makes the negative perception towards the MIO grow in the minds of users.

Knowing the panorama of dissatisfaction of the Cali users of the MIO with this model of transportation, and recognizing that a relocation or redistribution of routes and whereabouts can affect travel time on routes and even on route coverage, because a bus that covers a route in less time allows users to feel that efficiency and is available in less time to make another exit, thus increasing the coverage of routes, the work will be guided by seeking to answer this main question: What should be the spatial distribution of the whereabouts and the route of the MIO in commune 18 of Cali, for the purpose of improve the perception of the service by users?

A solid answer forces to previously answer these questions: What level of satisfaction have the inhabitants of the commune 18 of Cali, with the transport service provided by the MIO? Does the current spatial distribution of the whereabouts of the MIO in the commune 18 of Cali allows a perception of satisfaction on the part of the users?

1.2 Objectives

The purposes of the work are these:

1.2.1 General objective

Adjust the spatial distribution of the routes of the MIO system in commune 18 of Cali, to improve the perception of the service by users

1.2.2 Specific objectives

- Identify the level of satisfaction of the inhabitants of commune 18 of Cali with the transport service provided by the MIO.

- Identify what are the characteristics of the location of the routes and whereabouts of the transport of the MIO, of the commune 18 of Cali, which affect the travel time and the degree of accessibility

- Calculate the topological indicators of accessibility of the whereabouts of the routes of the MIO in commune 18 and of the new proposal of routes and whereabouts.

2 STATE OF THE ART

This chapter covers information related to the background of the problem, the framework contextual and end with the theoretical framework.

2.1 Background

“You must be aware that public transport has effects on the configurations sociocultural of the city. To understand a little the concept of partner configurations (Sachs-Jeantet, 1995) discussion paper is mentioned, who indicates that today cities have emerged as strategic territories for a whole range of essential social, economic and political processes of our era: globalization economy, international migration, the affirmation of services and the financing of producers as the growth driver sector in advanced economies, the new poverty, among other things, and as strategic places for theorizing these processes (Sassen, 1991 and 1994). As a return of the city to the forefront of the social sciences, can consider the representation of the social question in urban terms, the projection of separation between marginalization and integration (Dubet, 1994; Rosanvallon, 1995)” (Sachs Jeantet, 1995).

> *“In this urban civilization that is emerging lately, cities are place or meeting place where every day the main social problems, but also the most creative place of change. The city is a territory in which conflicts and contradictions converge and crystallize principals of a society that is going through a profound mutation, and its role is to better control these social transformations accelerated.” (Sachs*-Jeantet, 1995)

Globalization, exclusion, multiculturalism and ethnicity, government, science and technology are driving social transformations operating in cities, in various forms and in varying degrees of intensity and that pose to the inhabitants and the authorities a series of ongoing challenges. (Sachs-Jeantet, 1995)

Andres Monzon de Cáceres used accessibility indicators to characterize the service of transport in the community of Madrid,

> *"You can say that the measure of accessibility. in its various formulations, is an important contribution to the infrastructure planning process Of transport. Its usefulness as a tool is confirmed. to facilitate the understanding of transport dynamics and its interrelationship with planning of land uses" (Cáceres,* The accessibility indicators and their decision-making role in investments in transport infrastructure, 1988)

> *"The physical distances between each pair of nodes (Real Distance) are obtained. Operational Distances. that intend to reflect the behavior of the user in the itinerary choice. It is considered that In the worst case, the user is willing to travel a double distance from the Real, to circulate in optimal conditions." (Cáceres,* Accessibility indicators and their decision-making role in investments in transport infrastructure, 1988)

It is important to emphasize that Cáceres was based on accessibility indicators to realize of the shortcomings of the system and later with these same data, I try to improve the mobility from accessibility, which is a brilliant and different proposal I quote

> *"…Once this methodology is established, it is applied to the evaluation of three plans of transport in the area of the Community of Madrid. The results confirm the usefulness of the proposed indices for determining the alternative preferred, depending on the intended goals. The first alternative is a Beltway, which is shown to be preferable to reduce regional imbalances. within the province of Madrid. It also reduces passing traffic through the Metropolitan Area... The second alternative is a Distributor that communicates the southern zone (Alcorcón, Móstoles, Fuenlabrada. etc.) with the Madrid-Alcalá Corridor. It is the best solution from the point of view of decongesting the saturated roads in that part of the Metropolitan Area. By last, the Western Alternative, which would join the N-VI with the NV and the N-IV. is the one that most In general, it makes it easier for users to achieve the objectives of their trips, that is, they have a greater number of opportunities…" (Cáceres,* The indicators of accessibility and its decision-making role in investments in transport infrastructure, 1988).

On the other hand, Mellen P. Dajome Segura in her research *analysis of accessibility in the metropolitan area of santiago de cali from the perspective of public transport inter-municipal,* uses accessibility indicators to evaluate the quality of the service of transport that exists between the municipalities of Santiago de Cali, Palmira, Jamundí, Puerto Tejada, Yumbo , Candelaria, La Cumbre, Vijes, Dagua and El Cerrito

> *"…The results obtained by the different topological indicators, which allow a dynamic analysis of the network, the high values obtained by These indicators represent the lowest accessibility conditions, those tended over the municipalities located towards the periphery of the metropolitan area under study, these being La Cumbre, Vijes and Dagua, which give weight to the geographical location of the nodes, punishing these municipalities, due to their location towards the periphery of the study area and the irregular shape of its network of transport, these being further away from the center of the study area take greater travel time connecting with destinations…" (SEGURA,* 2016)

Sassen argues that the city has emerged as a site of new demands where capital uses it as "organizational merchandise" and considers that the development of cities does not can be understood in isolation from the fundamental changes taking place within the largest-scale organization in the advanced economy. (Sassen, March 1998) means the transport as a central point in the economy of the city and the globe.

"In view of the foregoing and locating itself in the subject that occupies the issue of mobility, Kaufmann *et al.* (2004) recognize that the interrelation between the different forms of mobility is complex, depends on the choice of individuals (fundamentally within a context family) and its conceptualization varies depending on the disciplines that deal with it. For example, the relationship between residential mobility and daily mobility (especially for work reasons) plays a central role within the analysis of counter-urbanization (Champion and Atkins, nineteen ninety six; Renkow and Hoover, 2000). (Left JM, 2008)

The author of the internet blog my urban diary José Manuel Landin makes an interesting summary on the pedestrian and the pedestrian section, in the city of Mexico DF, this based on various previous investigations, important aspects come to light in the text,

> *"…the average speed at which the pedestrian moves is approximately 4 kilometers per hour, it is estimated that the speed of walk for 5 minutes is 330 meters… It also brings out the efficiency of the use of the bicycle as the means of transport that most brings users closer to their destination 98.1% of bicycle users walk less than 5 minutes and it comes to light that it is not motorized…. of 1000 respondents, 91% feel difficulties when walking and 3 out of 10 pedestrians Have you had an accident while walking? On average and Regardless of the type of transport used, 78% of trips were walk from the last means of transport up to 330 m., 16% walk up to 670 m., 4% walk up to 1,000 m., 1% walk up to 1,330 m. Y the remaining percentage walks more than 1,670 km. See following map with buffers from 330 m, up to 2000 m. if the trip started in Zócalo de la Mexico City and the radius of the possible journey…" (Landin,* 2015)

José María Casado Izquierdo, studied daily mobility in Mexico and indicates that the population mobility is one of the areas still barely addressed. Cause fundamental to this relative abandonment is the scarcity and difficulty of generating (cost) information on this subject, although the study of flows of all kinds, both material and immaterial, has enjoyed increased interest as an essential feature of the process globalizer, as well as the recent processes of urban and urban-regional reconfiguration. As in practically all Latin American countries, the study of mobility life in Mexico is centered, prominently, in its capital city, Mexico City, either as a metropolitan area or zone, or through the analysis of a certain space of is. (Left JM, 2008)

"For his part, Gakenheimer (1998) states that the problem of mobility in large cities in the developing world is linked to their large population size and a growing motorization versus a slower increase in road infrastructure, despite which, the urban population of these countries presents a much greater mobility in relation to their rural residents. Gakenheimer acknowledges that most of these large cities have "more serious mobility problems than their counterparts in the developed world" (Ibid.37) and which is precisely in Latin America where the longest displacements occur.” (Gakenheimer, 1998)

For his part, Figueroa (2005) highlights the permanent crisis in which the urban transport in Latin American cities, as well as the important problems that experience their public transport (informality, low quality standards and degradation vehicle fleet physics). (Oscar, 2005)

As evidenced, transportation is undoubtedly a fundamental aspect of modern life, if want it can be said without fear of mistakes that transport is a facilitator of the fundamental human rights, which is why, for a ruler like the mayor of Cali, it is a challenge to solve the problem of public mobility, since this avoids exclusion Social.

Author	**Achievement**	**contribution to my work**
Sachs-Jeantet, Celine	Studies urban civilization and its interaction with aspects of urban life, transport, interculturality, economy, globalization and exclusion	It gives the importance of transportation in people's lives, it sets a precedent that helps me to give importance to the development of fair and accessible transportation
Andres Monzon de Caceres	I use topological indicators of accessibility in the city of Madrid, to later solve mobility from accessibility	Use the methodology applied by this author, his mathematical formulas and concepts.

Author	Achievement	contribution to my work
Mellen P Dajome	I use topological indicators of accessibility to measure the accessibility between the city of Santiago de Cali and the cities of Palmira, Jamundí, Puerto Tejada, Yumbo, Candelaria, The summit, Vijes, Dagua and El small hill	Use the methodology applied by this author in conjunction with the methodology of Cáceres, its mathematical formulas and concepts.
Sassen, Saskia	Understand cities as a link in the globalized economy	It gives an idea of how I should think about the proposed system, always thinking that it is a system that contributes to the globalized economy. Thus, a slow or inaccessible route will generate economic disadvantage.
Jose Maria Left Married	It understands mobility as a complex network of different situations, which affect the individual and even their family nucleus	helps to understand the importance of transportation in people's daily lives, therefore, it is necessary to survey the user in order to understand their needs
Jose Manuel Landin	I study the walking times of people in Mexico City DF	The time of 5 minutes corresponding to a walk of 300 meters was used as a standard walk for the organization of the nodes.
Ralph Gakenheimer	Understands that population density growth outpaces infrastructure growth	Use your analysis to propose routes with the current infrastructure of commune 18, in this way the routes could be implemented with the current infrastructure

Oscar Figueroa	It highlights the permanent crisis in which urban transport systems find themselves in Latin American cities, as well as the important problems experienced by their public transport (informality, low quality standards and physical degradation of the vehicle fleet).	Based on this author's analysis, I was able to pose questions for the pilot sample, which were later developed throughout Chapter 4.

2.2 Santiago de Cali

Santiago de Cali is a municipality in the Republic of Colombia, administrative capital of the Valle del Cauca department, its coordinates are 3°26'24ÿN 76°31'11ÿW. Your border area It has 22 communes, 249 neighborhoods and 15 districts, it is the third most populous city in Colombia; with around 2,907,328 inhabitants in its border area according to DANE figures (estimates to 2016, based on a census carried out in 2005) (DANE, 2005).

The history of transportation in Valle-Cali is the history of its economic growth (Vásquez, 1990)

"The historical process of Santiago de Cali during the 20th century must be analyzed within the framework of the economic-social development of the Valle del Cauca region. The specific shape of economic development of the region has been fundamentally determined by the activity coffee (production, transport, threshing, export), for the sugar activity (cultivation of cane, industrial transformation, generation of inputs for other branches, export) and, furthermore, by agricultural production of inputs for agribusiness." (Vasquez, 1990)

The end of slavery brought with it population growth in the Cauca River Valley, highlighting towns like Florida, Pradera, La Virginia and of course Cali. The need to move the coffee from the adjoining departments, to the threshers of Valle del Cauca and the Puerto de Buenaventura, generated what became known as the coffee route, which used mainly barges on the cauca river and mule tracks. Around the 1930s, the railway, the central road and a better port of Buenaventura forced the passage through Cali, generating activities that favored the demographic growth of the city. (Vasquez, 1990)

Although there are records of high growth in the sugar sector, between 1940 and 1952 (a cause of the second world war and the global demand that it brought with it), it was from the exclusion of Cuba from the North American market (1960), which Valle del Cauca began to supply sugarcane exports from Cuba and it is at this time that sugarcane cultivation takes really value and with this the industrialization of Valle del Cauca. Cali as its capital are seen affected by high population growth, which poses greater challenges for transport urban public within the hot and hectic city that was forming. (Vasquez, 1990)

"The emergence of most of the bus companies that operated throughout the twentieth century XX, occurred on a par with the increase in migratory waves from the fifties. The trend of these companies was to locate in peripheral areas that began to be occupied, illegally, by the new inhabitants of the city. The proximity of these two processes, led to a transport-settlement relationship that posed a benefit for both parties: the connection of the legal city with the "illegal" one. (Martinez, 2014)

Throughout its history, Valle del Cauca had many means of transportation whose objective was was to achieve communication within it, that is, neighborhoods, communes, municipalities, and achieve that the department communicates with Colombia and the world effectively, generating a economic growth in most municipalities of Valle del Cauca. The construction of trails, roads and highways would facilitate road transport (horses, carts, carts and automobiles), a transport system by rivers and sea (canoes, barges, steamboats and ships), railway, tram (cargo and passenger) and of course the airport. (From the From the 1930s to the present day, Valle del Cauca has had three airports, not including the private tracks of Jamundí and "el Limonar". (Aerocali SA, 2015))

The tramway, the railway and the steamboats deteriorated with the implementation of the roads, which seemed a good solution for a population that moved at ease within the city, then the politics and powerful families of Cali determine that public transport It must be the buses, organized in companies (Table 1).

Table 1 Bus routes around 1970-1980

	1970		1978		1980	
Companies	# buses	# Routes	# Buses # Routes		# buses	# Routes
Brittany Green	183	two	121	two	90	two
Saint Gray Ferdinand	152	1	148	4	103	4
black and white	108	1	244	5	189	5
saint green Ferdinand	117	two	146	two	122	3
Mall	110	two	100	two	99	two
Villanueva Belen	76	1	114	two	118	3
Cream Yellow	73	1	76	1	75	1
Silver Green	83	1	96	4	116	4
Blue Silver	42	1	78	two	91	3
Cream and Red	44	1	27	1	59	two
Gray Red	46	1	98	two	118	3
Express palmyra	27	1	99	two	41	3
Cream blue	102	two	77	two	65	two
Alfonso Lopez	56	two	58	two	83	two
Parrot	87	3	123	3	107	3
Cream and Green	12	two	123	3	123	3
Trans. River Cauca					8	1
Totals by year	**1318**	**24**	**1728**	**39**	**1607**	**46**

Source Jorge Dubón Jaramillo, Santiago de Cali: Urban growth public transport from 1900 to 1990

The traffic studies were carried out by the service providers and the mayor's office approved or not new routes (Martínez, 2014)

Transportation works, in our reality, bring with them employment, opportunity, equity, appreciation of the terreros, hope, love, peace and tranquility.

Additionally, the background of the city of Santiago de Cali, referring to the massive system of mobility are catastrophic, it is there where it is important to establish in what state is the city's public transport and its effect on the population. (Martinez, 2014)

Since 2009, the city of Santiago de Cali has had a massive transportation system MIO, which aims to meet the needs of the city, about 52% (IPSOS, 2015) of Caleños are users of collective public transport. This figure is significant validates the study, together with the evidence of the existence of a population vulnerable to exclusion social from mobility. It is then necessary to complement the study of the needs of transportation in the city of Santiago de Cali, covering as many aspects as possible, beyond the technical and geometric aspects.

It is important to mention that the main reference is the work done by (Alexa Delbocs, The spatial context of transport disadvantage, social exclusion and well-being, 2011) (Scott, 1907), who *studied* social exclusion in Melbourne Australia. This studio determined among other things that the lack of equity in transportation makes people more unproductive, miserable, makes them lose opportunities and in general promotes disadvantages compared to other citizens with better transport conditions. As a result of this the city council of Melbourne obtained data that allowed to have a broader vision of the transportation problem affecting people within its borders.

Apart from inquiring about technical aspects such as travel time, length of routes, average speed, the idea is to also study the perception of social exclusion generated for transportation in the city of Cali. Two particular studies are taken as a starting point, firstly, the one carried out in the area of Victoria, Australia (Alexa Delbocs, The spatial context of transport disadvantage, social exclusion and well-being, 2011) and secondly, the one carried out in the city of Cali, Colombia (Ciro Jaramillo, 2012) Comuna 18 a look general and global

The city of Santiago de Cali is divided into 22 communes and 15 districts. The study was focused on commune 18 because it is within the Responsibility Project Social of the Pontificia Universidad Javeriana of the year 2017.

2.2.1 Location

image 1 Communal division in Santiago de Cali Source: (Cali; Municipal)

Commune 18 is located in the southwest of the city. Delimiting by the south east with commune 22, to the east with commune 17 and to the north with commune 19. To the south and West of this commune is the limit of the urban perimeter of the city. (See map 1-1) Commune 18 covers 4.5% of the total area of the municipality of Santiago Cali with 542.9 hectares. - (Municipal, Administrative Planning Department, 2017). The commune is composed of 20 neighborhoods which are:

Table 2 Neighborhoods in the commune/sectors 18

Table two: Neighborhoods commune 18

Código	Barrio, Urbanización o sector	Código	Barrio, Urbanización o sector
1801	Buenos Aires	1812	Colinas del Sur
1802	Barrio Caldas	1813	Alferez Real
1803	Los Chorros	1814	Nápoles
1804	Meléndez	1815	El Jordán
1805	Los Farallones	1816	Cuarteles Nápoles
1807	Francisco Eladio Ramirez	1890	Sector Alto de los Chorros
1808	Prados del Sur	1891	Polvorines
1809	Horizontes	1896	Sector Meléndez
1810	Mario Correa Rengifo	1897	Sector Alto Jordán
1811	Lourdes	1898	Alto Nápoles

Source: (Cali; Municipal, Administrative Planning Department, 2017)

2.2.2 Population and social aspects

The population of commune 18 is 131,453 in 2015, this number is established as study population, because it is the figure used in the great mobility survey carried out by Cali subway in 2015.

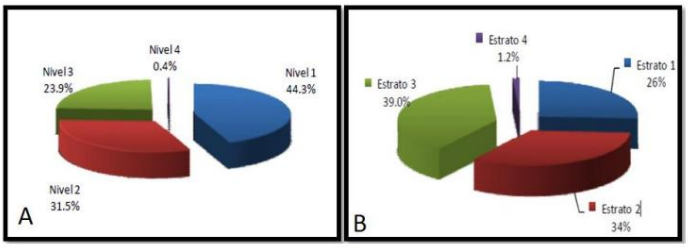


Figure 2 A-Distribution of the strata in commune 18, B-Population in SISBEN 18 Figure 2 population in the SISBEN Source: (Municipal) Population with SISBEN in the commune

Some relevant aspects are detailed:

The community identified for the Development Plan 2008 - 2011, shortcomings in communication and road development within the community. According to the study for the development plan 2009-2011, the communes present a constant general disinterest on the part of the city managers; which has undoubtedly led to a progressive deterioration of the existing road infrastructure and the non-construction of new road infrastructure for cover the neighborhoods located in hillside territory. The goal was then set paramount, improve communication and the pedestrian road system in the commune, improve communication with the mass transportation system. (Municipal, Administrative Department of Planning, 2017). From this initiative arises the interest of developing the present Work of Degree to which potential improvements are proposed in topological accessibility measures from commune 18.

2.3 Accessibility analysis and topological accessibility measures

> Accessibility - *"Measure of ease of communication between activities or human settlements through the use of a certain system transport, allows explaining and measuring the ease or difficulty provided by infrastructures and means of transport in mobility. can be distinguished three measures of accessibility: relative accessibility which is defined as the degree of connection between two places that belong to the same territory; Integral accessibility defined as the degree of interconnection that exists between a point or place and the rest of the points that are in the same territory and the global accessibility that is determined as the sum of the integral accessibility of all the nodes of the study area, the which represents the degree of connection of the entire network and reflects effects of*

any action on it"- (SEGURA, 2016). citing (Cáceres, Los accessibility indicators and their decision-making role in investments in transport infrastructure, 1988)

" *Topological Measurements* are the most elementary, they are based on the theory of graphs. simplifying the road network and representing it by a mesh. Each of the sections of the mesh joins two nodes, and is characterized by a scalar: time, distance, cost..." (Cáceres, Accessibility indicators and their decision-making role in investments in transport infrastructure, 1988)

To evaluate the accessibility and location of bus stops, both on existing routes and on the proposed routes, some topological accessibility measures were used, which are: Shimbel index (IS), route factor ( ), speed plotting index ( ) and indicator absolute global time (Tg).

2.3.1 Shimbel Index (SI):

The Shimbel index calculates what is the minimum number of trips necessary , for connect a node or stop, with another node of a network or route".- (SEGURA, 2016) citing (Fernandez-Santamaria, 2000.). Ingram in 1971 and Vickerman (1974) generalized the model Shimbel, arguing that the model should be able to show the urban grid as es, for this he develops a series of formulas based on the general Shimbel equation adding, the factor $\frac{1}{(}$. (Caceres, 1988). Thus, this Shimbel index is) obtains only by adding, the number of arcs between 2 or more nodes.

$$IS = ÿ \quad (1)$$

2.3.2 Path factor ( )

"This indicator allows quality to be measured (quality is understood in this case as the route that most resembles a straight line between two nodes) in the layout of a transport network, the the more it resembles the straight line, the better the index. It is calculated by constructing two matrices, one for distances over the network and another for distances in a straight line to and from each stop or node"-". - (SEGURA, 2016) citing (Cáceres, 1988) In this concept it is understood as *quality,* the fact that the indicator shows that the layout of a transport network is approaches the straight line.

$$= \frac{}{0} \qquad \text{(two)}$$

Where:

= minimum distance through the communications network between i and j

0 = geographic or straight-line distance from iaj

To determine the integral path factor, the following expression is used.

Adjusted to generalize all routes takes route geography into account

$$= \frac{1}{nÿ1} ÿ ÿ \, 1 \frac{\text{I said}}{dÿij} \qquad (3)$$

unadjusted original equation does not take route geography into account

$$= \frac{ÿdij}{ÿdÿij} \qquad (4)$$

= integral path factor of node i

n = number of nodes

A greater than 1.5 indicates a low level of accessibility, for equation (3). Equation (4) It will reflect better performance the closer it is to number 1. The reason why that is very simple the number 1.5 indicates that the path is only 50% above the perfect standard, it is necessary to remember that the roads are drawn on a city and topography pre-existing so having an ideal indicator of "1" is just a utopian idea, which moves away from reality.

2.3.3 Absolute indicator of global time ( )

“This indicator measures the sum of the time it takes to go through the MIO, from each to node to all the others, the point with the lowest sum is the best connected” (SEGURA, 2016) citing (Izquierdo R., 1991)

$$= ÿ_{=1}^{=} \qquad (5)$$

= Travel time from node *i* to *j* using the network

n= number of nodes

2.3.4 Tracking index – speed ( )

"It is a variety of the route factor, the highest values correspond to the most inaccessible. It is calculated with the construction of two matrices, one for the travel times over the network and one for travel times in a straight line to and from each of the nodes," (SEGURA, 2016) citing (Izquierdo R., 1991)

$$= \frac{}{_0} \quad (6)$$

Where:

= travel time of iaj using the network

$_0$ = fictitious time it would take to travel the distance ij in a straight line at the Velocity circulation average.

To determine the integral Velocity Trace factor, the following expression is used.

$$= \frac{1}{n} ÿ \frac{ÿ_{=1}^{=}}{ÿ_{=1}^{=} \; 0} \quad (7)$$

Where:

= plotted indicator of speed of node i

n = number of nodes in each zone.

2.3.5 Route Trace

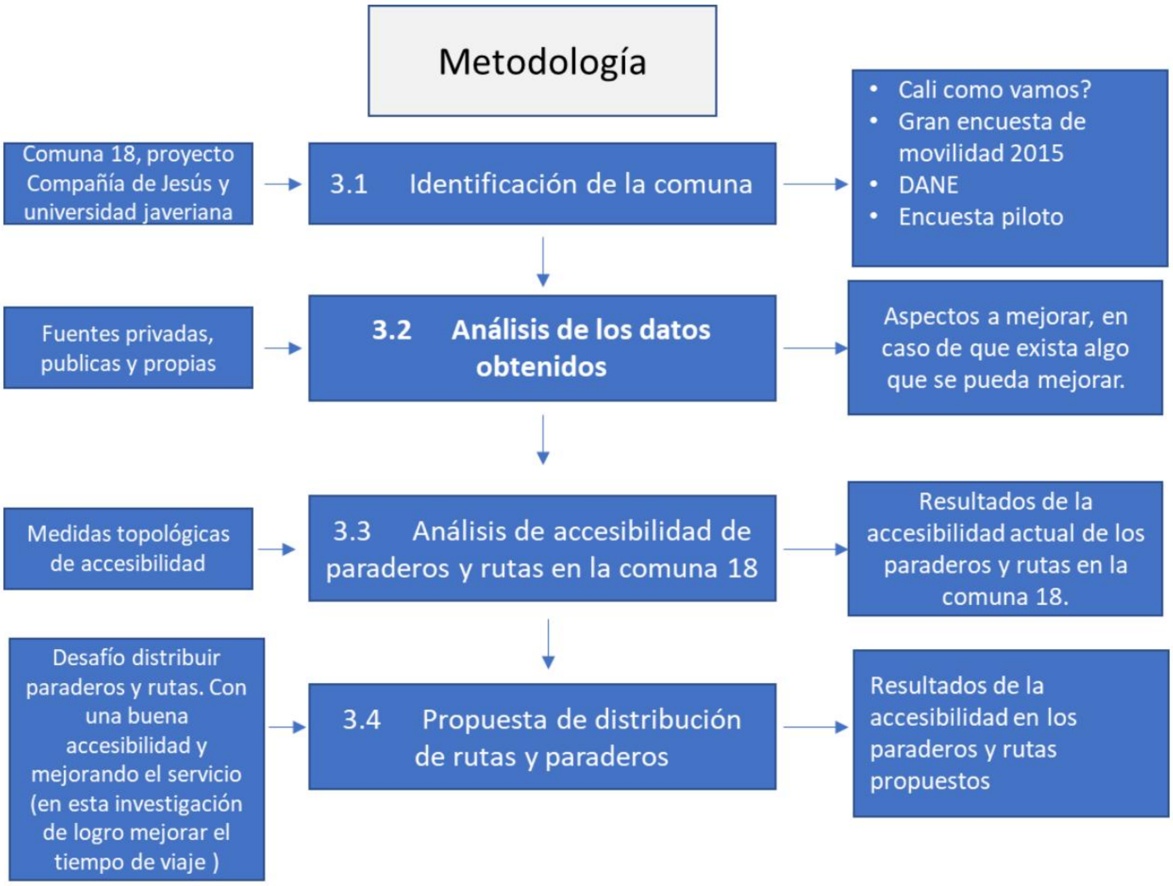
Routes are plotted from plotting station locations (Chapter 6), and plotting a route that joins the stations in such a way that the user can take the bus in the direction of one way or return, depending on your requirement.

3 METHODOLOGY

To comply with the General Objective which is to design the spatial distribution of the routes of the MIO system in commune 18 it was necessary to collect a large amount of information secondary school supplied directly by Metorcali. The study begins with the compilation of all this data in a graphic environment for which the following programs were used IT:

- Autodesk AutoCAD civil 2018: InfraWorks project was imported, to add standard geometry to the different roads of the commune.
- Autodesk AutoCAD 2018: Here, with the help of the Bing map system, the map of the spatial distribution by area of the stations within commune 18.
- Google Maps: The origin and destination of each person was geolocated. surveyed.
- Bing Maps: the contour lines, satellite map and location of stations of the MIO system.
- ArcGis Pro: Route modeling, spatial evaluation.

The information collected was evaluated to identify aspects to improve in the system of transportation. One of the important points was the walking distance of the pedestrian to access to the bus stop and an influence distance of 300 meters was taken to the bus stop. Finally, the system was proposed as can be seen in Chapter 6. The methodology is presented in the following diagram which is explained in more detail in numbers 3.1 to 3.4.



3.1 Identification of the commune

Commune 18 within the city of Santiago de Cali is chosen as the study objective, to continue with the social project carried out by the Pontificia Universidad Javeriana de Cali and the company of Jesus, in this commune.

The data for the characterization of the commune are obtained from the great mobility survey 2015, data provided by MetroCali updated to November 2017, information public DANE and a pilot survey in the convenience sampling modality carried out for this job.

It is necessary to indicate that it was an applied research, where the methodology used was that Melbourne Australia applied in the research" (Alexa Delbocs, The spatial context of transport disadvantage, social exclusion and well-being, 2011)", which is based on obtaining a concept of the problem, taking the user as a reference, for this the sample pilot and the data of the great mobility survey 2015 carried out by the firm Steer Davies for MetroCali.

3.2 Analysis of the data obtained

The data obtained is analyzed in order to carry out a characterization of the service offered by the MIO, based on users in commune 18.

3.3 Analysis of accessibility of bus stops and routes in commune 18

Once the aspects related to the service in the commune 18 have been identified and having given response to the first 3 specific objectives. An analysis of accessibility of each of the existing routes in the commune 18, for this it is necessary to analyze individually each of the bus stops that exist on the routes.

The routes analyzed correspond to the existing routes as of November 2017 (data supplied by MetroCali). Additionally, it is decided to use the topological measures of accessibility to evaluate the routes, due to the availability of the necessary information that allowed the use of these accessibility indicators (Cáceres, The accessibility indicators and its decision-making role in investments in transport infrastructure, 1988).

Once the accessibility results are obtained for each of the routes, you must compare this information with the opinion of the users of the transport system, to later to be able to better distribute routes and bus stops.

3.4 Proposal for the distribution of routes and bus stops.

The whereabouts of the system are distributed within the geographical area of commune 18, where it is possible under the current infrastructure to place bus stops and routes. Whereabouts are distributed with AUTOCAD Civil 3D help as follows:

- First, it was verified in the field which of the tracks allowed the turning radius of the vehicles of the system, to arrive from an origin, typically a Station, to a destination that was identified as the area farthest from the commune for each route existing. These origin and destination points are called *Primary Control Points.* in the route selection process (Cárdenas Grisales, 2014).

- Second, the previous information was transferred to the map and about the enabled roads. Radio buffer 300 m (maximum walk expected for the pedestrian). These points were considered *Secondary Control Points* to perform route selection.

- Finally, the possible routes were established (The routes are traced from the layout of the location of the stations (Chapter 6), and a route is drawn linking the stations of in such a way that the user can take the bus in the direction of outward or return, depending on their requirement.) that link the *Primary Control Points* and deal, to the extent possible to satisfy the *Secondary Control Points.*

As mentioned, the bus stops are distributed in such a way that people have to walk no more than 300 meters to the bus stop. After that, they are made new routes that reach these stops are evaluated under accessibility and safety indicators. comply with adequate accessibility (Numeral 2.3) is approved as route design acceptable.

To be able to improve the service of the users understanding the MIO transport, as a service aimed at moving large numbers of people at a low cost, which undoubtedly forces decrease the accessibility of the individual user, but improve the use by the majority.

4 APPLICATION AND ANALYSIS OF INFORMATION

4.1 **Processing of the pilot sample and the surveys ¿Cali, how are we doing? and great mobility survey 2015**

For the calculation of the indicators, data provided by MetroCali was used in the reports of mobility and the database supplied Annex *(A-101)* data such as; average speed feeders, area of influence, peak hour, off-peak hour, level of demand and cost. Is taken as a reference, the Meléndez station, where surveys were carried out and whose information on peak hour, demand and use, is found in the research analysis of waiting lines in the pedestrian accesses and circulation areas of the meléndez del sitm-mio station (OSCAR EDUARDO ACEVEDO PEÑA, 2017)

The pilot sample data were processed using the IBM SPSS Statistics program 23.

Table 3 Average demand for Meléndez station by days of the week

Source: Oscar Eduardo Acevedo Peña. 2017

Día de la semana	Promedio de usos pagos
Año	2015
Mayo	6110
domingo	3999
lunes	6069
martes	7172
miércoles	6771
jueves	6698
viernes	6575
sábado	5937

4.2 Pilot sample description

The pilot sample was used only as a contribution that enriches the data of the report Cali how are we doing? and those of the great in mobility slope 2015 and it was done to obtain from first hand the perception of the users of the MIO in the commune 18 towards the System of Massive transport.

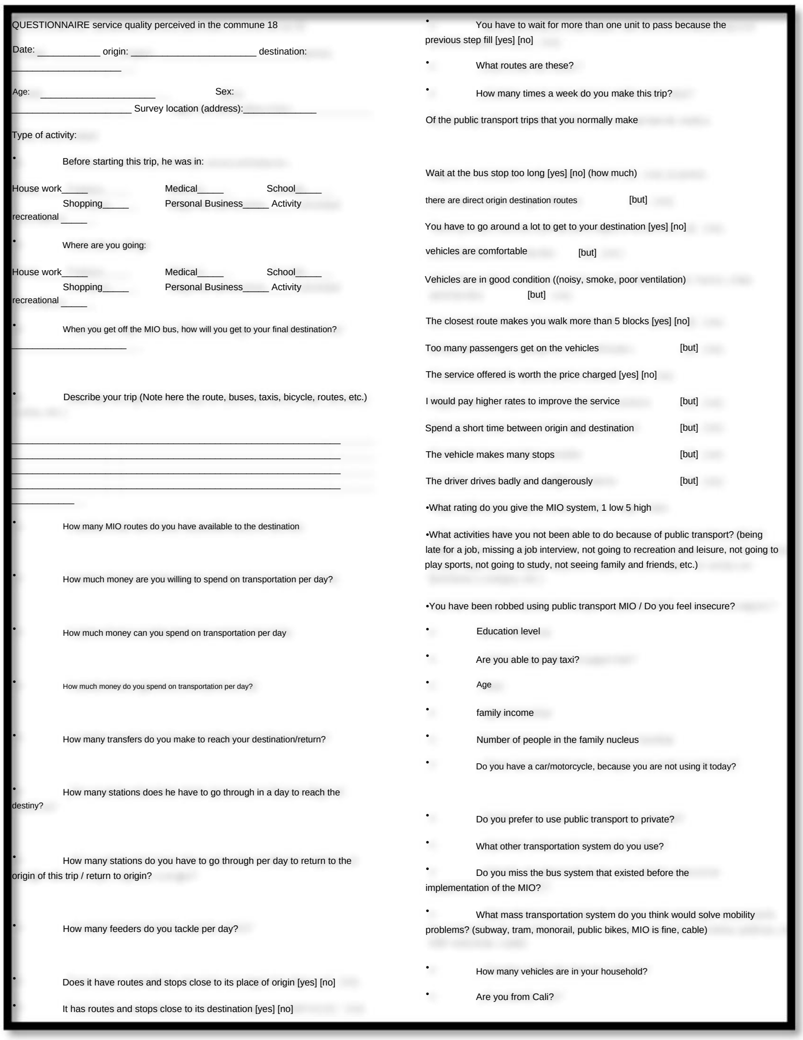
Sampling for convenience (non-probabilistic) was chosen, as opposed to sampling probabilistic used in the great mobility survey 2015, where a sample was taken to Cali, probabilistic, stratified and two-stage, sectioned by simple random sampling, by blocks with the same social stratum. Convenience sampling seeks to obtain data at from a population where there is a bias in which you try to study something, in this case, the perception of the quality of the MIO service, among the chosen population of effective users of the system in commune 18.

Sampling for convenience allows selecting those accessible cases that accept to be included. This, based on the convenient accessibility and proximity of the subjects to the investigator. - (Tamara Otzen, 2017)

44 surveys were carried out as a pilot sample to users at random, but chosen conveniently, that is to say that for example a person who is not a user of the MIO could never be surveyed, for this class of people we have data from the great mobility survey 2015. The survey carried out can be read in Image 2.

The statistical analysis of the survey was carried out using the IBM SPSS Statistics 23 program, With this program, the frequencies, valid percentage, accumulated percentage, bias, standard error, lower limit, upper limit, for quantitative data the mode, the mean and the median all the simulations were carried out for a population of 131453 inhabitants of commune 18, information provided by the Administrative Planning Department Santiago de Cali (2016 data). All Frequency Tables are included in (Annex A-1).

Image 2 Statistical simulation Source: Own elaboration using the IBM SPSS program Statistics 23



QUESTIONNAIRE service quality perceived in the commune 18

Date: ___________ origin: ______________________ destination: ____________________

Age: ____________________ Sex: ______________________ Survey location (address):_____________

Type of activity:

- Before starting this trip, he was in:

House work_____ Medical_____ School_____ Shopping_____ Personal Business_____ Activity recreational _____

- Where are you going:

House work_____ Medical_____ School_____ Shopping_____ Personal Business_____ Activity recreational _____

- When you get off the MIO bus, how will you get to your final destination? ____________________

- Describe your trip (Note here the route, buses, taxis, bicycle, routes, etc.)

____
____
____
____
____

- How many MIO routes do you have available to the destination
- How much money are you willing to spend on transportation per day?
- How much money can you spend on transportation per day
- How much money do you spend on transportation per day?
- How many transfers do you make to reach your destination/return?
- How many stations does he have to go through in a day to reach the destiny?
- How many stations do you have to go through per day to return to the origin of this trip / return to origin?
- How many feeders do you tackle per day?
- Does it have routes and stops close to its place of origin [yes] [no]
- It has routes and stops close to its destination [yes] [no]
- You have to wait for more than one unit to pass because the previous step fill [yes] [no]
- What routes are these?
- How many times a week do you make this trip?

Of the public transport trips that you normally make

Wait at the bus stop too long [yes] [no] (how much)

there are direct origin destination routes [but]

You have to go around a lot to get to your destination [yes] [no]

vehicles are comfortable [but]

Vehicles are in good condition ((noisy, smoke, poor ventilation) [but]

The closest route makes you walk more than 5 blocks [yes] [no]

Too many passengers get on the vehicles [but]

The service offered is worth the price charged [yes] [no]

I would pay higher rates to improve the service [but]

Spend a short time between origin and destination [but]

The vehicle makes many stops [but]

The driver drives badly and dangerously [but]

•What rating do you give the MIO system, 1 low 5 high

•What activities have you not been able to do because of public transport? (being late for a job, missing a job interview, not going to recreation and leisure, not going to play sports, not going to study, not seeing family and friends, etc.)

•You have been robbed using public transport MIO / Do you feel insecure?

- Education level
- Are you able to pay taxi?
- Age
- family income
- Number of people in the family nucleus
- Do you have a car/motorcycle, because you are not using it today?
- Do you prefer to use public transport to private?
- What other transportation system do you use?
- Do you miss the bus system that existed before the implementation of the MIO?
- What mass transportation system do you think would solve mobility problems? (subway, tram, monorail, public bikes, MIO is fine, cable)
- How many vehicles are in your household?
- Are you from Cali?

Image 3 Survey.

Each question contributes to meeting the general objective by allowing the objectives to be met. specific, because through them it was possible to know the level of satisfaction with the MIO by part of the users of the commune 18. A more detailed explanation of each question is found in Annex (A-98) , the following section shows the information process.

4.3 Daily activities of citizens

This section shows the daily activities of the users that can be affected by the public transport performance. According to the results obtained in the surveys carried out in this research, in addition to the great mobility survey of 2015, carried out for the Cali city.

4.3.1 Distribution of travel reasons

The survey showed that due to public transportation, people from urban strata 1, 2 and 3 are more affected in their work commitments (Figure 3), above 60% while that strata 4, 5 and 6 have an affectation of less than 19%, due to the fact that they depend less public service for transportation. The varieties of people's target activities demonstrate that public transport affects not only labor or economic issues, but also in the social ones, which coincides with the scholars consulted, saying that public transport determines the quality of life of users and their level of happiness.

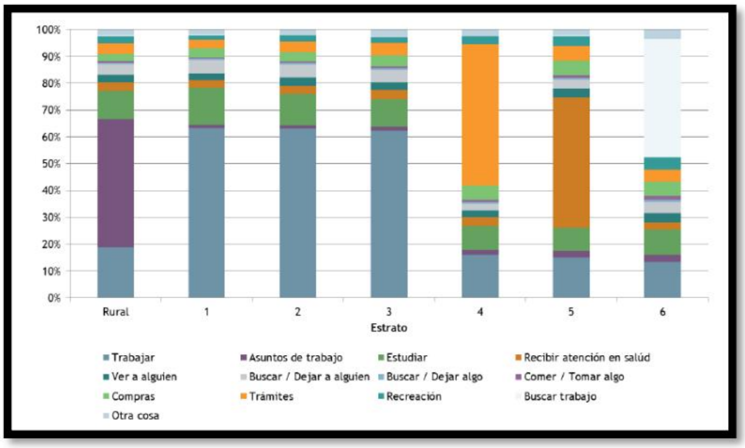


Figure 3 Percentage distribution by stratum of trips by reason in the study area

Source: Gleave, 2015

4.3.2 Age and gender of users of the MIO transport system

The transport system is used by people of all ages, prioritizing the young 19 years old, with 18.2% and 17 years old, with 9.1%, perhaps due to the fact that young people between 17 and 25 years of age, for the most part, do not have economic independence and if they do, they are not reaches its income to be transported by a means other than public transport. This group characterized by the fact that their life dynamics are centered on study, work, leisure or socialization, which that motivates them to have a higher mobilization than people of other ages.

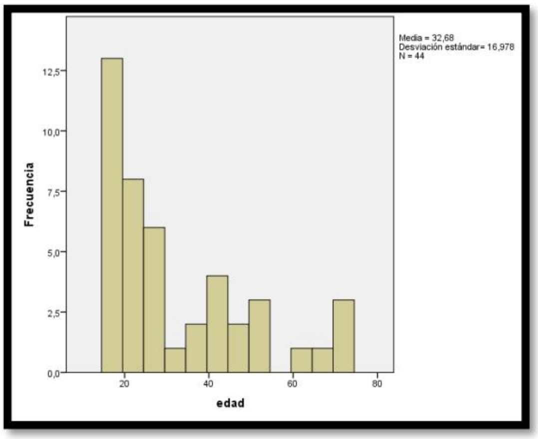


Figure 4 Age of the users of the MIO transport system Source: Own elaboration

Regarding the use of transport by gender, consequently, with the population statistics, women with 54.5% use the MIO system more than men. See annex A-56.

4.3.3 Activities not carried out due to public transport

About 68.18% of the surveyed population has stopped doing a daily activity, for the fault of public transport, arguing that the greatest problem is the waiting time in the seasons. The activities that are most affected are work, study, health and leisure, that is alarming because this set of activities guarantees a quality of life in the people, an improvement in the economic performance of the nation and is a reflection on the feeling welfare of the inhabitants.

Figure 5 Percentage distribution of activities not carried out Source: own elaboration

4.3.4 Money to spend on daily transport

They reflect the reality of a particularly poor Cali and commune 18, with little capacity spending on their transportation per day, since 63.6% expressed their willingness to spend on this item between 5000 and 3000 current pesos per year 2017. This indicates that the inhabitants of the commune strongly depend on public transport, as they would not be able to afford another transportation system that is faster, more timely, reliable and comfortable.

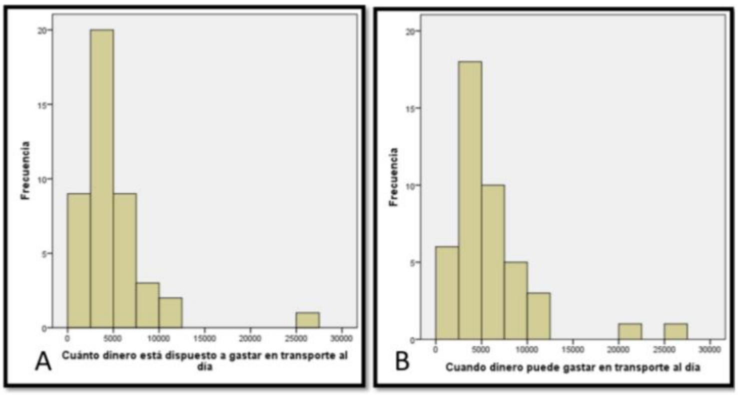


Figure 6 A-How much money are you willing to spend on transportation per day?, B- Do I count money can spend on transportation per day Source?

4.3.5 Willingness to pay a higher rate in order to improve transportation

Consequently (Exhibit A-57 A-36), with the previous answer, the majority of the inhabitants of commune 18, represented by 52.27%, is not willing to assume a higher cost for the public transport service, which is validated in the condition of poverty of the majority of people.

4.3.6 Preference between public and private transport

52.3% (Exhibit A-58 A-49) of those surveyed reflect people's preference for employing a private transport system, which is natural, considering that the public is associated in market economies like the Colombian are for the poor, and for this reason it is perceived as low quality and for those of lower social status. This being the case, this question and its answer may be inappropriate, but it was done and analyzed to present a flexible study, which sought to consider the greatest possible number of edges of the transport situation public in a representative commune of Cali.

4.3.7 Number of vehicles available for the family

Although 54.5% of the families in commune 18 do not have their own vehicle to satisfy transportation needs, 27.3% say they have one and 13.6% say they have one. of 2, but it is clear that even for those who say they have 4, in 2.3% of the time, some family members must use public transport for different reasons, meaning this that this mobility option is essential for the inhabitants not only of the commune studied but of the entire city of Cali. (Exhibit A-53)

4.3.8 Willingness of people to pay for a taxi

Consistently, the majority of citizens reveal, in 56.82%, their unwillingness to pay for the “private” public transport service materialized in the taxi, since this implies a on cost, impossible to assume, due to the economic situation of some of the inhabitants of the commune, even if this means improving the speed of movement, comfort and even travel safety. (Exhibit A-59 A-45)

4.3.9 Family income level

54.55% of those surveyed indicated having an income of a legal monthly minimum wage in force (smmlv), 40. 91% said they got two smmlv, and only 4.55% said they won three smmlv, corroborating this the situation of poverty of the inhabitants of the commune 18, which sustains their previous answer, contrary to being able to assume a higher cost of daily public transport. This shows that the majority of the inhabitants of this commune are objective clients of the MIO as Cali's public transportation system. (Figure 6-A)

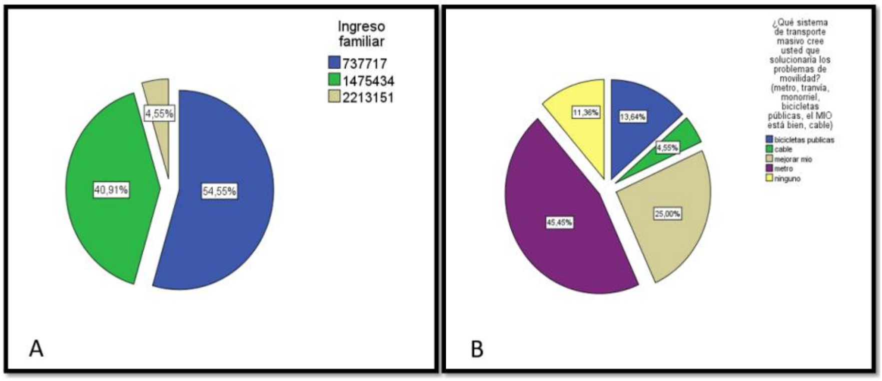


Figure 7 A-Income in pesos Source, B- Solutions raised by the surveyed population

4.3.10 Criteria of the people about the public transport system that would improve the mobility

45.45% of the citizens of commune 18 value that the solution to the massive problem of transportation in Cali lies in building an urban train or metro system, which coincides with the solution applied in cities like Medellin and in process for Bogota, so it is sensed that people have a vision of what this kind of solution entails, which is why they invoke it. However, 25% are inclined to solve the current situation of public transport as only improving the service of the MIO; 13.64% consider that a public bicycle system would be the solution, while 4.55% consider that a cable transport model would provide to the solution; which is not seen for 11.36% of the respondents, who consider that the problem has no solution or at least it does not have one among the range of alternatives proposed in the survey.

Any of these solutions represents a budgetary challenge for the city and the nation, It must be specified that some may be more appropriate than the others, being able to take an alternative after performing a cost-benefit analysis for each of them and its different possible combinations. (Figure 6-B)

4.3.11 Hourly coverage of public transport in Cali

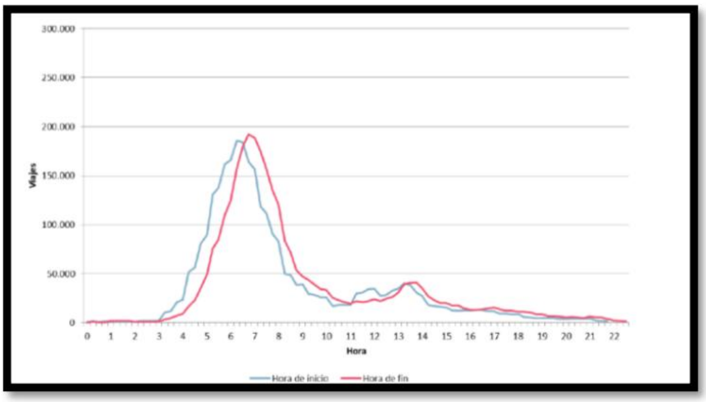


Figure 8 Hourly profile of work-related trips Source: Gleave, 2015

According to the mobility survey (Place the reference here) the MIO starts with some trips around 3:30 am, increasing their number significantly until 7:00 am. From At this time the number of trips begins to decrease gradually until the service is closed between 9:00 and 10:00 p.m.

4.3.12 General observations of the results chapter

With the data given by the survey, problems that should be pointed out by the improvement of public transportation in Cali.

- There is no just cause for which public transport, as the public service that that is, it is charged equally to all social strata of the population.

- The waiting time at the stations, if it affects activities in the private life of their users, causing this disadvantage with respect to those who have private transport.

- The most common activities that require transportation in the city are: Work, medical appointments, recreation, financial errands, shopping, eating, practicing a sport etc.

- A current minimum monthly salary for the year 2017, of $737,717 (without increases or discounts for social and parafiscal benefits) plus transportation assistance for

$83,140 (payable to workers who live more than one kilometer from the place of work and earn up to two monthly minimum wages), add up to $820,140, of which which are consumed in transportation $91,200 (comes from the value of a bus ticket from the MIO for $1,900 x 2 trips per day x 6 days per week x 4 weeks per month).

It means that the inhabitants of commune 18 on average spend more than the subsidy of transport to which they are entitled, this considering only a round trip transport to their work, because for additional mobilizations they have to spend a higher value on case of being forced to take two or more transports. Thus, a worker average is left with an income per month of $728,940, (comes from $820,140 - $91,200) for cover other basic expenses, which is hardly enough to cover the minimum vital needs of a worker, and less if he has a family that hold. Glave, 2015

4.4 Characteristics of the location of bus stops that affect the perception of cost and the real travel time of the users

The surveys show that the coverage of the transport system is optimal in the commune 18, however, the quality of the service, derived from the waiting time at bus stops and the time trips turn out to be the problem.

- The average travel time of the MIO feeders throughout the day is higher than the 40 minutes.

- The current MIO stations are well located, since they do not make people walk. people more than 300 meters to access them, however, the user requires a closer to home, which leads to the need to educate the population about the concept of area of influence.

- People consider that they should wait less time at bus stops.

- People demand to travel without overcrowding on buses, which is solved with a greater supply of them.

- People consider transportation to be a good system in most cases.

4.4.1 Frequency of transfers to reach the destination

The MIO system has the important quality of allowing the transfer of passengers between its different routes and modes of transport, which makes it a flexible system, which makes the displacement of users through the city and along the hillside. 36.4% of the users of the commune 18 transfer twice and 27.3% transfer three times, which allows deducting that people seek to fully utilize the service.

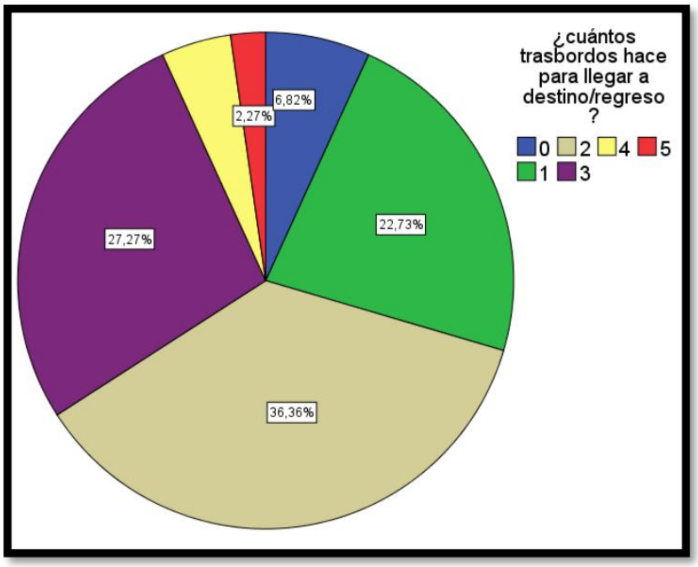


Figure 9 Number of transfers Own elaboration

4.4.2 Direct routes origin destination

This response allows us to deduce the efficiency of the available routes, finding that 52.3% of users would have the privilege of not having to do anything type of transshipment to reach its destination, this being also positive for the transport, as it avoids costs in the mobility of each user. (Annex A-60 A-30)

4.4.3 Efficiency in route tracing

Users have the perception in 56.8% of the times that the route is inefficient, since the The bus makes too many turns to reach the destination. Give rise to this to validate the focus of this work, referred to the restructuring of the stops and the routes themselves, if the first leads to the second. (Exhibit A-31)

4.4.4 Comfort of the vehicles in parallel to their conditions of functionality

To establish the integrality of the MIO service, we inquired about the comfort provided by the vehicles and their state of operation, although these elements in principle are not decisive of the efficiency in the arrangement of the stations and stops of the system and of the arrangement and efficiency of the routes, it is valued that if they influence the perception of *good service* that they can get to have users on the transport model.

The result obtained can be judged as contradictory, since 56.8% of those surveyed qualifies the buses as comfortable, while 52.3% indicate that they are not in good condition, because they generate noise inside, expel too much smoke and have poor ventilation, being evident that an automotive fleet that has these limitations could not be qualified with validity and logic as comfortable. (Exhibit A-61 A-32 A-33)

4.4.5 Cost-benefit correlation and willingness to pay more for a better service

54.5% of users would be inclined to assess that the service obtained is worth the price is paid, in this sense, the MIO grants the user the buyer's plus, that is, who buys considers that he gains with the product he receives for the money he has to pay, which puts the system one level above mere conformity or satisfaction with the perception cost/benefit that would be the least that could be expected between the price paid by the user and the service you receive.

Despite the above, 52.3% of users are opposed to paying more, even if the transportation service will improve on all or some of its fronts, otherwise normal response or expected for most tangible or intangible products in any economy of market, where the buyer is always expected to want more without paying for it. (Annex A 62A-63A-36A-37).

4.4.6 Alternative modes of transport to MIO

The inhabitants of commune 18 are recursive to meet their transportation needs, using from mobility on foot 35.4% of the time, to informal systems, such as the collective public transport 7.9% of the time, assuming the risks and inconveniences that this implies (Figure 21). Now, individual transport in vehicles such as motorcycles 15.6 % and own car 8.7% is growing, leading to increased traffic problems vehicular traffic on the same number of available roads, generating greater problems of traffic jams and environmental pollution by smoke emitted by that, ever-increasing, number of vehicles, that by transporting few people (most of the time one) become solutions socially and environmentally costly, given the high cost/benefit ratio they generate.

This problem has another edge, represented in that every time a user of MIO acquires its own transportation system is one less customer of public transportation, which indicates that the model will continue to increasingly lose customers, at a rate that can be higher than the growth rate due to the increase in the population of Cali. This is proven in the fact that the modern financial system is lending money to workers who earn up to a minimum wage for the purchase of a vehicle, being part of the payment the savings obtained by not paying for public transport. However, costs must be borne implicit of having your own vehicle, which is covered by the perception of earned benefit for the shorter time spent waiting for public transport and assuming its delays in route coverage. (Figure 9-A)

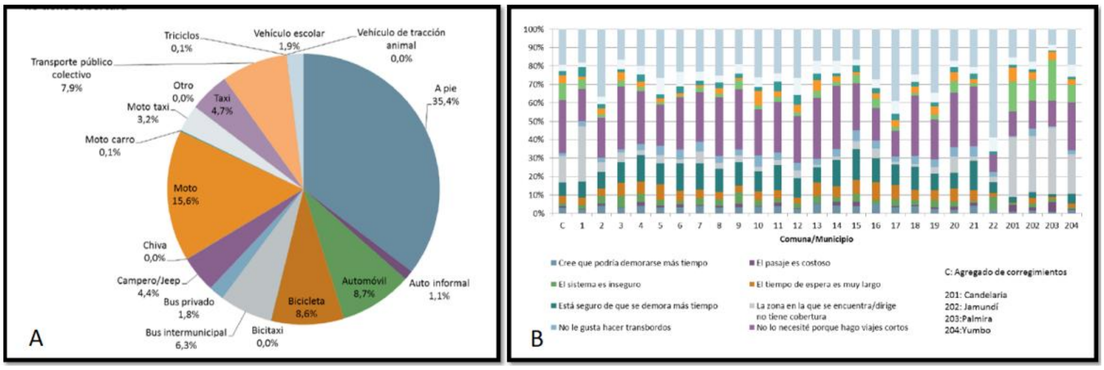


Figure 10 A-Modal partition of trips not made in MIO by reason: "The area in which is located/directs does not have coverage, B- Main reasons for not using the MIO in all of Cali Source: Gleave, 2015

4.4.7 Reasons why the MIO is not used

Caleños are reluctant to use public transport based on several reasons, being the perception of delay, which makes it clear that the frequency of passage of the vehicles by stops and the time it takes to move people from one place to another are the main sources of problems to be solved by the mass transport system in the city.

How to solve these elements requires high investments by the owners of the system, since demand acquired it for more vehicles, it is evident that applying this solution would take a long time, apart from the political decision to make the investment, especially if considers that the employers who contribute to the system continuously reiterate publicly their complaint about the economic losses they say they are suffering, due to poor planning operation of the system by its administrators. (Figure 9-B)

4.4.8 Perception of closeness of the bus stop to the house or place of destination

The analysis of the area of influence is referred to the coverage of the routes and the proximity that they have the bus stops in *relation* to the user's destination. To know perception was queried:

1) It was found that 54.55% of the interviewees indicate that they should not walk more than 5 blocks, which suggests that the location of the stops are in harmony with the principle accepted in several countries, according to which this distance should oscillate around the 300 meters, which is corroborated by the fact that 90.9% of people say they reach their final destination on foot, while the remaining 9.1% say they use a motorcycle taxi, which is acceptable due to the fact that buses cannot reach all sectors due to difficulties of geometric character in the streets. (Exhibit A-13)

2) To the question about whether there are routes and bus stops close to the final destination of the user, without establishing a specific unit of measurement, the perception in favor of good coverage is 79.55%, reiterating that the MIO administrators have done a good job of planning and application of shutdown scheduling.

In commune 18 there are particular conditions, in relation to issues of a geometry of the roads, in terms of their topographical structure, with steep slopes and narrow streets, which prevents the access of buses, preventing a better coverage in routes and stop sites, so users must endure in some areas of the commune a greater distance to cover on foot, between the place of the stop and its destination, than generally it is the place of habitation. (Exhibits A-64 A-65 A-34 A-23).

4.4.9 Perception of travel time

A critical factor to observe in this type of study is the travel time, that is, the perception of the user on how he values the efficiency in the coverage of the route by the operator of the system, finding that 50% of the people indicate that it takes a short time, but the another half perceives the opposite. This demonstrates the volatility of perception, depending on the personal travel circumstances and other factors, making it difficult to expect a response with a high degree of assertiveness by the majority of users. However, this is It is clear that the average speed at which the buses of the MIO system move, established in 13.5 kilometers (Metrocali, 2017) per hour, may be contributing to the travel time is being perceived negatively by 50% of users. (Exhibit A-66 A-38).

4.4.10 Perception of frequency of stops

In line with the travel time, the perception of the number of stops must be considered, since clearly the more stops the longer the delay in covering the route, which justifies that the 65.9% of users value them as many or excessive, since 50% had already said that travel time was long, this question is important as the plotting indicator of speed compares the actual route, with a straight line. (Exhibit A-39)

Notwithstanding this, the buses must have stops at least every 300 meters, since one programming more spaced stops would prevent the system from providing users with the plus or benefit of leaving them at an average distance of about that many meters from your place of destiny.

The only way to avoid the perception of too many stops would be to program routes shorter, which would lead to cover fewer stations or stops, but this would imply less efficiency in the coverage of each commune of the city by the system and also would represent for the citizens having to memorize more routes, which would make the system more complex to assimilate and understand in its operation by users.

4.4.11 Perception of overcrowding inside buses

81.82% of users consider that too many passengers get on the buses, which quarrels with the statistics of average use of the system, where an average occupation of the 58%, considering the entire service time slot of the MIO. Prove this, that you are before a problem of mental expectations of users, who mostly want a cheap, comfortable and exclusive public service, that is, people with the marked individualism typical of western society, does not want to assume any cost when receiving the privilege of public service, pretending to demand privacy in the public service, which is not can be given by the State and less so by the private sector that finances through investment the Cali transport system.

Overcrowding inside the buses occurs mainly during peak hours, in the morning, at noon and at the end of the afternoon, when the greatest demand for the service is registered, although system administrators regulate it by increasing the number of buses in the different routes, especially those where the statistical records confirm the highest bottleneck. (Annex A-65 A-35)

4.4.12 Driving the buses

Drivers' performance behind the wheel is rated as good and cautious by 68.2% of the users, giving this an element in favor of the system, since it contributes to improve the positive perception and avoid mistrust on the part of citizens as well as collective stress, causing different types of negative behaviors and conflicts social. (Exhibit A-40)

4.4.13 Perception of security when using the MIO system

Another factor marginal to the epicenter of the study, but relevant to analyze the way in which the user perceives and qualifies it, is to identify the perception of security, observing that a 90.9 % find it safe, although the ideal is that it should be 100%, which cannot be achieved until common crime in Cali is brought to zero, something that is being very away as long as the structural socioeconomic anomalies that afflict the city and to Colombia in general. (Exhibit A-43).

4.4.14 Perception of waiting time at the bus stop

Along with the perception of the travel time, the waiting time for the bus is also sensitive, against which 84.09% of users expressed themselves in the sense that it is too long, product of structural flaws in the system, such as the low number of buses for the size of the city, which derives in a frequency of passage of vehicles by the very distant stops in terms of the number of minutes.

This perception is perhaps more damaging to the MIO system than the other factors, because that annoys and irritates the user, to the point that it makes him lose not only confidence in the functionality of the system, but rather that it makes him uneasy against it, making it possible for him to see it and qualify Such a poor service on all fronts.

The solution to this serious flaw lies in improving the frequency of arrival at the bus stops. buses, but this is not possible as long as there is not a sufficient number of vehicles, minimize the operating output of the same due to mechanical failures or of another nature, and route planning, with the appropriate time range and the frequency of trips per day in function of the number of potential user inhabitants per commune. (Exhibit A-68 A-28)

4.4.15 Waiting time categorization

Complementing the perception of waiting time, users were asked to establish a measured in minutes of that time, as a way to endorse that perception, since it is clear that by having a more exact measurement it is possible to assess more technically the dimension of failures in route programming and frequency of passage of each route for each official stop.

The responses indicated that the most repeated delay is 30 minutes in 40.91% of the times, followed by 27.27% with 20 minutes and 9.09% with 35 minutes, which added shows a delay greater than 20 minutes in 77.27% of the time (Figure 10-A), this being serious, if a wait of 15 minutes is considered as a maximum upper threshold that should not be exceeded as the frequency of buses at each stop, since a wait greater than that time causes fatigue and irritation in most people (Figure 10-B) and makes them feel disrespected and mistreated in their personal self-esteem, by the administrators of a paid transport service that is supposed to be structured to be efficient, thanks to respecting the users time. (Exhibit A-69)

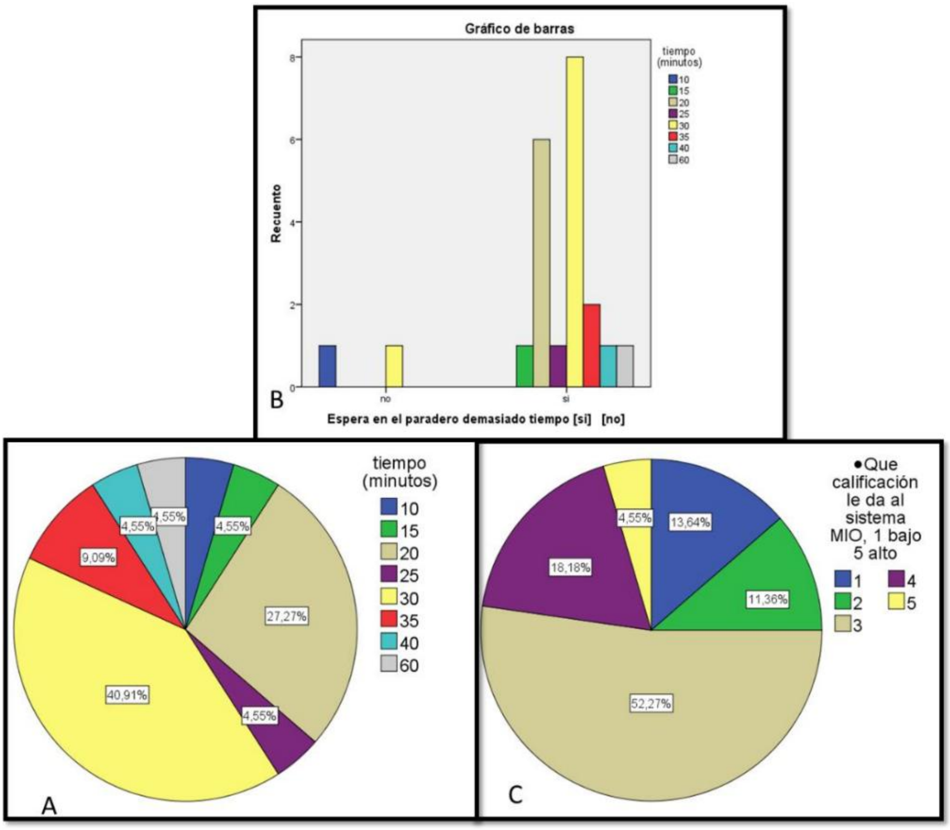


Figure 11 A- Waiting time at the station, B- Waiting time with respect to perception, C- Qualification to the MIO system

4.4.16 Waiting for another bus due to the impossibility of getting on over capacity

75% of those surveyed said they had to wait for another bus due to the impossibility of getting on to which I arrive due to the overcrowding of passengers that it had, is an element that aggravates the perception of delay registered mostly in the previous answer, which should be taken as something that occurs mainly in the hours of greatest demand for the service. The solution is part of the proposal raised in the previous point.

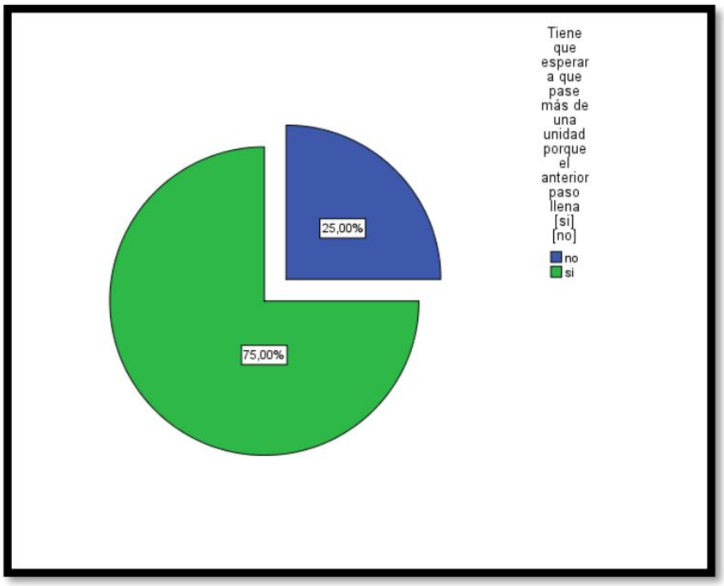


Figure 12 Does the user have to wait for more than one unit to pass because the previous one has past full? Own elaboration

4.4.17 Number of MIO routes available to reach the destination

In compensation for the fact of not being able to get on a bus due to overcrowding, the system provides users with alternative routes 72.8% of the time, corresponding to 3 routes 20.5%, and to 2 routes, 52.3% (Table 13), reflecting this a highly positive for the good of the users, who of course will have to value it in favor of the system MINE.

Table 4 Route of Mio available for the destination

Cuantas rutas MIO tiene disponible para el destino

		Frecuencia	Porcentaje	Porcentaje válido	Porcentaje acumulado	Simulación de muestreo para Porcentaje[a]			
						Sesgo	Error estándar	Intervalo de confianza a 95% Inferior	Superior
Válido	3	9	20,5	20,5	20,5	-1,1	4,8	11,4	29,2
	2	23	52,3	52,3	72,7	,2	6,5	38,6	63,6
	1	11	25,0	25,0	97,7	,7	7,1	9,8	44,4
	0	1	2,3	2,3	100,0	,2	2,4	,0	8,7
	Total	44	100,0	100,0		,0	,0	100,0	100,0

a. A menos que se indique lo contrario, los resultados de la simulación de muestreo se basan en 44 muestras de simulación de muestreo

4.4.18 Qualification of the MIO system as a public transport service

Notwithstanding, the negative qualifications in different investigated fronts, the users of the system of massive transport they qualify it integrally in a 52.27% with 3, in the common scale of 1 (what less) to 5 (the maximum), and where 3 means approved. If we add to this that 18.18% qualified with 4 and 4.55% did so with 5, it is clear that the total approval level is 75%, with 22.73% (it comes from adding 18.18% to 4.55%) that praises it with a note between 4 and 5, so it must be concluded that the MIO model is ultimately a transport service well valued by the users of the commune 18 of Cali.

It is evident that the approval figure of 75% has validity and a sense of justice, since clearly the MIO replaced a chaotic public transport system, (see Table 18, is it strange? the bus system that existed before the implementation of the MIO?), in which several companies with different, similar or complementary routes, competed on the roads for each passenger, in a disorderly wasp operation that came to be called "the war of the penny" because the drivers, who were paid per mobilized passenger, literally They were fighting for each passenger, regardless of whether they were fighting against a driver belonging to the same company or another.

On that stage the entire city, mainly its most important thoroughfares, was a theater of passenger mobility operations in total chaos, where stopping places were not respected neither by the citizens who used the service nor by the bus drivers, there were more probability of accidents, the buses passed with over capacity with users materially hanging on the front and back doors, speed limits were exceeded by drivers who expected to quickly drop off passengers and load others, and the drivers came to operate without time restrictions, in obsolete buses that lacked air conditioning.

The MIO is a unified transport system, it is appreciated by the citizens, mainly if are its users, a quality radically different from what existed before, from the bus stops current buses, some of them converted into well-equipped stations, to the provision in some roads of road corridors exclusive to the system, to which is added the option of power apply unified solutions to the different failures that are detected, by the administration of the system. (Exhibit A-51)

In addition to this, the city of Cali, as a living and socially dynamic supra system that it is, presents a development of vehicular traffic much more organized and therefore more functional and efficient, despite the natural traffic jams that occur daily, due to the lack of roads, faced with a saturation of private vehicles that may well be the real cause of the current problems, since it is inefficient for each citizen to mobilize individually in a vehicle, when it is more profitable financially, socially and environmentally mobilized by all citizens in a massive system like the MIO.

The highlight of this work is that the MIO, as a mass transportation system, is being well weighted by the users of districts such as 18 (Figure 10-C), which is representative in Cali, due to its socio-demographic characteristics, which typify the Cali user of the system. If the system administration manages to improve the main problems reported lack of routes and delays in the frequency of passage through stations, you will win every day more and more user confidence, an element that will allow the system to gain approval of users who today prefer to use the costly individual means of transport.

4.4.19 Perception of the cost of transportation with respect to socioeconomic status

The correlation between the perception of the cost of public transport MIO, with respect to the stratum social status, travel time, the supply of bus stops and the degree of accessibility to bus stops in the commune 18 object of study, can be analyzed from the following data.

Numerical calculations show that there is no correlation between the expense incurred in transport and social status, simply because the people who must use the system of transport they do it out of necessity, having to assume the cost that this implies.

Correlaciones					Ingreso familiar	Cuánto dinero gasta en transporte al día
Ingreso familiar	Correlación de Pearson				1	-,278
	Sig. (bilateral)					,210
	N				22	22
	Simulación de muestreo[c]	Sesgo			0	-,024
		Error estándar			0	,133
		Intervalo de confianza a 95,5%	Inferior		1	-,573
			Superior		1	,034
cuánto dinero gasta en transporte al día	Correlación de Pearson				-,278	1
	Sig. (bilateral)				,210	
	N				22	22
	Simulación de muestreo[c]	Sesgo			-,024	0
		Error estándar			,133	0
		Intervalo de confianza a 95,5%	Inferior		-,573	1
			Superior		,034	1

c. A menos que se indique lo contrario, los resultados de la simulación de muestreo se basan en 44 muestras de simulación de muestreo

Recuento

		Ingreso familiar			Total
		737.717 $	1.475.434$	2.213.151$	
cuánto dinero gasta en transporte al dia	3000 $	0	1	0	1
	3800 $	3	3	1	7
	4000 $	3	2	0	5
	4500 $	1	0	0	1
	5000 $	0	1	0	1
	6000 $	1	0	0	1
	7000 $	0	1	0	1
	7800 $	1	0	0	1
	8000 $	1	1	0	2
	10000 $	1	0	0	1
	20000 $	1	0	0	1
Total		12	9	1	22

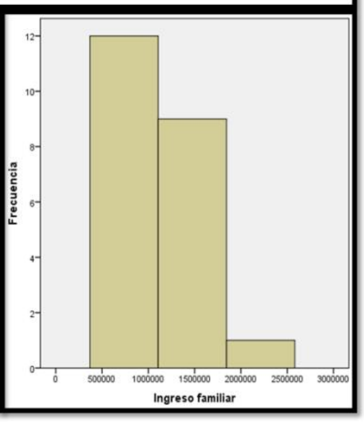


Figure 13 A5 family income vs money spent per day on transportation -, B-Family income Source own elaboration, C- Correlation between family income and money spent on transportation up to date.

Correlation, it can take positive or negative values, but if its absolute value is:

0.96 to 1 perfect, 0.85 to 0.95 strong, 0.70 to 0.84 significant, 0.5 to 0.69 moderate, 0.20 to 0.49 weak and minor nil

Using the Pearson correlation carried out with the help of the IBM SSPS Statistics 23 program, shows that there is no correlation since it gives a result of -0.27

5 ANALYSIS OF ACCESSIBILITY OF EXISTING MIO ROUTES IN THE COMMUNE 18

The accessibility analysis is carried out using the indicators described in number 2.3. (equations 1 to 7) in which the real distance and time between stops are taken into account and also considering the distance and travel time in the straight line between the stops.

Accessibility indicators are intended to assess the current accessibility situation of the routes for the users of commune 18, based on the results of said analysis, will study whether it is possible to modify the accessibility a little to improve mobility, given that a very accessible area leads to longer travel times, this as a consequence of the multiple nodes that a highly accessible system must have, given that in each node the bus MIO must pause, this in turn causes the average travel speed to be lower.

Commune 18 currently (2017) has 5 exclusive routes (image 4-A) and 2 routes that they have a small route within the commune but that is not significant for the study.

The speed used to evaluate each of the routes corresponds to the real average speed as indicated in (Image 5-A). The average speeds are obtained from the database provided by Metrocali for the month of November 2017, (Exhibit A-101)

On the other hand, it is important to note that the pilot survey showed that users do you travel outside commune 18 (Image 5) and therefore it is very important to reduce the time travel from any bus stop to the exchange station and vice versa.

Ruta	Recorrido total Km	Nodos	Velocidad media real km/h	Opera siempre
A12A	7,048	22	13,8703955	si
A12B	7,7531	24	13,11039631	si
A12C	4,9669	9	16,21784263	No domingo
A12D	9,6652	22	15,01180003	si
A78A	8,4656	21	15,1	si
A73 no evaluada	10,4465	NA	17,66571698	si
A71 no evaluada	8,4656	NA	18,47591735	si

A

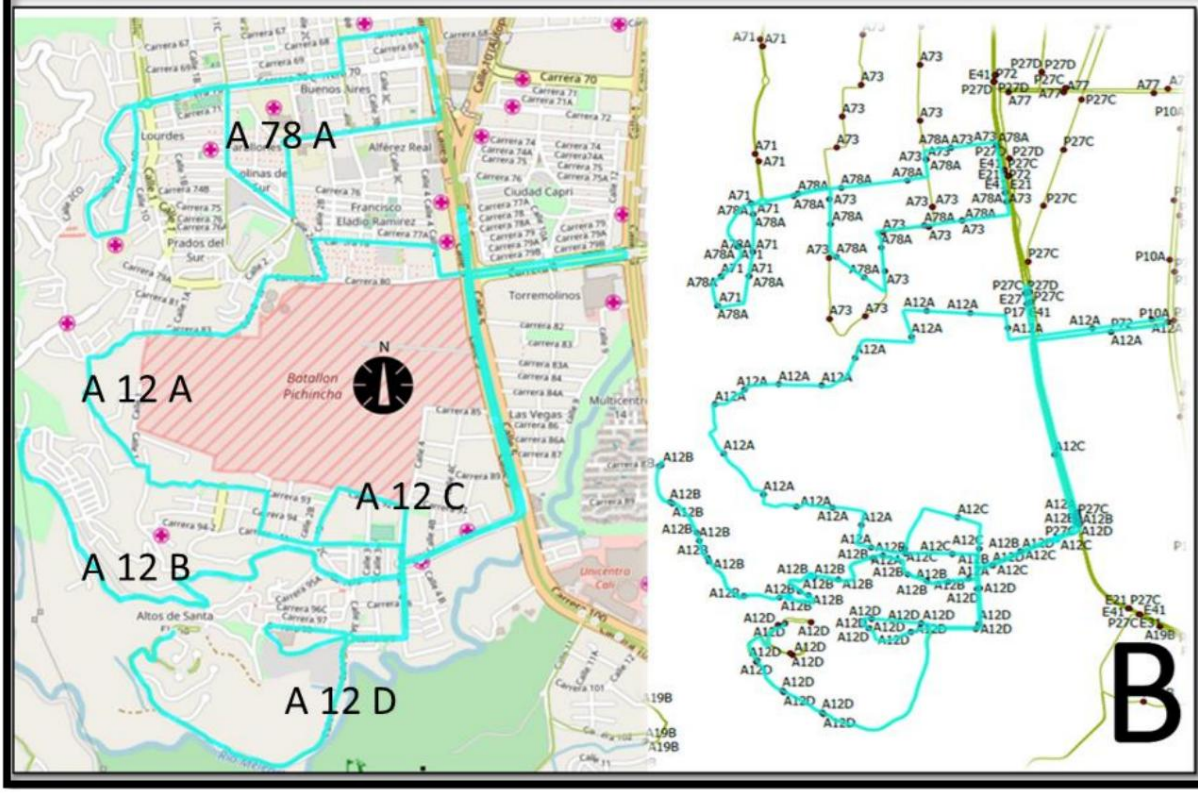


Image 4 A- Summary of commune routes (Annex A-101) 18 ,B- Routes subject to commune study 18 highlighted in blue Source: Own elaboration from data provided by Metrocali using the arcgis pro program

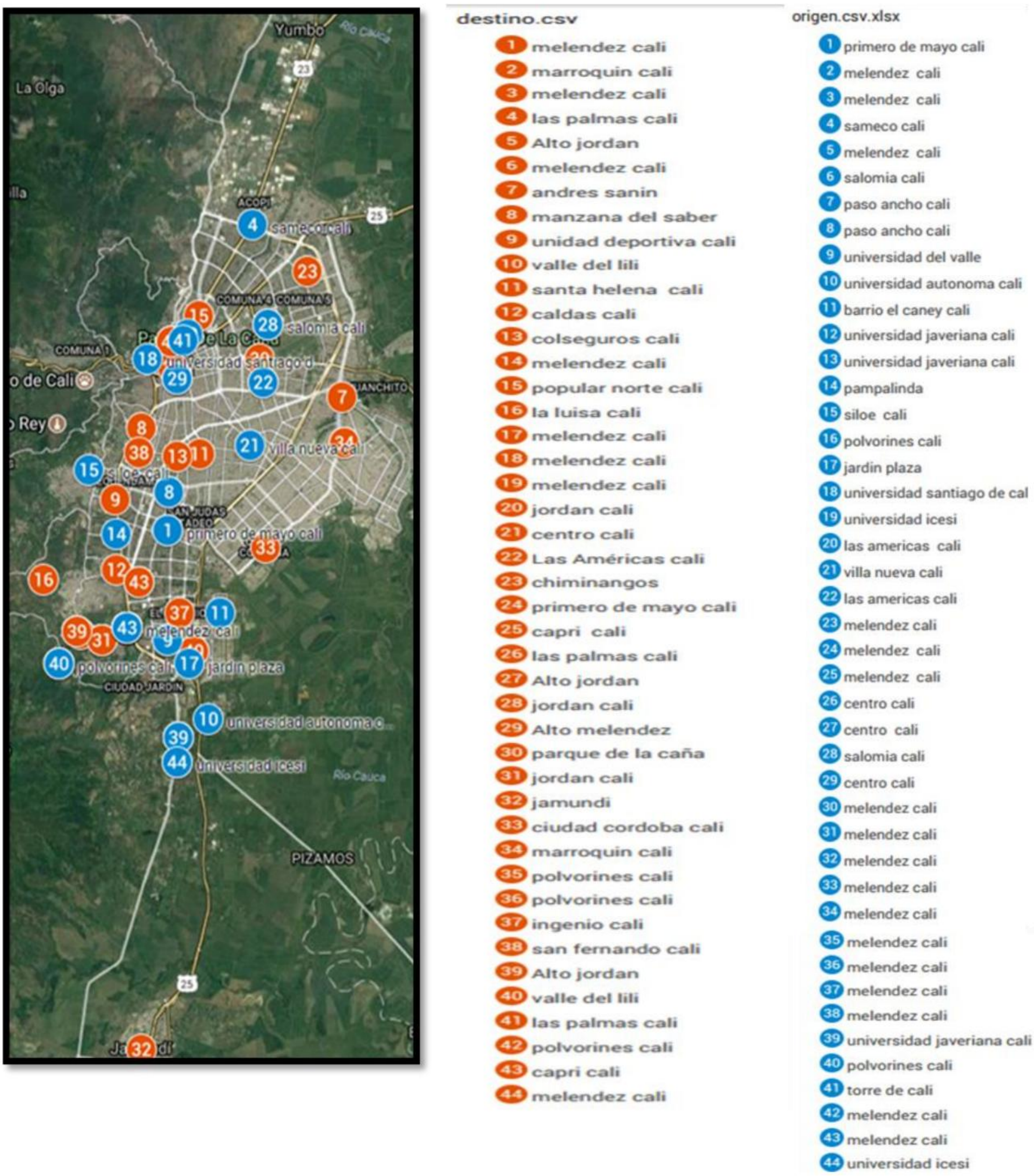


Image 5 Map of the pilot survey with origin (blue) and destination (red) of the respondents. Font Own elaboration made at ://www.google.com/maps

5.1 Route A12C

Route A12C, has a short route within commune 18, is used to move people in the vicinity of *Carrera 96 with Calle 4* to the *Capri station,* much of its route runs along *Calle* 5, where there are currently routes that could transport people from the *Meléndez* station to the *Capri* station (Image 6).

The route map (Image 6). is obtained from the database provided by MetroCali in which is the georeferenced location of each of the stations (nodes) and the route. Subsequently, the route is drawn in AutoCad 2017 and using the Bing map base, obtains the map of the city of Santiago de Cali

All the current routes (Numeral 5.1 5.2 .5.3 5.4 5.5) and the 2 proposals (Numeral 6.1 6.2) are analyzed in the same way as in this Chapter (Section 5.1).

The topological accessibility indicators of route A-12C are calculated and for the other routes, the same procedure as in this route was followed.

The route has the peculiarity that the user can climb in any direction that wants, that is to say towards the station or towards the farthest stop from the station, therefore, it is studied the route in only one direction, the study nodes will be highlighted in the matrices where require such differentiation.

The steps carried out on each Study Route and proposal are discussed below

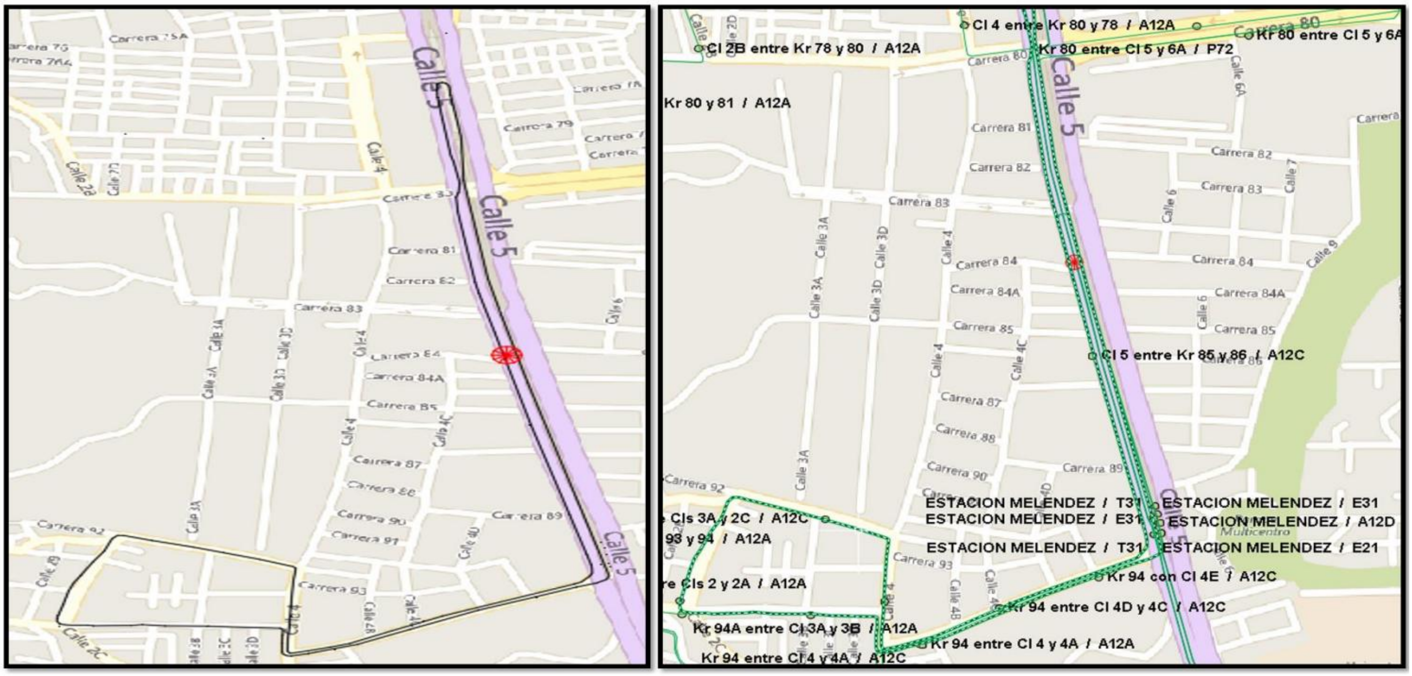


Image 6 Route A12C

First of all, the work area must be georeferenced in AutoCad Civil, it must be use a valid coordinate system for the area in question, in this case the

Magna Colombia West system. For the current routes, a SHP database was used, provided by Metrocali.

Calculation of indicators

5.1.1 Shimbel matrix

The Shimbel matrix (Table 6), is made by counting the number of arcs that exist between each node/stop and it accumulates (image 7-A). Following equation (1) cited in the Number 2.3.1. To exemplify, the count is performed starting from the *Station* node *Capri* to the Cl4 node *between Kr 92 and 94* (Table 6). The route of this route is done in 3 arcs and 4 nodes, therefore the Shimbel matrix is equal to 3.

IS = ÿ(1) (Cáceres, Accessibility indicators and their decision-making role in investments in transport infrastructure, 1988)

Table 6 Shimbel Matrix Route A12C

	CAPRI SEASON					
CAPRI STATION	0	1	two	3	4	5
Cl 5 between Kr 85 and 86	1	0	1	two	3	4
Kr 94 between Cl 4D and 4C	two	1	0	1	two	3
Cl 4 between Kr 92 and 94	3	two	1	0	1	two
Kr 92 between Cls 3A and 2C	4	3	two	1	0	1
Cl 2C between Kr 94 and 94A	5	4	3	two	1	0

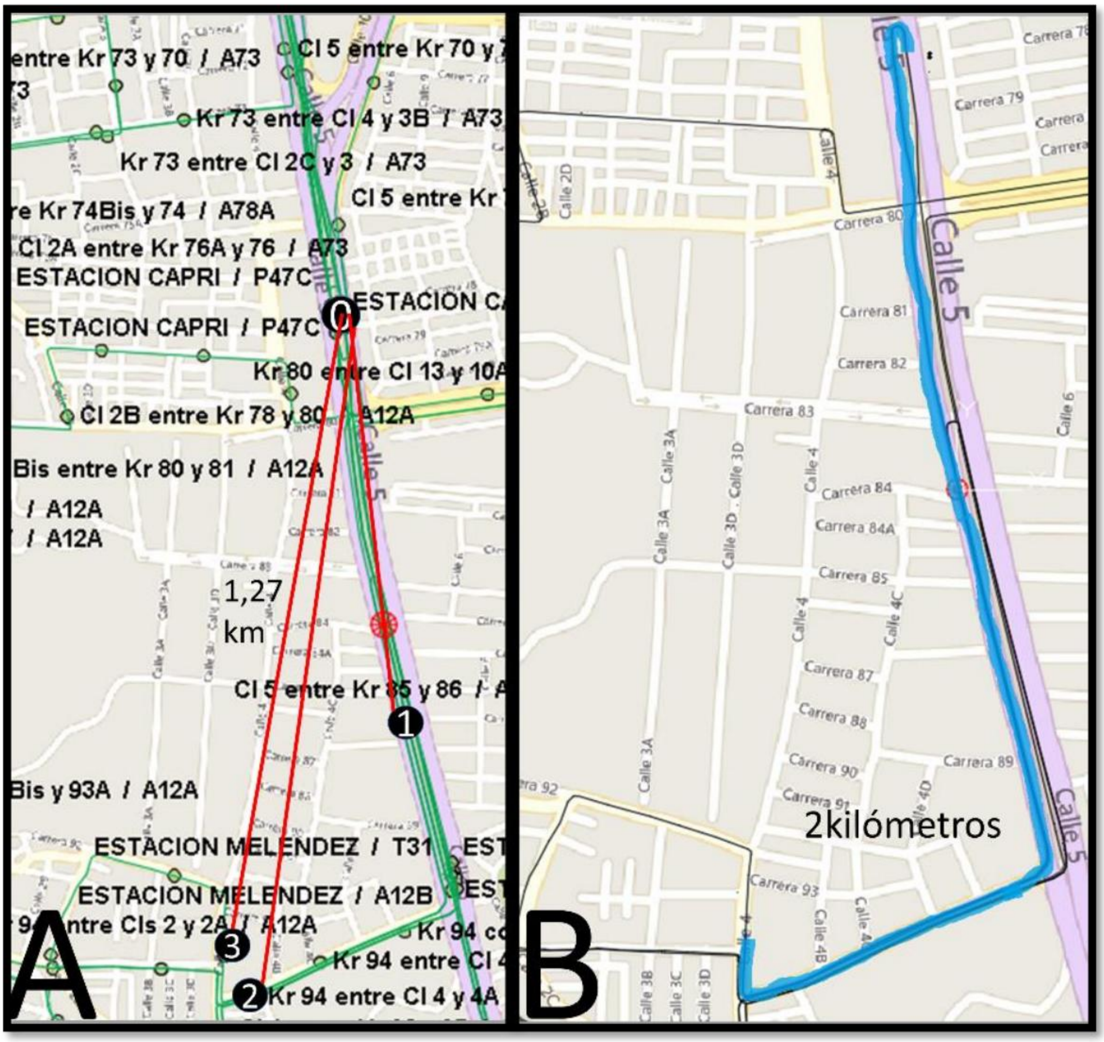


image 7-A Counting of stations for the Shimbel matrix, in red line the distance in line

Figure 7-B Distance en route

5.1.2 Distance matrix km en route A12C

To prepare the route distance matrix (Table 7), the distance over the polyline (arc) between each of the stops (nodes), then the existing distance is accumulated between each group of nodes through which the bus must pass (Image 7-B).

For the selected example, the sum of the distance (Table 7), corresponds to the distance existing from *Capri* station to *Cl 4 between kr 92 and 94,* following the route of the MIO bus (blue color **Image 7-B).** Thus, the distance between *(Capri Station)* and *(Cl 5 between Kr85 and 86)* is 0.98 Km, the distance between *(Cl 5 between Kr85 and 86)* and *(Kr 94 between Cl 4D and 4C)* is 0.7km which in cumulative sum gives 1.68km and finally between and *(Kr 94 between Cl 4D and 4C)* and *(Cl4 between Kr 92 and 94)* there are 0.32 km which gives a cumulative total of 2 Kilometers.

Table 7 Distance matrix km en route A12C

CAPRI STATION	0.00	0.98	1.68	2.00	2.25	2.66	2.92	3.18	3.53
Cl 5 between Kr 85 and 86	0.98	0.00	0.70	1.03	1.27	1.69	1.94	2.21	2.56
Kr 94 between Cl 4D and 4C	1.68	0.70	0.00	0.33	0.57	0.99	1.24	1.51	1.86
Cl 4 between Kr 92 and 94	2.00	1.03	0.33	0.00	0.25	0.66	0.92	1.18	1.53
Kr 92 between Cls 3A and 2C	2.25	1.27	0.57	0.25	0.00	0.41	0.67	0.93	1.28
Cl 2C between Kr 94 and 94A	2.66	1.69	0.99	0.66	0.41	0.00	1.94	1.24	0.92
Kr 94A between Cl 3A and 3B	2.92	1.94	1.24	0.92	0.67	1.94	0.00	0.26	0.61
Kr 94 between Cl 4 and 4A	3.18	2.21	1.51	1.18	0.93	1.24	0.26	0.00	0.35
Kr94 with Cl4E	3.53	2.56	1.86	1.53	1.28	0.92	0.61	0.35	0.00

5.1.3 Distance matrix km in a straight line A12C

The distance in a straight line (Table 8) between the main Stop *(Capri)* and each of the stops (nodes), is calculated, by using equation (8), which requires the coordinates *x,y* for each node y find the magnitude of the vector that joins them by the shortest path (straight line) (red line Image 7-A).

Equation (8), is replaced by the values selected in the example (Table 9), to arrive at the result of 1.27 kilometers between the node *(Capri station)* and *(Cl4 between Kr 92 and 94)* (Image 7-A).

The coordinates are given by MetroCali in Megameters, therefore they must be passed to kilometres

= [ÿ(ÿ76.547121 ÿ (ÿ76.54489)) two + (3.375747 ÿ 3.38830) two] ÿ 100 ÿ 1.27

Table 8 Distance matrix km in a straight line A12C

CAPRI STATION	0.00	0.80	1.27	1.27	1.15	1.37	1.33	1.35	1.22
Cl 5 between Kr 85 and 86	0.80	0.00	0.50	0.57	0.53	0.81	0.66	0.61	0.41
Kr 94 between Cl 4D and 4C	1.27	0.50	0.00	0.19	0.33	0.51	0.30	0.14	0.17
Cl 4 between Kr 92 and 94	1.27	0.57	0.19	0.00	0.18	0.33	0.12	0.10	0.35
Kr 92 between Cls 3A and 2C	1.15	0.53	0.33	0.18	0.00	0.28	0.18	0.28	0.45
Cl 2C between Kr 94 and 94A	1.37	0.81	0.51	0.33	0.28	0.00	0.21	0.40	0.68
Kr 94A between Cl 3A and 3B	1.33	0.66	0.30	0.12	0.18	0.21	0.00	0.19	0.47
Kr 94 between Cl 4 and 4A	1.35	0.61	0.14	0.10	0.28	0.40	0.19	0.00	0.31
Kr94 with Cl4E	1.22	0.41	0.17	0.35	0.45	0.68	0.47	0.31	0.00

Table 9 Coordinates of the route nodes A12C

NODO	Coordenada X	coordenada Y
ESTACION CAPRI	-76,5448983	3,3883018
Cl 5 entre Kr 85 y 86	-76,5437765	3,3803517
Kr 94 entre Cl 4D y 4C	-76,5452751	3,3756298
Cl 4 entre Kr 92 y 94	-76,5471217	3,3757480
Kr 92 entre Cls 3A y 2C	-76,5480765	3,3772914
Cl 2C entre Kr 94 y 94A	-76,5504229	3,3757654
Kr 94A entre Cl 3A y 3B	-76,5483132	3,3754964
Kr 94 entre Cl 4 y 4A	-76,5465185	3,3749440
Kr 94 con Cl 4E	-76,5436759	3,3762102

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (8)$$

5.1.4 Route time matrix in minutes A12C

The route travel time matrix (Table 10) is the result of dividing the matrix of route distance (Table 7), between the average speed of the route (supplied by MetroCali image A-4), in this case it is 16.21 km/h and multiplying it by 60.

= (ÿ2 16.21) ÿ (60) ÿ 7.41

In (Table 10) you can easily see the largest and shortest paths that can have a particular user, in this case the maximum is 9.86 minutes, it is important emphasize that this route, as it is not circular, allows users to decide in which direction they want get on

Table 10 Matrix of time traveled en route minutes A12C

CAPRI STATION	0.00	3.62	6.21	7.41	8.33	9.86	10.80	11.78	13.07
Cl 5 between Kr 85 and 86	3.62	0.00	2.59	3.79	4.71	6.24	7.19	8.16	9.46
Kr 94 between Cl 4D and 4C	6.21	2.59	0.00	1.20	2.12	3.65	4.60	5.57	6.87
Cl 4 between Kr 92 and 94	7.41	3.79	1.20	0.00	0.92	2.45	3.39	4.37	5.66
Kr 92 between Cls 3A and 2C	8.33	4.71	2.12	0.92	0.00	1.53	2.47	3.45	4.75
Cl 2C between Kr 94 and 94A	9.86	6.24	3.65	2.45	1.53	0.00	7.19	4.60	3.39
Kr 94A between Cl 3A and 3B	10.80	7.19	4.60	3.39	2.47	7.19	0.00	0.98	2.27
Kr 94 between Cl 4 and 4A	11.78	8.16	5.57	4.37	3.45	4.60	0.98	0.00	1.30
Kr94 with Cl4E	13.07	9.46	6.87	5.66	4.75	3.39	2.27	1.30	0.00

5.1.5 Matrix of time traveled in a straight line minutes A12C

The time matrix in straight line travel (Table 11) is the result of dividing the matrix of distance in a straight line, between the average speed of the route, in this case it is 16.21 km/h (Image 4-A) and multiplying it by 60.

= (ÿ1.27(8) / 16.21(4 ÿ)) ÿ (60) ÿ 4.72

This matrix is used to evaluate what the minimum travel time will be, if the possibility exists. of making routes in a straight line, for example, for the greatest distance the minimum time would be 4.69 minutes.

Table 11 Matrix of time traveled in a straight line minutes A12C

CAPRI STATION	0.00	2.97	4.69	4.72	4.24	5.07	4.90	4.98	4.50
Cl 5 between Kr 85 and 86	2.97	0.00	1.83	2.11	1.95	2.99	2.46	2.24	1.53
Kr 94 between Cl 4D and 4C	4.69	1.83	0.00	0.68	1.21	1.91	1.13	0.53	0.63
Cl 4 between Kr 92 and 94	4.72	2.11	0.68	0.00	0.67	1.22	0.45	0.37	1.29
Kr 92 between Cls 3A and 2C	4.24	1.95	1.21	0.67	0.00	1.04	0.67	1.04	1.68
Cl 2C between Kr 94 and 94A	5.07	2.99	1.91	1.22	1.04	0.00	0.79	1.48	2.50
Kr 94A between Cl 3A and 3B	4.90	2.46	1.13	0.45	0.67	0.79	0.00	0.69	1.74
Kr 94 between Cl 4 and 4A	4.98	2.24	0.53	0.37	1.04	1.48	0.69	0.00	1.15
Kr94 with Cl4E	4.50	1.53	0.63	1.29	1.68	2.50	1.74	1.15	0.00

5.1.6 Integral Path Factor Matrix (Fr) A12C

The route factor matrix (Table 12) is the result of applying equation (2), which consists of dividing the matrix of distance in route route (Table 7), between the matrix of travel distance in a straight line (Table 8).

$$= \frac{}{0} \qquad = \frac{ÿ2 \qquad 7)}{(ÿ1.27 (\qquad 8)} ÿ 1.57 \text{ (2) (Explanation Numeral 2.3.2)}$$

In the integral path factor (Table 12) it can be seen how efficient is the tracing of the current route, with respect to the plotted minimum straight line route, between the number east plus close to 1.0, the best will be the layout of said route between two nodes/stops. When the path has a circular route, the farthest nodes from each other will present a lower efficiency. Based In this, it can be said that the worst route trace, among the data studied, is undoubtedly the existing between *(Cl5 between Kr85 and 86)* and *(Kr 92 between Cls 3A and 2C)* which has a Factor of route of 2.41 which means that the route is 1.41 times less efficient than it could be, in a hypothetical case in which routes equivalent to the straight route could be traced.

Table 12 Integral Path Factor Matrix (Fr) A12C

Integral Path Factor									
CAPRI STATION	0.00	1.22	1.32 0.00	1.57	1.96	1.94	2.20	2.37	2.91
Cl 5 between Kr 85 and 86	1.22	1.41	1.41 [illegible]	1.80	2.41	2.09	2.92	3.64	6.17
Kr 94 between Cl 4D and 4C	1.32	1.76	2.41 [illegible]	1.76	1.76	1.92	4.08	10.60	10.91
Cl 4 between Kr 92 and 94	1.57	1.92	2.92 [illegible]	0.00	1.37	2.00	7.53	11.74	4.40
Kr 92 between Cls 3A and 2C	1.96	10.60	6, 17 10.91	1.37	0.00	1.47	3.69	3.31	2.83
Cl 2C between Kr 94 and 94A	1.94			2.00	1.47	0.00	9.13	3.11	1.36
Kr 94A between Cl 3A and 3B	2.20			7.53	3.69	9.13	0.00	1.40	1.31
Kr 94 between Cl 4 and 4A	2.37			11.74	3.31	3.11	1.40	0.00	1.13
Kr94 with Cl4E	2.91			4.40	2.83	1.36	1.31	1.13	0.00

5.1.7 Indicator matrix plotting speed between nodes i and j A12C

The velocity trace indicator matrix (Table 13) is the result of applying the equation (6), which consists of dividing the time matrix in route travel (Table 10), between the straight-line travel time matrix (Table 11). The reason why you give same value as in integral path factor, it is very simple this path is evaluated in the sense maximum that the user can travel, if it were a circular route the values would vary. By Therefore, for this particular case the worst time is exactly the same as the worst plot of route, this corresponds to the nodes *(Cl5 between Kr85 and 86)* and *(Kr 92 between Cls 3A and 2C)* the which has a path speed trace index of 2.41 which means the path is 1.41 times less efficient than it could be, in a hypothetical case in which draw routes equivalent to the straight route.

$$= \frac{}{0} = \frac{10)}{ÿ7.41(\ ÿ4.72(\ 11)} ÿ\ 1.57 \qquad (6)$$

(Explanation Numeral 2.3.4)

In the indicator matrix plotting speed between nodes *i* and *j* it can be seen how efficient is the time of the current route, with respect to the minimum time traveled in a straight line, between the This number is closer to 1.0, the better the time of said path between two nodes/stops. This factor does not take into account the corrections of Ingram in 1971 and Vickerman (1974) (Cáceres, Accessibility indicators and their decision-making role in investments in infrastructures transport, 1988), therefore, it shows the efficiency of the route without taking into account the amount of nodes through which it must pass, it is very useful to analyze what is the extra time, which is being using in each route by not following a linear behavior

Table 13 Indicator matrix plotting speed between nodes i and j A12C

Speed Plot Index (TV)	CAPRI SEASON	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4E
CAPRI STATION	0.00	1.22	1.32	1.57	1.96	1.94	2.20	2.37	2.91
Cl 5 between Kr 85 and 86	1.22	0.00	1.41	1.80	2.41	2.09	2.92	3.64	6.17
Kr 94 between Cl 4D and 4C	1.32	1.41	0.00	1.76	1.76	1.92	4.08	10.60	10.91
Cl 4 between Kr 92 and 94	1.57	1.80	1.76	0.00	1.37	2.00	7.53	11.74	4.40
Kr 92 between Cls 3A and 2C	1.96	2.41	1.76	1.37	0.00	1.47	3.69	3.31	2.83
Cl 2C between Kr 94 and 94A	1.94	2.09	1.92	2.00	1.47	0.00	9.13	3.11	1.36
Kr 94A between Cl 3A and 3B	2.20	2.92	4.08	7.53	3.69	9.13	0.00	1.40	1.31
Kr 94 between Cl 4 and 4A	2.37	3.64	10.60	11.74	3.31	3.11	1.40	0.00	1.13
Kr94 with Cl4E	2.91	6.17	10.91	4.40	2.83	1.36	1.31	1.13	0.00

5.1.8 Global results table

The velocity trace indicator for one of the nodes together with the absolute indicator of global time and the integral path factor of the node (Table 12), is calculated with the equations (3,4, 5,6,7, Explained better in Chapter 2). The maximum travel time for each route is calculated as the maximum distance that a user of that route can travel, differs from the time maximum that a bus can travel because this bus must pass through all the stations for each tour.

• Column 1 (Table 14), simply shows the address of the node or stop, which it is obtained from the SHP database or from the observing map.

• Column 2 (Table 14), shows the accumulated number of total arcs for each station, it is a purely theoretical concept used for equation 3 and 7 (Chapter 2).

shimbel	ESTACION CAPRI	Cl 5 entre Kr 85 y 86	Kr 94 entre Cl 4D y 4C	Cl 4 entre Kr 92 y 94	Kr 92 entre Cls 3A y 2C	Cl 2C entre Kr 94 y 94A	Kr 94A entre Cl 3A y 3B	Kr 94 entre Cl 4 y 4A	Kr 94 con Cl 4E	suma
ESTACION CAPRI	0	1	2	3	4	5	1	2	3	21
Cl 5 entre Kr 85 y 86	1	0	1	2	3	4	5	6	7	29
Kr 94 entre Cl 4D y 4C	2	1	0	1	2	3	4	5	6	24
Cl 4 entre Kr 92 y 94	3	2	1	0	1	2	3	4	5	21
Kr 92 entre Cls 3A y 2C	4	3	2	1	0	1	2	3	4	20
Cl 2C entre Kr 94 y 94A	5	4	3	2	1	0	1	2	3	21

Figure 14 This figure shows the Shimbel summation for each node

$$= \frac{1}{nÿ1} \; ÿ \; ÿ \; 1 \frac{\text{I said}}{dÿij} \qquad \text{(3) (Explained Section 2.3.2)}$$

$$= \frac{1}{n} \; ÿ \; \frac{ÿ \; {}^{=}_{=1}}{ÿ \; 0 {}^{=}_{=1}} \qquad \text{(7) (Explained Section 2.3.4)}$$

• Column 3 (Table 14), shows the sum for each node of its path factor integral and will be used in Equation 3 (Chapter 2).

Factor de Ruta Integral	ESTACION CAPRI	Cl 5 entre Kr 85 y 86	Kr 94 entre Cl 4D y 4C	Cl 4 entre Kr 92 y 94	Kr 92 entre Cls 3A y 2C	Cl 2C entre Kr 94 y 94A	Kr 94A entre Cl 3A y 3B	Kr 94 entre Cl 4 y 4A	Kr 94 con Cl 4E	suma
ESTACION CAPRI	0,00	1,22	1,32	1,57	1,96	1,94	2,20	2,37	2,91	8,02
Cl 5 entre Kr 85 y 86	1,22	0,00	1,41	1,80	2,41	2,09	2,92	3,64	6,[illegible]	8,94
Kr 94 entre Cl 4D y 4C	1,32	1,41	0,00	1,76	1,76	1,92	4,08	10,60	10,91	8,17
Cl 4 entre Kr 92 y 94	1,57	1,80	1,76	0,00	1,37	2,00	7,53	11,74	4,[illegible]	8,50
Kr 92 entre Cls 3A y 2C	1,96	2,41	1,76	1,37	0,00	1,47	3,69	3,31	2,[illegible]3	8,98
Cl 2C entre Kr 94 y 94A	1,94	2,09	1,92	2,00	1,47	0,00	9,13	3,11	1,36	9,43

Figure 15 This figure shows the sum of the integral path factor for each node

• Column 4 (Table 14), shows the result of a division between 1 and the number of nodes minus 1. This will be used for equation 3 (Chapter 2).

For example $\frac{1}{1ÿ} = (\frac{1}{1ÿ21}) = 0.05$

$$= \frac{1}{nÿ1} \; ÿ \; ÿ \; 1 \frac{\text{I said}}{d0ij} \qquad \text{(3) (Number 2.3.2)}$$

• Column 5 (Table 14), shows the result of the integral path factor of node i of the equation 3 (Chapter 2)

$$= \frac{1}{n ÿ 1} ÿ ÿ_1 \frac{\text{I said}}{d0ij} = \frac{1}{21 ÿ 1} ÿ 8.02 = 0.40 \text{ (3) (Explained Section 2.3.2)}$$

• Column 6 (Table 14), shows the result of a division between 1 and the number of nodes. This will be used for equation 7 (Chapter 2).

For example $\frac{1}{} = (\frac{1}{\text{twenty-one}}) = 0.047$

$$= \frac{1}{n} ÿ \frac{ÿ_{=1}^{=}}{ÿ\,0_{=1}^{=}} \quad \text{(7) (Explained Section 2.3.4)}$$

• Column 7 (Table 14), calculates the extra time used in each run of the node y is a measure adapted from equation 7 and should give the same result (Chapter two).

$$= \frac{ÿ_{=1}^{=}}{ÿ\,0_{=1}^{=}} \quad (7)$$

(Only the second part of the equation is taken. Numeral 2.3.4)

• Column 8 (Table 14), using Equation 7 shows the velocity plot for each note taking into account the geography of the terrain and the number of stops (Chapter two).

$$= \frac{1}{n} ÿ \frac{ÿ_{=1}^{=}}{ÿ_{=1}^{=}\,0} = \frac{1}{\text{twenty-one}} ÿ \frac{35.41}{21.68} = 0.077 \text{ (7)}$$

• Column 9 (Table 14), this shows the global time absolute, it is intended to be short and is calculated with Equation 5(Chapter 2).

Tiempo recorrido	ESTACION CAPRI	Cl 5 entre Kr 85 y 86	Kr 94 entre Cl 4D y 4C	Cl 4 entre Kr 92 y 94	Kr 92 entre Cls 3A y 2C	Cl 2C entre Kr 94 y 94A	suma
ESTACION CAPRI	0	3,615792	6,207015	7,41042	8,32829	9,855645	35,4172
Cl 5 entre Kr 85 y 86	3,6158	0	2,591224	3,79463	4,712499	6,239853	20,954
Kr 94 entre Cl 4D y 4C	6,207	2,591224	0	1,2034	2,121275	3,64863	15,7715
Cl 4 entre Kr 92 y 94	7,4104	3,794628	1,203404	0	0,917871	2,445225	15,7715
Kr 92 entre Cls 3A y 2C	8,3283	4,712499	2,121275	0,91787	0	1,527355	17,6073
Cl 2C entre Kr 94 y 94A	9,8556	6,239853	3,64863	2,44523	1,527355	0	23,7167

Figure 16This figure shows the sum of global time for each node

= ÿ = =1 (5) (Number 2.3.3)

• Column 10 (Table 14), shows the route factor, without taking into account the geography of the terreiro is calculated using Equation 4 (Chapter 2).

= ÿdij / ÿdÿij (4) (Number 2.3.2)

Table 14 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

CAPRI STATION	twenty-one	8.02	0.05	0.4010322	0.047619		1.63	0.077772465	35.42 1.633222
Cl 5 between Kr 85 and 86	29	8.94	0.035714	0.3191288	0.034483		1.77	0.060982058	20.95 1.76848
Kr 94 between Cl 4D and 4C	24	8.17	0.043478	0.355246	0.041667		1.53	0.063691119	15.77 1.528587
Cl 4 between Kr 92 and 94	twenty-one	8.50	0.05	0.4250249	0.047619		1.68	0.079901467	15.77 1.677931
Kr 92 between Cls 3A and 2C	twenty	8.98	0.052632	0.472642		0.05	1.93	0.096697936	17.61 1.933959
Cl 2C between Kr 94 and 94A	twenty-one	9.43	0.05	0.4712696	0.047619		1.94	0.092435629	23.72 1.941148

• The second column (Table 14) shows the number of nodes relative to a node in particular, result of the Shimbel matrix, the smaller this number is, the faster and the node will be easily accessed. Although this suggests that routes with few nodes, it is also important to emphasize that a route with few nodes will represent a less availability of bus stops for users.

• The third column (Table 14) shows the sum of the Integral Path Factor (between the lower this factor, the better the accessibility), this data is necessary for the subsequent computation of the Ri.

- The fourth column (Table 14) shows the Ingram modulator in 1971 and Vickerman (1974), which is multiplied by the integral path factor, to find the true *Ri* that if you take into account the number of nodes through which each route passes.

- The fifth column (Table 14) shows *Ri* (integral path factor i), if it is greater than 1.5 the level of accessibility is low. Therefore, the A12C pathway has a degree of high accessibility, this due to the high number of the Shimbel summation that enters show accessibility level.

- The sixth (Table 14) column shows the speed trace index modulator, this modulator plays a very important role, since it will reduce the index velocity tracing that does not take into account the number of nodes through which the bus on its way.

- The seventh column (Table 14) shows the plotted indicator of speed of node *i* for each of the nodes. This is obtained by adding the time it takes for each node to communicate with the other nodes en route and subsequently dividing this by the result of the sum of the time it takes each node to communicate with the other nodes in a straight line. This outputs how inefficient the path is for that node, being "1.0" perfect efficiency and more than "1.5" highly inefficient.

- The eighth column (Table 14) shows the velocity plot indicator of node *i* real, that is, it takes into account how many nodes it passed through before calculating the time, like this therefore, a route that passes through 9 nodes cannot be called inefficient (Table 7). In this In this particular case, Capri presents a trace indicator of node *i* of 0.078, which it means that it has an excellent behavior.

- The ninth column (Table 14) shows the overall time index in minutes, this The smaller the indicator, the better for the user. then show the time of connection that exists in each node with respect to the rest of the nodes, therefore, for this route A12C presents low values (longest time 35.42 minutes), which indicates a shorter travel time with respect to routes that describe a circular route, however, if you want to know the real travel time for each of the nodes, just check the final number in the enroute time matrix (Table 10).

- The tenth column (Table 14), shows the route factor, without taking into account the adaptation of Ingram in 1971 and Vickerman. Here it is observed that all the values for In general, they will always give greater than 1.5 because they do not take geography into account. of land and number of stations that would increase accessibility.

5.2 Route A12A

Route A12A (Image 8) covers the route *Altos de la Luisa - Estación Melendez* , is a path that covers the immediate vicinity of the battalion, its route describes a circle.

In annexes are the Tables corresponding to Route A12A (See Annexes: *A- 70 Matrix of Shimbel Route A12A, A- 71 Distance matrix km en route A12A, A- 72 Distance matrix km in a straight line A12A, A- 73 Matrix of time traveled en route minutes A12A, A- 74 Matrix of time traveled in a straight line minutes A12A, A- 75 Integral Route Factor Matrix (Fr) A12A and A- 76 Indicator matrix plotting speed between nodes i and j A12A)*

Route A12A (Image 8) has a circular route, which increases travel time and increases the values in *(A- 75 Integral Path Factor Matrix (Fr) A12A and A- 76 Matrix traced indicator speed between nodes i and j A12A), these* values show that the path is poorly designed (for example there are values that reach even numbers so far from 1 such as the number 75) and makes the users of said route use more time than they should, therefore the route becomes inefficient in terms of travel time.

- The second column (Table 15) shows the number of nodes relative to a node in particular, result of the Shimbel matrix, the smaller this number is, the faster and the node will be easily accessed. Although this suggests that routes with few nodes, it is also important to emphasize that a route with few nodes will represent a less availability of bus stops for users. This number does not vary in this route because it is a circular route which means that each node is on the same condition with respect to the rest, which generates highly accessible nodes, but very inefficient in time.

- The third column (Table 15) shows the sum of the Integral Path Factor (between the lower this factor, the better the accessibility), this data is necessary for the subsequent computation of Ri. For example, node *Kr80 between CK5 and 6A* obtains a value of 177.7 which indicates that its accessibility will be the least for that node.

- The fourth column (Table 15) shows the Ingram modulator in 1971 and Vickerman (1974), which is multiplied by the integral path factor, to find the true *Ri* that if you take into account the number of nodes through which each route passes, in this case in particular the modulator gives the same number because it is a route that follows a flow circular.

- The fifth column (Table 15) shows *Ri* (integral path factor i), if it is greater than 1.5 the level of accessibility is low (Section 2.3.2). Therefore, the A12A route presents a high degree of accessibility, this due to the high number of the Shimbel summation that enters to operate in the *Ri formula.*

- The sixth (Table 15) column shows the velocity trace index modulator, this modulator plays a very important role, since it will reduce the index velocity tracing that does not take into account the number of nodes through which the bus on its way.

- The seventh column (Table 15) *shows the plotted indicator of speed of node i* for each of the nodes. This is obtained by adding the time it takes for each node to communicate with the other nodes en route and subsequently dividing this by the result of the sum of the time it takes each node to communicate with the other nodes in a straight line. This outputs how inefficient the path is for that node, being "1.0" perfect efficiency and more than "1.5" highly inefficient.

- The eighth column (Table 15) shows the velocity plot indicator of node *i* real, that is, it takes into account how many nodes it passed through before calculating the time, like this Therefore, a route that passes through many nodes cannot be labeled as inaccessible, in this case In particular, Meléndez presents a trace indicator of node *i* of 0.00117, which it means that it has an excellent behavior.

- The ninth column (Table 15), the global index of time in minutes, this indicator the smaller it is, the better for the user. If you want to know the real time of tour for each of the nodes, just check the final number in the matrix of time en route *(Matrix of time traveled en route minutes A12A), it* then shows the connection time that exists in each node with respect to the rest of the nodes, thus, for this route A12A presents high values, which indicates a longer travel time with respect to the routes that do not describe a circular route (longest time 361.73 minutes).

- The tenth column (Table 15), shows the route factor, without taking into account the adaptation of Ingram in 1971 and Vickerman. Here it is observed that all the values for In general, they will always give greater than 1.5 because they do not take geography into account. of land and number of stations that would increase accessibility.

Therefore, the A12A route has a high level of accessibility, this helps the individual user, but it harms the user collectively, because a system with such a degree of accessibility high becomes a very slow one (Max Travel Time 28.31 minutes) because the bus decreases its average speed, stopping at each node, apart from the fact that the route becomes very long I have unjustified for some nodes, therefore an improvement proposal must achieve find adequate levels of accessibility, without losing the idea of collective transport.

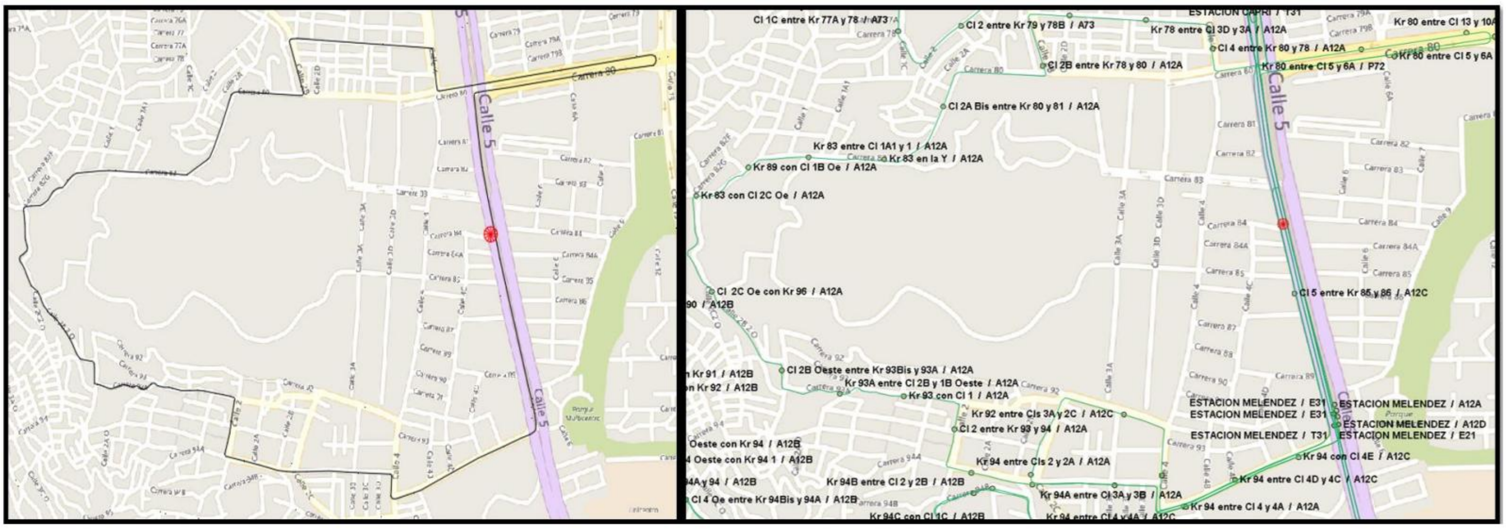


Image 8 Route A12A Source: own elaboration from Metrocali database

Table 15 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i A12A

MELENDEZ STATION	231 59.319 231		0.00435 **0.257909** 0.00432900 0.00435			**2.72 0.011787 3.35**		**276.62** 2.7227	
Kr 80 between Cl 5 and 6A	177.7 231		**0.772606** 0.00432900 0.00435 0.378516			**0.014481 2.92**		**361.73** 3.3451	
Kr 80 between Cl 13 and 10A	87.059 231		0.00432900 **0.00435** 0.392743 0.00432900			**0.012622 3.29**		**359.67** 2.9157	
Kr 80 between Cl 10A and 9	90.331 231		**0.00435** 0.065751 **0.00432900** 0.00435			**0.014224 0.57**		**340.06** 3.2858	
Cl 4 between Kr 80 and 78	15.123 231		**0.00435 553639** 0.00432900 0.00435			**0.002464 4.27**		**48.48** 0.5691	
Kr 78 between Cl 3D and 3A	127.34 231		**0.575502** 0.00432900			**0.01848 4.32**		**353.86** 4.2689	
Kr 78 between Cl 3 and 2C	132.37					**0.018711**		**346.57** 4.3223	
Cl 2B between Kr 78 and 80	231 111.38		0.00435 **0.484275** 0.00432900			**4.60 0.019907**		**339.10** 4.5985	
Cl 2A Bis between Kr 80 and 81	231 132.5 231		0.00435 **0.576066** 0.00432900 0.00435			**4.77 0.020644 4.87**		**339.14** 4.7687	
Kr 83 on the Y	144.85		**0.629796** 0.00432900 0.00435 0.644176			**0.021063 4.34**		**340.68** 4.8655	
Kr 83 between Cl 1A1 and 1	231 148.16		0.00432900 0.00435 **0.581349** 0.00432900			**0.018775 3.83**		**333.20** 4.3369	
Kr89 with Cl1BOe	231 133.71 231		0.00435 **0.427188** 0.00432900 **0.00435**			**0.01657 3.38**		**321.87** 3.8278	
Kr 83 with Cl 2C Oe	98.253 231		0.00435 **0.00435 338448** 0.00432900			**0.014621 3.14**		**308.94** 3.3775	
Cl 2C Oe with Kr 96	77.843		0.00435 **0.569547** 0.00432900			**0.013596 3.73**		**277.64** 3.1408	
Cl 2B West between Kr 93Bis and 93A	231	131				**0.016158**		**304.56** 3.7326	
Kr 93A between Cl 2B and 1B West	231 134.91		0.00435 **0.586554** 0.00432900			**3.90 0.016882**		**298.66** 3.8997	
Kr93 with Cl1	231 138.37 231		0.00435 **0.601594** 0.00432900 0.00435			**4.01 0.017363 3.83**		**287.73** 4.0109	
Cl 2 between Kr 93 and 94	147.38		**0.640782** 0.00432900 0.00435 0.495129			**0.016587 3.43**		**279.18** 3.8317	
Kr 94 between Cls 2 and 2A	231 113.88		0.00432900 **0.00435** 0.408521 0.00432900			**0.014845 3.18**		**267.22** 3.4291	
Cl 2C between Kr 94A and 95	231 93.96 231		**0.00435** 0.376209 **0.00432900** 0.00435			**0.013767 2.93**		**254.13** 3.1803	
Kr 94A between Cl 3A and 3B	86.528 231		0.00435 253438 0.00432900			**0.012699 2.61**		**246.09** 2.9335	
Kr 94 between Cl 4 and 4A	58.291					**0.011284**		**242.61** 2.6067	

5.3 Route A12B

Route A12B (Image 9) covers the *Meléndez - Las Palmas route,* it is a route that is introduced in Commune 18 uses the same road in both directions and Carrera 94 as an escape route towards *5th street.*

In annexes are the Tables corresponding to Route A12B *(A- 77 Matrix of Shimbel Route A12B A- 78, Route km distance matrix A12B A- 79, Straight line km distance matrix A12B A- 80, Route time matrix in minutes A12B A- 81, Time matrix route in a straight line minutes A12A A- 82, Integral Route Factor Matrix (Fr) A12B A 83, Speed trace indicator matrix between nodes i and A12B)*

The route (Image 8) has the peculiarity that the user can get on any direction you want, that is to say towards the station or towards the stop farthest from the station, for

Therefore, the route is studied in only one direction, the study nodes will be highlighted in the arrays where such differentiation is required.

- The second column (Table 16) shows the number of nodes relative to a node in particular, result of the Shimbel matrix, the smaller this number is, the faster and the node will be easily accessed. Although this suggests that routes with few nodes, it is also important to emphasize that a route with few nodes will represent a less availability of bus stops for users.

- The third column (Table 16) shows the sum of the Integral Path Factor (between the lower this factor, the better the accessibility), this data is necessary for the subsequent computation of Ri. For example, the node *Kr 94c with Cl 1c* obtains a value of 297 which indicates that its accessibility will be the least for that node.

- The fourth column (Table 16) shows the Ingram modulator in 1971 and Vickerman (1974), which is multiplied by the integral path factor, to find the true *Ri* that if you take into account the number of nodes through which each route passes, in this case in In particular, the modulator varies a lot since this route follows an operation that describes a line and not a circle.

- The fifth column (Table 16) shows *Ri* (integral path factor i), if it is greater than 1.5 the level of accessibility is low (Section 2.3.2). Therefore, the A12B pathway has a low degree of accessibility, the routes marked in red show a degree of low accessibility.

- The sixth (Table 16) column shows the speed trace index modulator, this modulator plays a very important role, since it will reduce the index velocity tracing that does not take into account the number of nodes through which the bus on its way.

- The seventh column (Table 16) *shows the plotted indicator of speed of node i* for each of the nodes. This is obtained by adding the time it takes for each node to communicate with the other nodes en route and subsequently dividing this by the result of the sum of the time it takes each node to communicate with the other nodes in a straight line. This outputs how inefficient the path is for that node, being "1.0" perfect efficiency and more than "1.5" highly inefficient.

- The eighth column (Table 16) shows the velocity trace indicator of node *i* real, that is, it takes into account how many nodes it passed through before calculating the time, like this Therefore, a route that passes through many nodes cannot be labeled as inaccessible, in this case In particular, Meléndez presents a trace indicator of node *i* of 0.033 which means say that it has a good degree of access for said route A12B.

- The ninth column (Table 16) the global index of time in minutes, this indicator the smaller it is, the better for the user. If you want to know the real time of tour for each of the nodes, just check the final number in the matrix of time en route *(Matrix of time traveled en route minutes A12B), it* then shows the connection time that exists in each node with respect to the rest of the nodes, thus, for this route A12B presents low values (longest time 168.45).

- The tenth column (Table 16), shows the route factor, without taking into account the adaptation of Ingram in 1971 and Vickerman. Here it is observed that all the values for In general, they will always give greater than 1.5 because they do not take geography into account. of land and number of stations that would increase accessibility.

This type of routes where the user can get on the bus in the direction he needs and does not have to take an unnecessary tour, they will always have a lower level of accessibility, as a cost of having better travel time (maximum possible 20.52 minutes), this suggests that the model of routes that must be done must be directed to a similar system, to the routes that describe trajectories closer to straight lines and farther from circular routes. However, it must be able to carry out routes with acceptable accessibility levels.

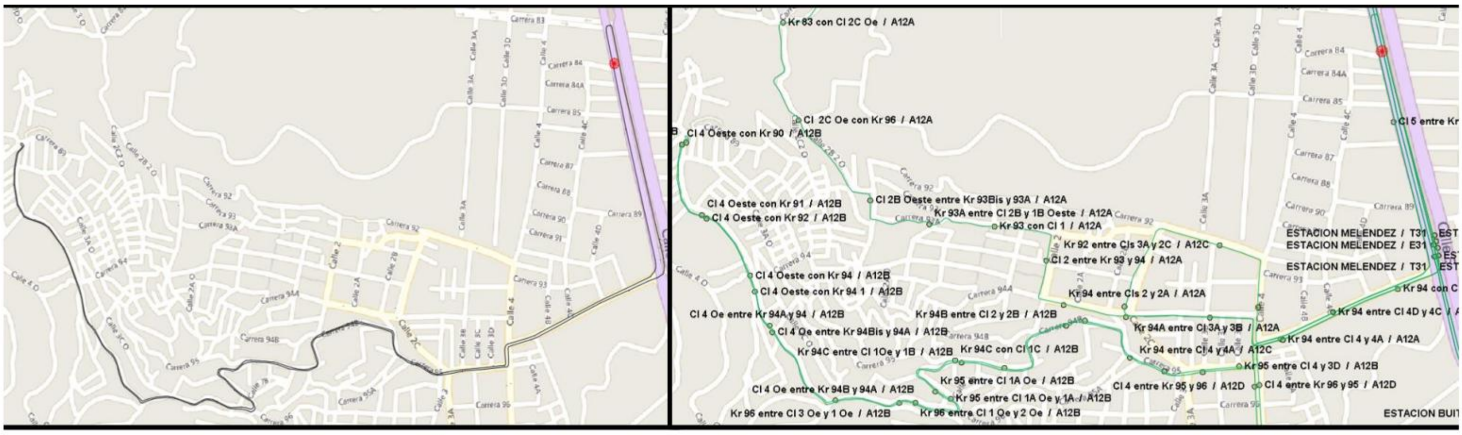


Image 9 Route A12B

Source: own elaboration from MetroCali database

Table 16 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

MELENDEZ STATION	78	34 0.01299 0.446 0.01282 2.57437 0.033 168.4508 2.574368357							
Kr 94 between Cl 4D and 4C	67	114 0.01515 1.728 0.01493 1.64354 0.02453 84.77955 1.643542657							
Kr 95 between Cl 4 and 3D	58	167 0.01754 2.932 0.01724 1.6836 0.02903 71.14383 1.683596944							
Kr 95 between Cl 3 and Kr 95A	51	181 0.02 3.615 0.01961 1.76545 0.03462 64.39722 1.76544729							
Kr 94B between Cl 2B and 2	46	192 0.02222 4.273 0.02174 1.7973 0.03907 57.84501 1.797296705							
Kr 94C between Cl 2 and 1A Oe	43	138 0.02381 3.28 0.02326 1.80446 0.04196 53.3822 1.804455275							
Kr 94C with Cl 1C	42	297 0.02439 7.246 0.02381 1.7916 0.04266 52.75716 1.791600136							
Kr 95 between Cl 1A Oe and 1A	43	177 0.02381 4.218 0.02326 1.76678 0.04109 53.66734 1.766781008							
Kr 96 between Cl 1 Oe and 2 Oe	46	175 0.02222 3.882 0.02174 1.78264 0.03875 56.46298 1.782635891							
Cl 4 Oe between Kr 94B and 94A	51	79 0.02 1.589 0.01961 1.6814 0.03297 61.66458 1.681397237							
Cl 4 Oe between Kr 94A and 94	58	133 0.01754 2.339 0.01724 1.72848 0.0298 71.08495 1.728480933							
Cl 4 West with Kr 91	67	81 0.01515 1.226 0.01493 1.70588 0.02546 86.33898 1.705883728							
Cl 4 West with Kr 89	78	41 0.01299 0.528 0.01282 1.73172 0.0222 98.33164 1.731724742							

Remarks: Accessibility on this route must be improved because the Ri exceeds 1.5 in multiple nodes.

5.4 Route A12D

Route A12D (Image 10) covers *Meléndez - Altos de Santa Elena,* follows the only possible route in the current infrastructure as of *Carrera 98.*

In annexes are the Tables corresponding to *(Route A12D A- 84 Shimbel Matrix Route A12D, A- 85 Route km distance matrix A12D, A- 86 Straight line km distance matrix*

A12D, A- 87 Route time matrix in minutes A12D, A- 88 Time matrix route in a straight line minutes A12D, A- 89 Integral Route Factor Matrix (Fr) A12D, A 90 Indicator matrix plotting speed between nodes i and j A12D)

This route cannot currently be changed without building new infrastructure, for this reason this route is established as route number 4, for the proposals made in the Chapter 6 (Numbers 6.2 and 6.3). The respective study of accessibility to said route is carried out, which would have a maximum journey time of 21.8 minutes for the furthest user (this is the time of travel for the user, not for the bus, because the bus must pass through each node at least one time).

The route has the peculiarity that the user can climb in any direction that wants, that is to say towards the station or towards the farthest stop from the station, therefore, it is studied the route in only one direction, the study nodes will be highlighted in the matrices where require such differentiation.

- The second column (Table 17) shows the number of nodes relative to a node in particular, result of the Shimbel matrix, the smaller this number is, the faster and the node will be easily accessed. Although this suggests that routes with few nodes, it is also important to emphasize that a route with few nodes will represent a less availability of bus stops for users.

- The third column (Table 17) shows the sum of the Integral Path Factor (between the lower this factor, the better the accessibility), this data is necessary for the subsequent computation of Ri. For example, the *Altos de Santa Elena stop 4* node obtains a value of 54,408 even though it is the largest number, it is still very small that means say that this route will present a high level of accessibility.

- The fourth column (Table 17) shows the Ingram modulator in 1971 and Vickerman (1974), which is multiplied by the integral path factor, to find the true *Ri* that if you take into account the number of nodes.

- The fifth column (Table 17) shows *Ri* (integral path factor i), if it is greater than 1.5 the level of accessibility is low (Section 2.3.2). Therefore, the A12D pathway has a fairly high degree of accessibility.

- The sixth (Table 17) column shows the speed trace index modulator, this modulator plays a very important role, since it will reduce the index velocity tracing that does not take into account the number of nodes through which the bus on its way.

- The seventh column (Table 17) *shows the plotted indicator of speed of node i* for each of the nodes. This is obtained by adding the time it takes for each node to communicate with the other nodes en route and subsequently dividing this by the result of the sum of the time it takes each node to communicate with the other nodes in a straight line. This outputs how inefficient the path is for that node, being "1.0" perfect efficiency and more than "1.5" highly inefficient.

- The eighth column (Table 17) shows the velocity plot indicator of node *i* real, that is, it takes into account how many nodes it passed through before calculating the time, like this Therefore, a route that passes through many nodes cannot be labeled as inaccessible, in this case In particular, Meléndez presents a trace indicator of node *i* of 0.04 which means say that it has a good degree of access for said route A12D.

- The ninth column (Table 17) the global index of time in minutes, this indicator the smaller it is, the better for the user. If you want to know the real time of tour for each of the nodes, just check the final number in the matrix of route time *(A12D minutes route time matrix), it* then shows the connection time that exists in each node with respect to the rest of the nodes, thus, for this route A12D presents low values, therefore, the times are quite short this indicates a good connection between the nodes (Greatest time 169.633).

- The tenth column (Table 17), shows the route factor, without taking into account the adaptation of Ingram in 1971 and Vickerman. Here it is observed that all the values for In general, they will always give greater than 1.5 because they do not take geography into account. of land and number of stations that would increase accessibility.

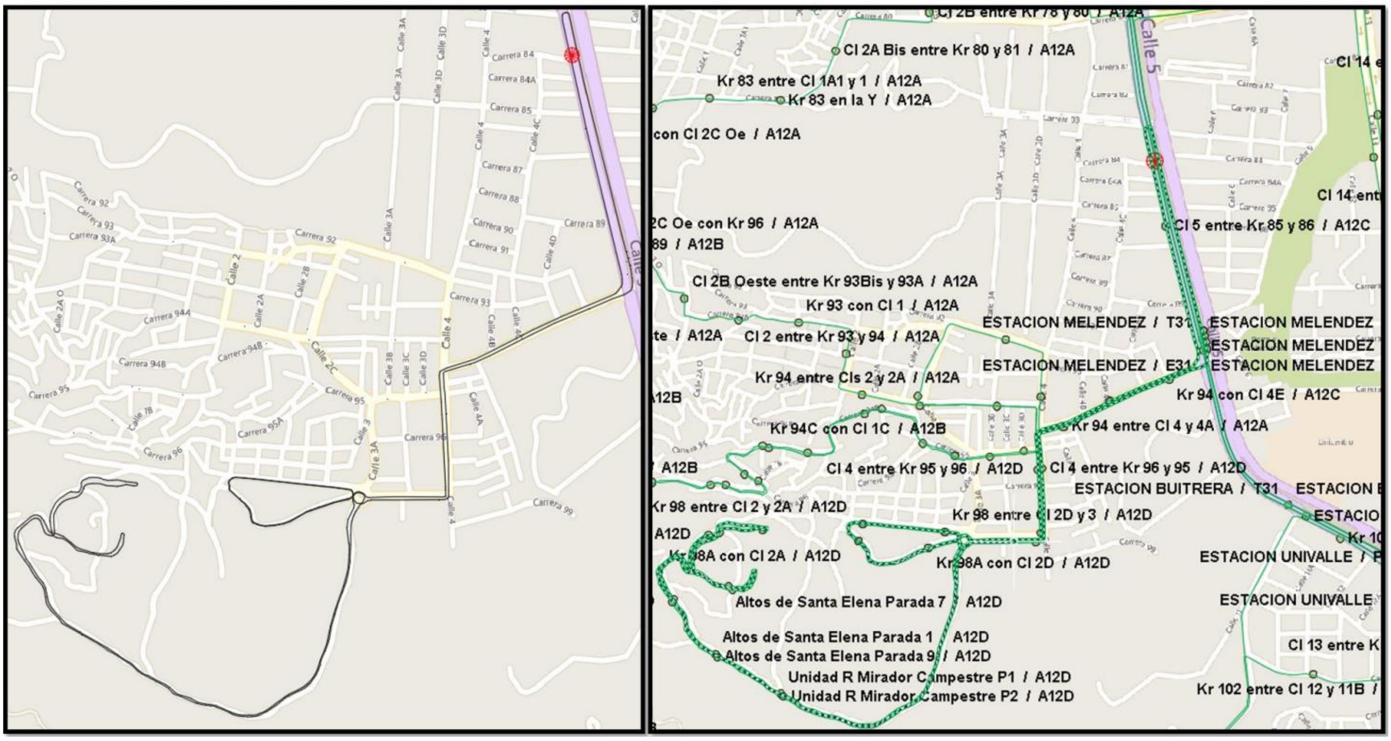


Image 10 Route A12D

Source: own elaboration from Metrocali database

Table 17 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i A12D

MELENDEZ STATION	78,000 41,978 0.01299 0.545175 0.012821 3,3429 67,000						0.042857862	169.633	3.34291
Kr 94 between Cl 4D and 4C	30,152 0.01515 0.456853 0.0149225 2,523 58,000 31,522						0.037656659	95,786	2,523
Cl 4 between Kr 95 and 96	0.01754 0.553018 0.017241 2,8725 51,000 29.82 0.024 0.59						0.049525091	83.168	2.87246
Cl 4 between Kr 96 and 98	019608 2,734						0.053607294	77.908	2.73397
Kr 98A with Cl 2D	46.000 42.035 0.02222 0.934113 0.021739 3.177						0.06906591	70,508	3,17703
Kr98A with Cl2A	43.000 40.838 0.02381 0.972331 0.023256 3.1111						0.072350006	67.424	3.11105
Kr 98 between Cl 2 and 2A	42.000 39.165 0.02439 0.955237 0.02381 3.0768						0.073257393	66,902	3,07681
Kr 98 between Cl 2D and 3	43.000 41.776 0.02381 0.994662 0.023256					3	0.069767201	67.886	2.99999
Unit R Campestre Viewpoint P1	46.000 29.001 0.02222 0.644456 0.021739 2.5808						0.056104056	82.949	2.58079
Altos de Santa Elena Stop 1	51,000 29,514		0.02 0.590288 0.019608 2.6789				0.052526749	87.534	2.67886
Altos de Santa Elena Stop 2	58.000 30.138 0.01754 0.528737 0.017241 2.7484						0.047385399	93.536	2.74835
Altos de Santa Elena Stop 3	67.000 42.075 0.01515 0.637494 0.014925 3.6939						0.055132674	107.625	3.69389
Altos de Santa Elena Stop 4	78.000 54.408 0.01299 0.706595 0.012821 4.3999						0.056409168	113,708	4,39992

5.5 Route A78A

Route A78A (Image 11) covers *Los Chorros - Caldas* describes a circular route, this route presents a challenge because it supplies points of attraction for travel as important as a university, which which means that it requires good accessibility and good travel time for users (Current time 20.69 minutes).

In annexes are the Tables corresponding to *(A- 91 Shimbel Matrix Route A78A, A- 92 Route km distance matrix A78A, A- 93 Straight line km distance matrix A78A, A- 94 Matrix of time traveled en route minutes A78A, A- 95 Matrix of time traveled online straight minutes A78A, A- 96 Integral Route Factor Matrix (Fr) A78A, A- 97 Indicator matrix velocity plot between nodes i and j A78A).*

- The second column (Table 18) shows the number of nodes relative to a node in particular, result of the Shimbel matrix, the smaller this number is, the faster and the node will be easily accessed. Although this suggests that routes with few nodes, it is also important to emphasize that a route with few nodes will represent a less availability of bus stops for users and therefore less accessibility.

- The third column (Table 18) shows the sum of the Integral Path Factor (between the lower this factor, the better the accessibility), this data is necessary for the subsequent computation of the Ri.

- The fourth column (Table 18) shows the Ingram modulator in 1971 and Vickerman (1974), which is multiplied by the integral path factor, to find the true *Ri* that if you take into account the number of nodes through which each route passes, in this case in particular the modulator gives the same number because it is a route that follows a circular tour.

- The fifth column (Table 18) shows *Ri* (integral path factor i), if it is greater than 1.5 the level of accessibility is low (Section 2.3.2). Therefore, the A78A route has a fairly high degree of accessibility.

- The sixth (Table 18) column shows the velocity trace index modulator, this modulator plays a very important role, since it will reduce the index velocity tracing that does not take into account the number of nodes through which the bus on its way.

- The seventh column (Table 18) *shows the plotted indicator of speed of node i* for each of the nodes. This is obtained by adding the time it takes for each node to communicate with the other nodes en route and subsequently dividing this by the result of the sum of the time it takes each node to communicate with the other nodes in a straight line. This outputs how inefficient the path is for that node, being "1.0" perfect efficiency and more than "1.5" highly inefficient.

- The eighth column (Table 18) shows the velocity trace indicator of node *i* real, that is, it takes into account how many nodes it passed through before calculating the time, like this Therefore, a route that passes through many nodes cannot be labeled as inaccessible, in this case In particular, CALDAS presents a trace indicator of node *i* of 0.0014, which it means that it has a good degree of access for said route A78A.

- The ninth column (Table 18) the global index of time in minutes, this indicator the smaller it is, the better for the user. If you want to know the real time of tour for each of the nodes, just check the final number in the matrix of time en route *(Matrix of time traveled en route minutes A78A), it* then shows the connection time that exists in each node with respect to the rest of the nodes, thus, for this route A78A presents high values, which indicates again that the routes non-efficient circulars (highest value 230.81).

- The tenth column (Table 18), shows the route factor, without taking into account the adaptation of Ingram in 1971 and Vickerman. Here it is observed that all the values for In general, they will always give greater than 1.5 because they do not take geography into account. of land and number of stations that would increase accessibility.

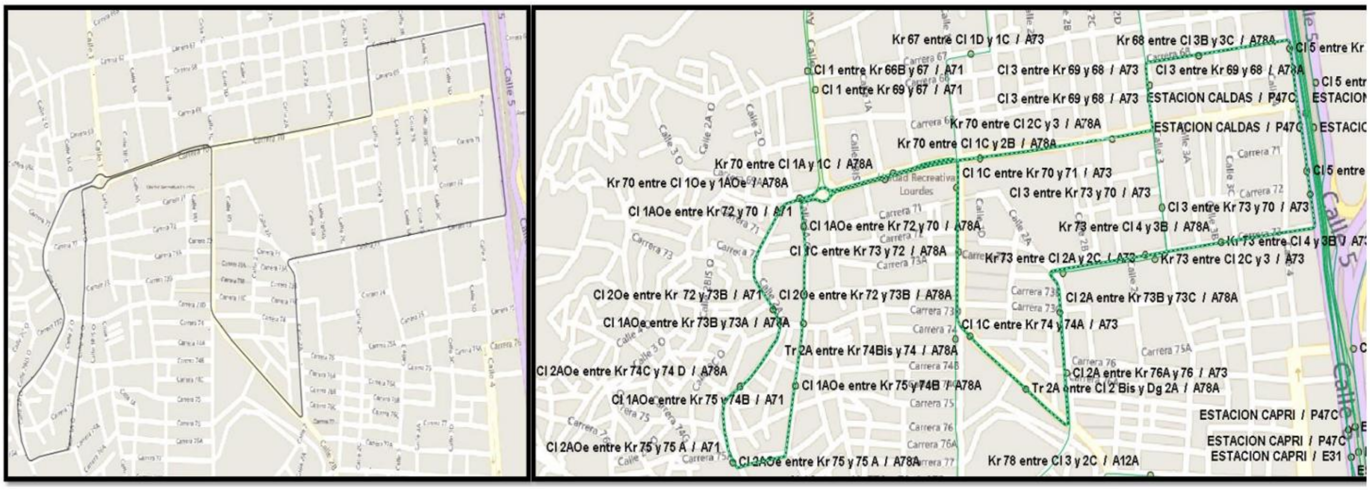


Image 11 Route A78A

Source: own elaboration from Metrocali database

Table 18 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

CALDAS STATION	230.00	113.1190706	0.0044 0.49397 0.0044		0.004347826 3.391995 0.01475		210.249 3.392		
Cl 5 between Kr 70 and 73	229.00	85.02446677	0.372914	0.0044	0.004366812 3.264015 0.01425		196.767 3.26402		
Kr 73 between Cl 4 and 3B	228.00	107.1461476	0.472009	0.0044	0.004385965 4.145974 0.01818		203.682 4.14597		
Kr 73 between Cl 3 and 2C	227.00	110.7363368	0.489984	0.0044	0.004405286 4.700376 0.02071		198.038 4.70038		
Cl 2A between Kr 73B and 73C	226.00	141.7002718	0.629779		0.004424779 5.234535 0.02316		203.877 5.23453		
Tr 2A between Cl 2 Bis and Dg 2A	225.00	126,3266043	0.0045 0.563958		0.004444444 4.93638 0.02194 211.768 4.93638				
Tr 2A between Kr 74Bis and 74	224.00	143,7595154	0.0045 0.644662		0.004464286 5.679099 0.02535		220.189 5.6791		
Cl 1C between Kr 73 and 72	223.00	155,0370683	0.0045 0.698365		0.004484305 6.257526 0.02806		227.496 6.25753		
Kr 70 between Cl 1B and 1A	222.00	290,991353	0.0045 1.316703		0.004504505 5.570994 0.02509		226.164 5.57099		
Kr 70 between Cl 1Oe and 1AOe	221.00	139,9807321	0.0045 0.636276		0.004524887 4.744929 0.02147		229.44 4.74493		
Cl 2Oe between Kr 72 and 73B	220.00	196,3954399	0.0046 0.896783		0.004545455 4.46735 0.02031 224.514 4.46735				
Cl 2AOe between Kr 74C and 74 D	219.00	150,8473726	0.0046 0.69196 0.0046		0.00456621 3.797194 0.01734		218.482 3.79719		
Cl 2AOe between Kr 75 and 75 A	218.00	93,70384638	0.431815	0046	0.004587156 3.42253 0.0157 220.096 3.42253				
Cl 1AOe between Kr 75 and 74B	217.00	116,8796193	0.541109	0.0047	0.004608295 4.112469 0.01895		209.861 4.11247		
Cl 1AOe between Kr 73B and 73A	216.00	114,7914526	0.533914	0.0047	0.00462963 4.814781 0.02229		227.037 4.81478		
Kr 70 between Cl 1A and 1C	215.00	199,1656741	0.930681	0.0047	0.004651163 5.516096 0.02566		225.354 5.5161		
Kr 70 between Cl 1C and 2B	214.00	138,5137053	0.650299	0.0047	0.004672897 6.019748 0.02813		230.818 6.01975		
Kr 70 between Cl 2C and 3	213.00	167,9004222	0.791983	0.0058	0.004694836 5.425915 0.02547		225.166 5.42592		
Cl 3 between Kr 69 and 68	174.00	149,5529793	0.864468	0.0053	0.005747126 4.687929 0.02694		218.944 4.68793		
Kr 68 between Cl 3B and 3C	191.00	122,3954904	0.644187	0.0048	0.005235602 4.128623 0.02162		217.469 4.12862		
Cl 5 between Kr 68 and 69	210.00	108,8390133	0.520761		0.004761905 3.381652 0.01587		210.249 3.38165		

Remarks: Accessibility on this route must be improved because the Ri exceeds 1.5 in several cases

6 DESIGN OF THE SPATIAL DISTRIBUTION OF KEY WHEREABOUTS TO IMPROVE THE SERVICE OF MIO, IN COMMUNITY 18

The spatial distribution of the current whereabouts of commune 18 is adequate according to the Ri found in Chapter 6, within the areas in which the MIO can reach taking into account account the actual geometry of the tracks.

There are areas where the MIO cannot currently reach due to track geometry, but these same areas the motorcycle taxi and the campero if they arrive. For this reason, it is suggested to integrate the system I own these vehicles to ensure transportation in these hillside areas. currently mine it does not reach the sectors of Minas, Veraneras and Esperanza in commune 18.

Image 12 Las Minas Sector Source: Google Maps photos

6.1 Proposal for the spatial distribution of stops within the commune 18

The area of influence is the area that forms around a bus stop, this being what that the user will walk to reach it, whose diameter varies according to the quality of service to be given, it determines the maximum separation between stops in a location.

- For the proposals, an area of influence of 0.282743 kilometers is established. squares, corresponding to a circle with a radius of 300 meters, as the area of maximum separation between bus stops.

- For distribution, it is assumed that the user's walking speed is 4 km/h, which gives an arrival time of 4.5 minutes.

It is proposed to design the bus routes according to the following arguments:

- Maximum travel time on the bus of 20 minutes
- *Ri* node integral path factor less than 1.5 (acceptable from 1.8).
- Indicator traced speed between nodes *i* and j, the closest to 1 in each node of the matrix, i.e. paths close to the straight line.
- Travel time of iaj using the network or global time indicator, this value measures the time connectivity of each node with respect to all other nodes, is expected reduce this value to the minimum possible.

It is intended that the bus be able to pick up people on the same stop in two directions, in this way the user will be able to choose properly whether to get on the bus in the direction of the main station or to any of the nodes before the node in which it is located.

For proposal 1 (Numeral 6.2), the bus stops are located in the center of an area of influence of 0.282743 square kilometers, corresponding to a circle with 300 meters of radio.

For proposal 2 (Numeral 6.3), the bus stops are located in the center of an area of influenced 0.282743 square kilometers, corresponding to a circle with 300 meters of radio, but in addition to that stops are established at critical points such as hospitals, nursing homes and educational centers

For both proposals, route A12D (Numeral 5.4) seen in the image (Image 10) does not will be modified because currently there is only one way to reach your destination and it is by path that marks the route.

The same methodology with which the current routes were evaluated is followed, but with the particularity that the travel time of the proposed routes is calculated with the least registered speed on current routes, which is 13 km/h (Image 4-A)

The route route was shortened by not forcing the bus to arrive at the Meléndez, Caldas or Capri, now the feeder bus has a stop in front of the station, in this way avoids putting the feeders through lane 5, thus avoiding an unnecessary route on said street (Image 13 A-Current routes, B-Proposed route 1, C- The current route D that is not going to be Modify).

image 13 A-Current routes, B-Proposed route 1, C- The current route D that will not be modified

6.2 Route proposal 1

For proposal 1 *Route* , the rules commented on (Section 6.1) are followed. then 3 routes for said proposal route A, route by route c and the methodology of accessibility assessment used in Chapter 5.

The indicator calculations follow the same methodology explained in Section 5.1, the Proposal 1 does not take into account travel attraction places, it only considers distributing the possible nodes in the geographical area of commune 18, to subsequently generate possible routes.

6.2.1 Route A proposal 1

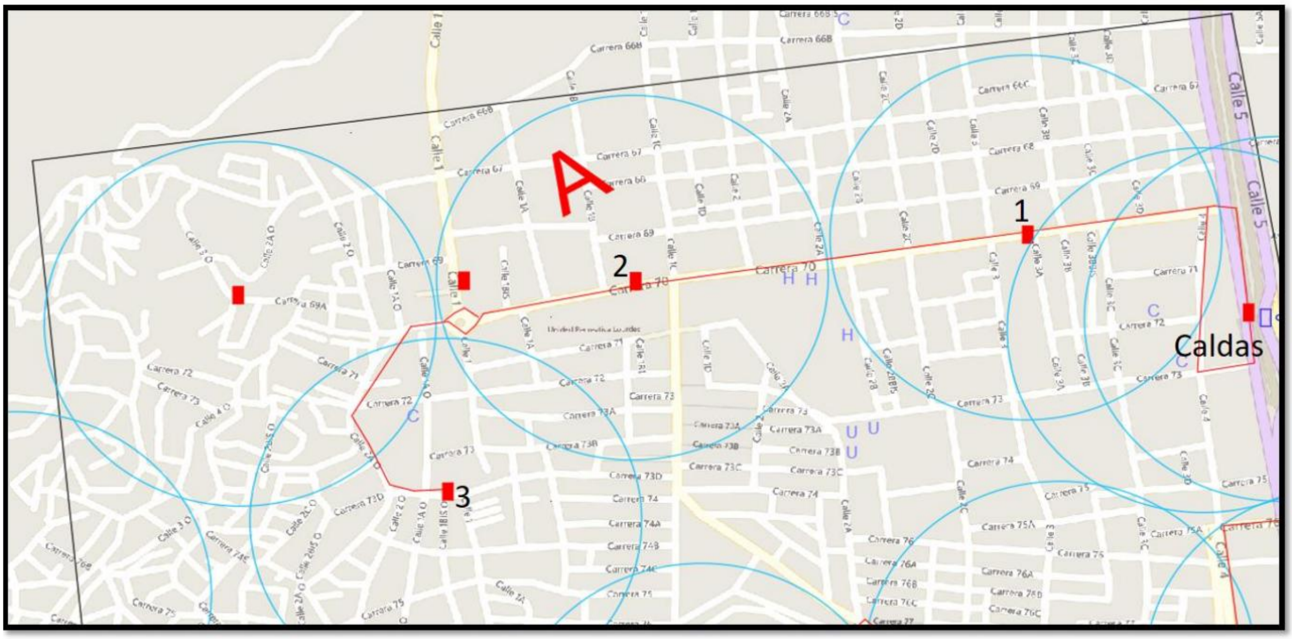


Image 14 Route A

The route arises as an alternative proposal to route A78A (Numeral 5.5) Calculation of indicators for route A proposal 1 (Image 14)

- **Shimbel Matrix route A proposal 1**

The Shimbel matrix (Table 19) shows that the maximum number of arcs between two nodes for a user is only 3, this means that its accessibility could be negatively affected,
but the average speed will improve.

Table 19 Shimbel Matrix Route A

shimbel matrix				
Route A	Caldes	stop 1	stop 2	stop 3
Caldes	0	1	two	3
stop 1	1	0	1	two
stop 2	two	1	0	1
stop 3	3	two	1	0

- Route km distance matrix A proposal 1

This matrix (Table 20) indicates that the maximum travel distance for said route is 1.85 kilometers, therefore, it is a short route, which will improve the travel time.

Table 20 Distance matrix km en route A

Distance en route				
Route A	Caldes	stop 1 stop 2 0.47076		stop 3
Caldes	0	1.0964716 1.8527435		
stop 1	0.47076	0	0.6257116 1.3819835	
stop 2	1.0964716	0.6257116	0	0.7562719
stop 3	1.8527435	1.3819835	0.7562719	0

- ## Distance matrix km in a straight line A proposal 1

It is observed what the measure of the distance would be, if a hypothetical route could be built in straight line between two nodes, this matrix is generated for further calculations.

Table 21 Distance matrix km in a straight line A

Straight line distance				
Route A	Caldes	stop 1 stop 2 0.3893178		stop 3
Caldes	0	0.9671896		1.282359
stop 1	0.3893178	0	0.5978616 0.9757335	
stop 2	0.9671896	0.5978616	0	0.4326377
stop 3	1.282359	0.9757335	0.4326377	0

- ## Matrix of time traveled en route minutes A proposal 1

It shows (Table 22) the time that the bus would take to travel from one node to another, the speed used are 13km/h because it is the minimum speed recorded by commune 18 in some of their routes.

Table 22 Matrix of time traveled en route minutes A

Travel time en route				
Route A	Caldes	stop 1 stop 2 0		stop 3
Caldes	2.172738462 5.06063815 8.55112385			
stop 1	2.17273846	0 2.88789969 6.37838538		
stop 2	5.06063815	2.887899692 0 3.49048569		
stop 3	8.55112385	6.378385385 3.49048569		0

speed of 13km/h.

- ## Matrix of time traveled in a straight line minutes A proposal 1

The straight line travel matrix (Table 23) shows the time it would take for the bus to travel the distance between two nodes, a hypothetical and utopian distance, is used for subsequent calculations.

Table 23 Matrix of time traveled in a straight line minutes A

Travel time straight line stop 1				
Route To Caldas		stop 2 0 1.796851385 4463952		stop 3
Caldes	5.91858			
stop 1 1.796851385 0 2.759361123 4.50338538				
stop 2 0 1.99678938 4463952 2.759361231				
stop 3	5.91858 4.503385385 1.99678938			0

13km/h

- ## Integral Path Factor Matrix (Fr) A proposal 1

The route factor matrix (Table 24) shows how much difference there is in the route traced between two nodes and the utopian path in a straight line. It can be stated by looking at the results that the route presents a good similarity to the perfect route, because it was thought to be carried out following the criterion of not following circular routes.

Table 24 Integral Path Factor Matrix (Fr) A

Path factor (fr)				
Route A	Caldes	stop 1 stop 2 0		stop 3
Caldes	1	209192079 1.13366769 1.444793151		
stop 1	1.209192079	0	1.04658269 1.41635344	
stop 2	1.13366769	1.046582687	0	1.748049
stop 3	1.444793151	1.416353441	1.748049	0

- ## Indicator matrix plotting speed between nodes i and j A proposal 1

The plotted speed indicator matrix (Table 25) compares the route speed with the utopian route speed in a straight line, as this route is not circular it will tend to present the same values of the path factor matrix.

Table 25 Indicator matrix plotting speed between nodes i and j A

plotted speed index				
Route To Caldas		stop 1 stop 2 0 1.209192079		stop 3
Caldes	1.13366769 1.44479315			
stop 1 1.209192079 0 1.04658269 1.41635344				
stop 2 1.13366769 1.046582687 0 1.748049				
Stop 3 1.444793151 1.416353441 0			1.748049	

- Indicator plotted speed of node i, Absolute Indicator Of Global time and integral path factor of node i proposal 1

The importance of this Table (Table 26) corresponds to the results of column 5 *Ri,* the column 6 *sum indicator plotting speed between nodes,* column 8 *time* index *global.* The other columns are explained in detail in Chapter 5 (Chapter 5).

- Column 5 *Ri (Table 26):* The route has adequate accessibility, since no value exceeds 1.5, which makes it an accessible path.

- Column 6 *sum indicator plotted speed between nodes (Table 26):* The indicator plot speed remains low (less than 1.5), suggesting that the route bears an apt resemblance to the straight-line utopian route.

- Column 9 *global time index (Table 26):* the travel times over the network and another for travel times in a straight line to and from each of the nodes, are, short I feel the longest only 18.41 minutes its level of connectivity is adequate between nodes.

- The maximum route travel time for passengers is 8.55 minutes, that means say that it is fulfilled with the speed less than 20 minutes.

Table 26 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

Caldes	6	3.79	0.2 3.67	0.7575	1.296001609 0.166667		0.21600	15.78450	1.29600161
stop 1	4	0.33333333 3.93		1.2240	1.262641404 0.25 1.3094		0.31566	11.43902	1.2626414
stop 2	4	0.33333333 4.61		1.240661196 0.25 0.9218			0.31017	11.43902	1.2406612
stop 3	6	0.2		1.48324 0089 0.166667			0.24721	18.41999	1.48324009

6.2.2 Proposed Route B 1

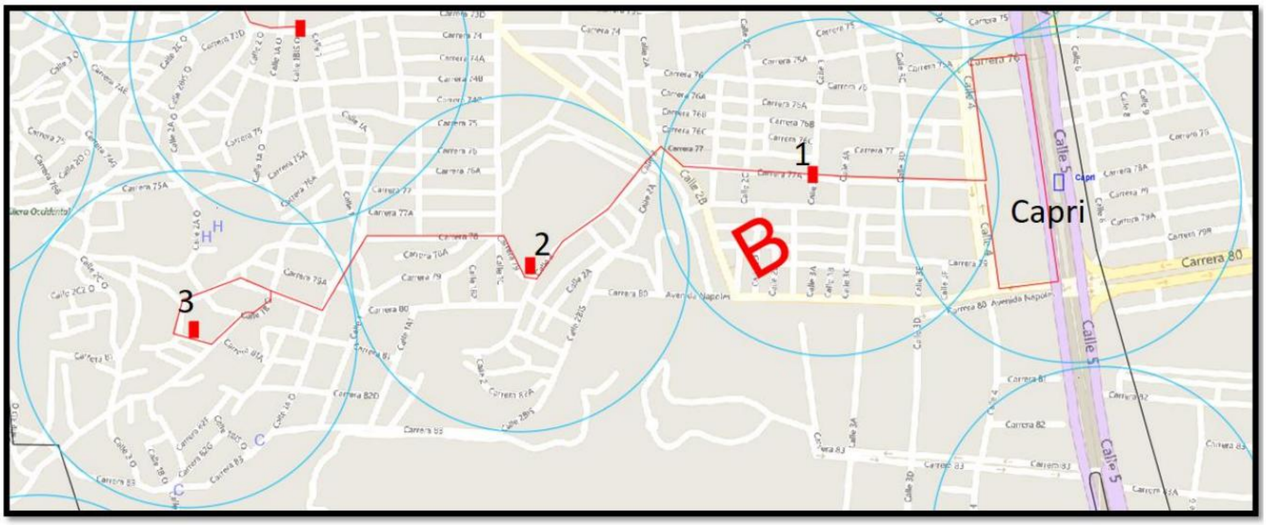


Image 15 Route B

This route arises as an alternative proposal to part of route A12A (Numeral 5.2) Calculation of indicators proposed route B 1 (Image 15)

- Proposed Shimbel Route B Array 1

The Shimbel matrix (Table 27) shows that the maximum number of arcs between two nodes for a user is only 3, this means that its accessibility could be negatively affected, but the average speed will improve.

Table 27 Shimbel Route B Matrix

shimbel matrix				
Route B	Capri	stop 1	stop 2	stop 3
Capri	0	1	two	3
stop 1	1	0	1	two
stop 2	two	1	0	1
stop 3	3	two	1	0

- ## Distance matrix km on proposed route B 1

This matrix (Table 28) indicates that the maximum travel distance for said route is 2.24 kilometers, therefore, it is a short route, which will improve the travel time.

Table 28 Distance matrix km on route B

Distance en route				
Route B	Capri	stop 1 stop 2 0.842246		stop 3
Capri	0	1.4817313 2.2487367		
stop 1	0.842246	0	0.6394853 1.4064907	
stop 2	1.4817313	0.6394853	0	0.7670054
stop 3	2.2487367	1.4064907 0.7670054		0

- ## Distance matrix km in a straight line B proposed 1

It is observed (Table 29) what would be the measurement of the distance, if a route could be built hypothetical and utopian between two nodes, this matrix is generated for further calculations.

Table 29 Distance matrix km in a straight line B

Straight line distance				
Route B	Capri	stop 1 stop 2 0.4366349		stop 3
Capri	0	0.9485193		1.552849
stop 1	0.4366349	0	0.533718 1.1384589	
stop 2	0.9485193	0.533718	0	0.6068164
stop 3	1.552849	1.1384589 0.6068164		0

- ## Matrix of time traveled en route minutes B

It shows (Table 30) the time that the bus would take to travel from one node to another, the speed used are 13km/h because it is the minimum speed recorded by commune 18 in some of their routes.

Table 30 Matrix of time traveled en route minutes B

Travel time en route				
Route B	Capri	stop 1 stop 2 0		stop 3
Capri	3.887289231	6.83875985	10.3787848	
stop 1	3.88728923	0	2.95147062	6.49149554
stop 2	6.83875985	2.951470615	0	3.54002492
stop 3	10.3787848	6.491495538	3.54002492	0

speed of 13km/h.

- ## Matrix of time traveled in a straight line minutes B

The straight line travel matrix (Table 31) shows the time it would take for the bus to travel the distance between two nodes, a hypothetical and utopian distance, is used for subsequent calculations

Table 31 Matrix of time traveled in a straight line minutes B

Travel time straight line				
Route B	Capri	stop 1	stop 2	stop 3
Capri	0	2.015238	4.37778138	7.16699538
stop 1	2.015238	0	2.46331385	5.25442569
stop 2	4.37778138	2.463313846	0	2,80069108
Stop 3	7.16699538	5.254425692	2.80069108	0

13 km/h.

- ## Integral Path Factor Matrix (Fr) B proposal 1

The route factor matrix (Table 32) shows how much difference there is in the route traced between two nodes and the utopian path in a straight line. It can be stated by looking at the results that the path bears a good resemblance to the perfect path between some of its nodes, but it can also be finds nodes with values of 1.9 which indicates that the path is 90% more curved than the line line that describes you.

Table 32 Integral Path Factor Matrix (Fr) B

Path factor (fr)				
Route B	Capri	stop 1 stop 2 0 1.928947961		stop 3
Capri	1.56215198 1.4481361			
stop 1	1.92894796	0	1.19817076 1.23543388	
stop 2	1.56215198 1.198170757		0	1.26398265
stop 3	1.4481361 1.235433883 1.26398265			0

- Indicator matrix plotting speed between nodes i and j route B Proposal 1

The plotted speed indicator matrix (Table 33) compares the route speed with the utopian route speed in a straight line, as this route is not circular it will tend to present the same values of the path factor matrix.

Table 33 Indicator matrix plotting speed between nodes i and j path B

plotted speed index				
Route B	Capri	stop 1 0	stop 2	stop 3
Capri	1.928947961 1.56215198 1.4481361			
stop 1	1.92894796	0	1.19817076 1.23543388	
stop 2	1.56215198 1.198170757		0	1.26398265
stop 3	1.4481361 1.235433883 1.26398265			0

- Indicator plotted speed of node i, Absolute Indicator Of Global time and integral path factor of node i proposal 1

The importance of this Table (Table 34) corresponds to the results of column 5 *Ri,* the column 6 *sum indicator plotting speed between nodes,* column 8 *time* index *global.* The other columns are explained in detail in Chapter 5 (Chapter 5).

- Column 5 *Ri (Table 34):* The route has adequate accessibility, since no value exceeds 1.5, which makes it an accessible path.
- Column 6 *sum indicator plotted speed between nodes (Table 34):* The indicator plot speed remains low (less than or close to 1.5), suggesting that the route bears a suitable resemblance to the straight-line utopian route.
- Column 9 *global time index (Table 34):* the travel times over the network and another for travel times in a straight line to and from each of the nodes, are

short, the longest being only 21,105 minutes, therefore, its level of connectivity is suitable between nodes.

- The maximum route travel time for passengers is 10.38 minutes, that means that the time is less than 20 minutes.
-

Table 34 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

Capri	6	4.94	0.2	0.98784721 1.556401981	0.166667		0.259	21,105	1,55640198
stop 1	4	4.36	0.33333333 1.4541842	1.369596851	0.25 4.02	0.33333333	0.342	13,330	1,36959685
stop 2	4	1.34143513	1.382550386	0.25 3.95	0.2 0.78951053	1.340832667	0.346	13,330	1,38255039
stop 3	6	0.166667					0.223	20,410	1,34083267

6.2.3 Proposed Route C 1

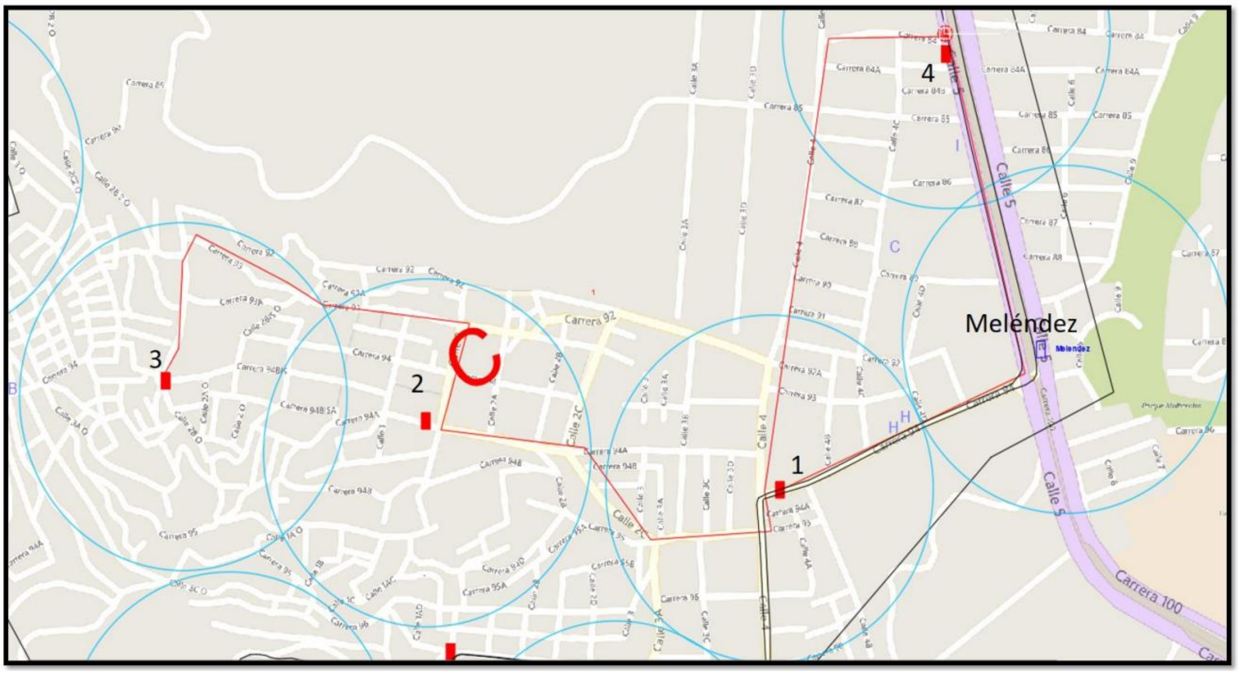


image 16 Route C Source: own elaboration

This route arises as an alternative proposal to parts of routes A12A (Numeral 5.2), A12B (Item 5.3), A12C (Item 5.1), A12A (Item 5.2) Calculation of indicators for the route C proposal 1 (Image 16)

- ## Proposed Shimbel Route C Array 1

The Shimbel matrix (Table 35) shows that the maximum number of arcs between two nodes for a user is only 3 (because of the way the route is designed, stop 4, only presents 1 arc Image 16), this means that its accessibility could be negatively affected, but the average speed will improve.

Table 35 Shimbel Matrix Route C

shimbel matrix					
Route C	Melendez	stop 1	stop 2	stop 3	stop 4
Melendez	0	1	two	3	1
stop 1	1	0	1	two	1
stop 2	two	1	0	1	1
stop 3	3	two	1	0	1
stop 4	1	1	1	1	0

- ## Distance matrix km on proposed route C 1

This matrix (Table 36) indicates that the maximum travel distance for said route is 2.7 kilometers, therefore, it is a short route, which will improve the travel time.

Table 36 Distance matrix km on route C

Distance en route					
Route C	Melendez	stop 1 stop 2 0.5462402		stop 3	stop 4
Melendez	0	1.3247872 2.2775282 0.778547 1.731288			0.5117011
stop 1	0.5462402	0	0.952741		2.7565724
stop 2	1.3247872	0.778547	0		1.9780254
stop 3	2.2775282	1.731288	0.952741	0	1.0252844
stop 4	0.5117011	2.7565724 1.9780254 1.0252844			0

- ## Distance matrix km on line route C proposal 1

It is observed what would be (Table 37) the measurement of the distance, if a route could be built hypothetical and utopian between two nodes, this matrix is generated for further calculations.

Table 37 Distance matrix km on line route C

Straight line distance					
Route C	Melendez	stop 1	stop 2	stop 3	stop 4
Melendez	0	0.52947	1.1325	1.6045	0.5541
stop 1	0.52947	0	0.6626	1.14523	0.81029
stop 2	1.1325	0.6626	0	0.48195	1.15097
stop 3	1.6045	1.14523	0.48195	0	1,542
stop 4	0.5541	0.81029	1.15097	1,542	0

- ## Matrix of time traveled en route minutes route C proposal 1

It shows (Table 38) the time that the bus would take to travel from one node to another, the speed used are 13km/h because it is the minimum speed recorded by commune 18 in some of their routes

Table 38 Matrix of time traveled en route minutes route C

time en route					
Route C	Melendez	stop 1 stop 2		stop 3	stop 4
Melendez	0	2.521108615	6.11440246	10.5116686	2.361697385
stop 1	2.52110862	0	3.59329385	7.99056	12.72264185
stop 2	6.11440246	3.593293846	0	4.39726615	9.129348
stop 3	10.5116686	2.361697385 7.99056	4.39726615	0	4.732081846
stop 4	12.72264185		9.129348	4.73208185	0

speed of 13km/h.

- ## Matrix of time traveled in a straight line minutes proposed route C 1

The matrix (Table 39) of the route in a straight line shows the time that the bus would take to travel the distance between two nodes, a hypothetical and utopian distance, is used for subsequent calculations

Table 39 Matrix of time traveled in a straight line minutes route C

straight line time					
Route C	Meléndez stop 1		stop 2	stop 3	stop 4
Melendez	0	2.443707692	5.22692308	7.40538462	2.557384615
stop 1	2.44370769	0	3.05815385	5.28567692	3.7398

stop 2	5.22692308	3.058153846	0	2.22438462	5.312169231
Stop 3	7.40538462	5.28576923	2.22438462	0	7.116923077
stop 4	2.55738462	3.7398	5.31216923	7.11692308	0

speed of 13km/h.

- ## Integral Path Factor Matrix (Fr) proposed path C 1

The route factor matrix (Table 40) shows how much difference there is in the route traced between two nodes and the utopian route in a straight line, connections between nodes are detected where the fact of route is too big bequeathing even up to a 3.4.

Table 40 Integral Path Factor Matrix (Fr) path C

Path factor (fr)					
Route C	Melendez	stop 1	stop 2	stop 3	stop 4
Melendez	0	1.03167356	1.16979002	1.41946289	0.923481502
stop 1	1.03167356	0	1.17498793	1.51173825	3.401957818
stop 2	1.16979002	1.174987926	0	1.97684615	1.718572508
stop 3	1.41946289	1.511738253	1.97684615	0	0.664905577
stop 4	0.9234815	3.401957818	1.71857251	0.66490558	0

- ## Indicator matrix plotting speed between nodes i and j path C Proposal 1

The plotted speed indicator matrix (Table 41) compares the route speed with the utopian route speed in a straight line, as this route is not circular it will tend to present the same values of the path factor matrix.

Table 41 Indicator matrix tracing speed between nodes i and j route C

plotted speed index					
Route C	Melendez	stop 1	stop 2	stop 3	stop 4
Melendez	0	1.03167356	1.16979002	1.41946289	0.923481502
stop 1	1.03167356	0	1.17498793	1.51173825	3.401957818
stop 2	1.16979002	1.174987926	0	1.97684615	1.718572508
stop 3	1.41946289	1.511738253	1.97684615	0	0.664905577
stop 4	0.9234815	3.401957818	1.71857251	0.66490558	0

- Indicator plotted speed of node i, Absolute Indicator Of Global time and integral path factor of node i proposal 1

The important thing about this Table (Table 42) corresponds to the results of column 5 *Ri,* the column 6 *sum indicator plotting speed between nodes,* column 8 *time* index *global.* The other columns are explained in detail in Chapter 5 (Item 5).

- Column 5 *Ri (Table 42):* The route has adequate accessibility at the Capri node, stop 2 and stop 3, since no value exceeds 1.5, however, the nodes stop 1 and stop 4 present values that exceed the maximum, however it is necessary to reduce a little accessibility to achieve mobility, an accessible route is expected to possess a *Ri* 50% greater than the utopian in this case we obtain 2 nodes one with a *Ri 71% greater than the utopian and another 123% greater,* however, as can be seen later this route continues to gain a lot in mobility and meets the norm of walks no greater than 300 meters.
- Column 6 *sum indicator plotted speed between nodes (Table 42):* The indicator speed trace remains low (less than or equal to 1.5), suggesting that the route bears a suitable resemblance to the straight-line utopian route, exact for the stop node 1.
- Column 9 *global time index (Table 42):* the travel times over the network and another for travel times in a straight line to and from each of the nodes, are short the longest time is only 28.94 minutes, therefore, its level of connectivity is suitable between nodes.
- The maximum route travel time for passengers is 12.72 minutes, that means that the time is less than 20 minutes.

Table 42 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

Capri	7	4.54	0.16666667	0.7574	1.220	0.142857	0.174	21,509	1,21978048
stop 1	5	7.12	0.25	1.7801	1,847	0.2	0.369	26,828	1,84669782
stop 2	5	6.04	0.25	1.5100	1.469	0.2	0.294	23,234	1,46851553
stop 3	7	5.57	0.16666667	0.9288	1.254	0.142857	0.179	27,632	1,25413551
stop 4	4	6.71	0.33333333	2.2363	1,546	0.25	0.386	28,946	1,54573006

6.3 Routes 2 proposal

For proposal 2, the rules discussed in Section 6.1 are followed, then 3 are shown routes for said proposal route a, route by route c and the evaluation methodology of accessibility used in Chapter 5.

The whereabouts here are located having as an additional criterion the attracting centers of commune travel, such as schools, universities, health posts and sports venues

The indicator calculations follow the same methodology explained in Section 5.1, the Proposal 1 does not take into account travel attraction places, it only considers distributing the possible nodes in the geographical area of commune 18, to subsequently generate possible routes.

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6.3.1 Route A proposal 2

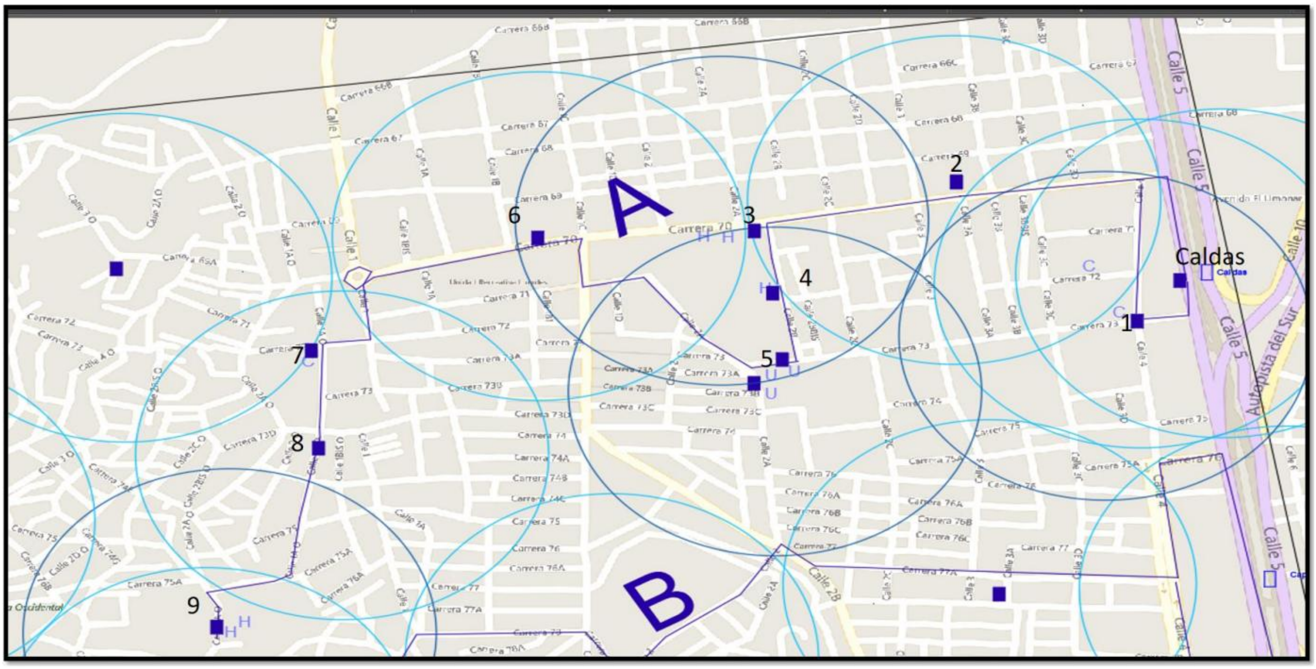

image 17 Route A Source: own elaboration

This route arises as an alternative proposal to part of route A78A (Numeral 5.5) Calculation of indicators (Image 17)

- ## Shimbel Matrix Route A proposal 2

The Shimbel matrix (Table 43) shows that the maximum number of arcs between two nodes for a user is only 9, this means that its accessibility could be positively affected.

Table 43 Shimbel Matrix Route A proposal 2

Route A	Shimbel matrix									
	Caldas	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7	Stop 8	Stop 9
Caldes	0	1	two	3	4	5	6	7	8	9
stop 1	1	0	1	two	3	4	5	6	7	8
stop 2	two	1	0	1	two	3	4	5	6	7
stop 3	3	two	1	0	1	two	3	4	5	6
stop 4	4	3	two	1	0	1	two	3	4	5
stop 5	5	4	3	two	1	0	1	two	3	4
stop 6	6	5	4	3	two	1	0	1	two	3
stop 7	7	6	5	4	3	two	1	0	1	two
stop 8	8	7	6	5	4	3	two	1	0	1
stop 9	9	8	7	6	5	4	3	two	1	0

- ## Route km distance matrix A proposal 2

This matrix (Table 44) indicates that the maximum travel distance for said route is 2.76 kilometers, therefore, it is a short route, which will improve the travel time.

Table 44 Distance matrix km en route A proposal 2

Route A	Distance en route									
Caldes	Caldas Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Caldes	0	0.13831 0.63311		0.92	2.9 1,028	1,167	1,687	2,259998	2,429	
stop 1	0.1383	0	0.4948 0.78169 0.88969 1.02869 1.54869 2.12169 2.29069 2.76169							
stop 2	0.6331 0.4948 0.92		0	0.28689 0.39489 0.53389 1.05389 1.62689 1.79589 2.26689						
stop 3	0.78169 0.28689 1.028			0	0.108 1.98	0.247	0.767	1.34 1.509 1.232		
stop 4	0.88969 0.39489 1.167			0.108	0	0.139	0.659	1.401 1.0930.1522		1,872
stop 5	1.02869 0.53389 1.687			0.247	0.139	0	0.52	0.742 0 0.169169		1,733
stop 6	1.54869 1.05389 2.26 2.12169			0.767	0.659	0.52	0	0.64		1,213
stop 7	1.242169 .29069 1.79589			1.34	1.232	1.093	0.573			0.64
stop 8	2.9 2.76169 2.26689			1.509	1.401	1.262	0.742		0	0.471
stop 9				1.98	1.872	1.733	1.213		0.471	0

- ## Distance matrix km in a straight line A proposal 2

It is observed what would be (Table 45) the measure of the distance, if a route could be built hypothetical and utopian between two nodes, this matrix is generated for further calculations.

Table 45 Distance matrix km in a straight line A proposal 2

Route A	Straight line distance									
	Caldas Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Caldes	0	0.11	0.37156 0.62878 0.364		0.606	0.6	0.942	1,271 1,285 1,539		
stop 1	0.11	0	0.591 0.31 0		0.535	0.32	0.89	1.203 1.218 1.46		
stop 2	0.3716	0.364	0		0.35	0.413	0.638	1.005 1.05 1.343		
stop 3	0.6288	0.591	0.31		0.108	0.216	0.315	0.678 0.74 1.061		
stop 4	0.606	0.535	0.35	0.108	0	0.131	0.357	0.671 0.717 1.006		
stop 5	0.6	0.32	0.413	0.216	0.131	0	0.415	0.689 0.704 0.951		
stop 6	0.942	0.89	0.638	0.315	0.357	0.415	0	0.391 0.494 0.853		
stop 7	1.271	1.203	1.005	0.678	0.671	0.689	0.391	0	0.181 0.527	
stop 8	1.285	1.218	1.05	0.74	0.717	0.704	0.494	0.181 0 0.367		
stop 9	1.539	1.46	1.343	1.061	1.006	0.951	0.853	0.527 0.367		0

- ## Matrix of time traveled en route minutes A proposal 2

It shows (Table 46) the time that the bus would take to travel from one node to another, the speed used are 13km/h because it is the minimum speed recorded by commune 18 in some of their routes.

Table 46 Matrix of time traveled en route minutes A proposal 2

Route A	time en route									
	Caldas Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Caldes	0 0.63834 2.92204 4.24614 4.74461 5.38614 7.78614 10.43076 11.2108 13.3846									
stop 1	0.6383	0 2.28369 3.6078 4.10626 4.7478 7.1478 9.792415 10.5724 12.7463								
stop 2	2.922 2.28369		0 1.32411 1.82257 2.46411 4.86411 7.508723 8.28872 10.4626							
stop 3	4.2461 3.6078 1.32411 4.7446			0 0.49846 3.54 6.18461154 6.96462 9.13846						
stop 4	4.10626 1.82257 0.49846 5.3861 4.7478				0 0.64154 3.04154 5.686154 6.46615					8.64
stop 5	2.46411 1.14 0.64154 7.7861 7.1478 4.86411 3.54 3,					0	2.4 5.044615 5.82462 7.99846			
stop 6	04154 10.431 9.79242 7.50872 6.18462 5.6446215 5.24462					2.4	0 2.644615 3.42462 5.59846			
stop 7	10.5724 8.28872 6.96462 6.46615 5.82462 3.42462 132146 3 1214.385							0	0.78 2.95385	
stop 8								0.78	0 2.17385	
stop 9					8.64 7.99846 5.59846 2.953846 2.17385					0

speed of 13km/h.

- ## Matrix of time traveled in a straight line minutes A proposal 2

The straight line travel matrix (Table 47) shows the time it would take for the bus to travel the distance between two nodes, a hypothetical and utopian distance, is used for subsequent calculations

Table 47 Matrix of time traveled in a straight line minutes A proposal 2

Route A	time in a straight line									
	Caldas Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
caldas	0 0.50769 1.71489 2.90206 2.79692 2.76923 4.34769 5.866154 5.93077 7.10308									
stop 1	0.5077	0	1.68 2.72769 2.46923 1.47692 4.10769 5.552308 5.62154 6.73846							
stop 2	1.7149 1.68 2.9021		0 1.43077 1.61538 1.90615 2.94462 4.638462 4.84615 6.19846							
stop 3	2.72769 1.43077 2.7969			0 0.49846 0.99692 1.45385 3.129231 3.41538 4.89692						
stop 4	2.46923 1.61538 0.49846 2.7692 1.47692				0 0.60462 1.64769 3.096923 3.30923 4.64308					
stop 5	1.90615 0.99692 0.60462 4.3477 4, 10769 2.94462					0 1.91538 3.18 3.24923 4.38923				
stop 6	1.45385 1.64769 1.91538 0 1.804615 5.8662 5.55231 4.63846 3.12923 3.09692 3.18 1.80462								2.28 3.93692	
stop 7	5.9308 5.62154 4.846153 8 3.30923 3.24923 2.28 0.835385 7.10816370846389238436992 0 0.83538 2.43231									
stop 8	2.432308 1.69385								0 1.69385	
stop 9										0

speed of 13km/h.

- ## Integral Path Factor Matrix (Fr) A proposal 2

The route factor matrix (Table 48) shows how much difference there is in the route traced between two nodes and the utopian path in a straight line. It can be stated by looking at the results that the route presents a good similarity to the perfect route, because it was thought to be carried out following the criterion of not following circular routes.

Table 48 Integral Path Factor Matrix (Fr) A proposal 2

Route A	Path factor (fr)										
Caldes	Caldas	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7	Stop 8	Stop 9	
Caldes	0	1.25735	1.70392	1.46315	1.69637	1.945	1.79087	1.778126	1.89027	1.88434	
stop 1	1.2573	0	1.35934	1.32266	1.66297	3.21466	1.7401	1.763666	1.8807	1.89157	
stop 2	1.7039	1.35934	0	0.92545	1.12826	1.29271	1.65187	1.618796	1.71037	1.68793	
stop 3	1.4631	1.32266	0.92545	1.6964	0	1	1.14352	2.43492	1.976401	2.03919	1.86616
stop 4	1.66297	1.12826	1.945	3.21466	1	0	1.06107	1.84594	1.836066	1.95397	1.86083
stop 5	1.29271	1.14352	1.06107				0	1.25301	1.586357	1.79261	1.82229
stop 6	1.7909	1.7401	1.65187	2.43492	1.84594	1.25301 1.7781	1.76367	0	1.465473	1.50202	1.42204
stop 7	1.6188	1.9764	1.83607	1.58636	1.46547	1.8903 1.8807	1.71037	2, 03919 1.95397	0	0.9337	1.21442
stop 8	1.79261	1.50202	0.933702	1.8843	1.89157	1.68793	1.86616	1.86083	1.82229 1.42204	0	1.28338
stop 9	1.214421	1.28338									0

- ## Indicator matrix plotting speed between nodes i and j A proposal

two

The plotted speed indicator matrix (Table 49) compares the route speed with the utopian route speed in a straight line, as this route is not circular it will tend to present the same values of the path factor matrix.

Table 49 Indicator matrix plotting speed between nodes i and j A proposal 2

Route A	plotted speed index										
Caldes	Caldas Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9										
Caldes	0 1.25735 1.70392 1.46315 1.69637 1.945 1.79087 1.778126 1.89027 1.88434										
stop 1	1.2573	0 1.35934 1.32266 1.66297 3.21466 1.7401 1.763666 1.8807 1.89157									
stop 2	1.7039 1.35934		0 0.92545 1.12826 1.29271 1.65187 1.618796 1.71037 1.68793								
stop 3	1.4631 1.32266 0.92545 1.6964			0	1 1.14352 2.43492 1.976401 2.03919 1.86616						
stop 4	1.66297 1.12826 1.945 3.21466			1	0 1.06107 1.84594 1.836066 1.95397 1.86083						
stop 5	1.29271 1.14352 1.06107					0 1.25301 1.586357 1.79261 1.82229					
stop 6	1.7909 1.7401 1.65187 2.43492 1.84594 1.25301 1.7781 1.76367						0 1.465473 1.50202 1.42204				
stop 7	1.6188 1.9764 1.83607 1.58636 1.46547 1.8903 1.8807 1.71037 2, 03919 1.95397							0 0.9337 1.21442			
stop 8	1.79261 1.50202 0.933702 1.8843 1.89157 1.68793 1.86616 1.86083 1.82229 1.42204 1.214421								0 1.28338		
stop 9	1.28338										0

- Indicator plotted speed of node i, Absolute Indicator Of Global time and integral path factor of node i proposal 2

The important thing about this Table (Table 50) corresponds to the results of column 5 *Ri,* the column 6 *sum indicator traced speed between nodes,* column 8 *lobal time index.*
The other columns are explained in detail in Chapter 5 (Chapter 5).

- Column 5 *Ri (Table 50):* The route has adequate accessibility, since no value exceeds 1.5, which makes it an accessible path.
- Column 6 *sum indicator plotted speed between nodes (Table 50):* The indicator plot speed remains low (less than 1.5), suggesting that the route bears an apt resemblance to the straight-line utopian route.
- Column 9 *global time index (Table 50):* the travel times over the network and another for travel times in a straight line to and from each of the nodes, are short the longest recorded time is only 73.09 minutes, therefore, their level of connectivity is adequate between nodes.
- The maximum route travel time for passengers is 13.38 minutes, that means that the time is less than 20 minutes.

Table 50 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i proposed 2

Caldes	Four. Five	15.41	0.02273	0.350	1.7900	0.022222222 0.0398 60.750	1.78999		
stop 1	37	16.09	0.02778	0.447	1.8018	0.027027027 0.0487 55.643	1.80181		
stop 2	31	13.08	0.03333	0.436	1.5548	0.032258065 0.0502 41.941	1.5548		
stop 3	27	14.17	0.03846	0.545	1.7083	0.037037037 0.0633 36.644	1.70825		
stop 4	25	14.05	0.04167	0.585	1.7236	0.04 0.0689 35.647	1.72363		
stop 5	25	15.11	0.04167	0.630	1.7399	0.04 0.0696 35.647	1.73994		
stop 6	27	15.11	0.03846	0.581	1.6551	0.037037037 0.0613 40.447	1.65507		
stop 7	31	14.17	0.03333	0.472	1.6710	0.032258065 0.0539 51.026	1.67104		
stop 8	37	14, 99	0.02778	0.416	1.7865	0.027027027 0.0483 55.706	1.7865		
stop 9	Four. Five	14.93	0.02273	0.339	1.7391	0.022222222 0.0386 73.097	1.73906		

6.3.2 Proposed Route B 2

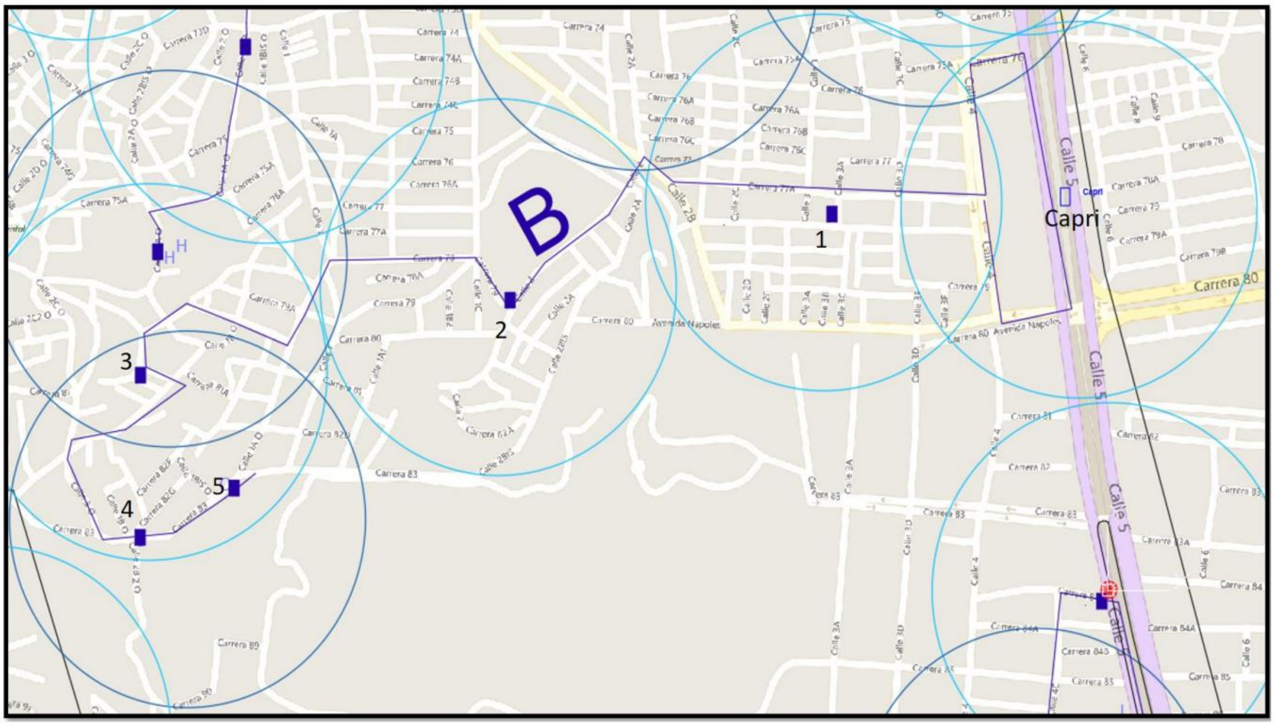

image 18 Route B Source: own elaboration

This route arises as an alternative proposal to part of route A12A (Numeral 5.2) and route A78A (Chapter.5) Calculation of indicators (Image 18)

• Proposed Shimbel Route B Array 2

The Shimbel matrix (Table 51) shows that the maximum number of arcs between two nodes for a user is only 5, this means that its accessibility could be negatively affected, but the average speed will improve.

Table 51 Shimbel Matrix Proposed Route B 2

shimbel matrix						
Route B	Capri	stop 1	stop 2	stop 3	stop 4	stop 5
Capri	0	1	two	3	4	5
stop 1	1	0	1	two	3	4
stop 2	two	1	0	1	two	3
stop 3	3	two	1	0	1	two
stop 4	4	3	two	1	0	1
stop 5	5	4	3	two	1	0

• Distance matrix km on proposed route B 2

This matrix (Table 52) indicates that the maximum travel distance for said route is 2.96 kilometers, therefore, it is a short route, which will improve the travel time

Table 52 Distance matrix km on proposed route B 2

Distance en route						
Route B	Capri	stop 1	stop 2	stop 3	stop 4	stop 5
Capri	0	0.84225	1.48173	2.24874	2.74974	2.96274
stop 1	0.8422	0	0.63949	1.40649	1.90749	2.12049
stop 2	1.4817	0.63949	0	0.76701	1.26801	1.48101
stop 3	2.2487	1.40649	0.76701	0.501	0.714	0
stop 4	2.7497	1.90749	1.26801	0.213	0.501	0
stop 5	2.9627	2.12049	1.48101	0.714	0.213	0

• Distance matrix km in a straight line B proposed 2

It is observed what would be (Table 53) the measurement of the distance, if a route could be built hypothetical and utopian between two nodes, this matrix is generated for further calculations.

Table 53 Distance matrix km in a straight line B proposal 2

Straight line distance						
Route B	Capri	stop 1	stop 2	stop 3	stop 4	stop 5
Capri	0	0.43663	0.94852	1.55285	1.663	1.471
stop 1	0.4366	0	0.53372	1.13846	1.208	1.104
stop 2	0.9485	0.53372	0	0.60682	0.731	0.549
stop 3	1.5528	1.13846	0.60682	0	0.256	0.238
stop 4	1.663	1.208 1.104 0.731 0.549 1.471		0.256	0	0.184
stop 5				0.238	0.184	0

- Matrix of time traveled en route minutes B proposal 2

It shows (Table 54) the time that the bus would take to travel from one node to another, the speed used are 13km/h because it is the minimum speed recorded by commune 18 in some of their routes.

Table 54 Matrix of time traveled en route minutes B proposal 2

time en route						
Route B	Capri	stop 1	stop 2	stop 3	stop 4	stop 5
Capri	0	3.88729	6.83876	10.3788	12.6911	13.6742
stop 1	3.8873	0	2.95147	6.4915	8.8038	9.78688
stop 2	6.8388	2.95147	0	3.54002	5.85233	6.83541
stop 3	10.379	6.4915	3.54002	0	2.31231	3.29538
stop 4	12.691	8.8038	5.85233 2.31231	13.674	0	0.98308
stop 5	9.78688	6.83541	3.29538	0.98308		0

speed of 13km/h.

- Matrix of time traveled in a straight line minutes B proposal 2

The straight line travel matrix (Table 55) shows the time it would take for the bus to travel the distance between two nodes, a hypothetical and utopian distance, is used for subsequent calculations.

Table 55 Matrix of time traveled in a straight line minutes B proposal 2

straight line time						
Route B	Capri	stop 1	stop 2	stop 3	stop 4	stop 5
Capri	0	2.01524	4.37778	7.167	7.67538	6.78923
stop 1	2.0152	0	2.46331	5.25443	5.57538	5.09538
stop 2	4.3778	2.46331	0	2.80069	3.37385	2.53385
stop 3	7.167	5.25443	2.80069	0	1.18154	1.09846
stop 4	7.6754	5.57538	3.37385	1.18154	0	0.84923
stop 5	6.7892	5.09538	2.53385	1.09846	0.84923	0

speed of 13km/h.

- ## Integral Path Factor Matrix (Fr) B proposed 2

The route factor matrix (Table 56) shows how much difference there is in the route traced between two nodes and the utopian path in a straight line. It can be stated by looking at the results that the route presents a good similarity to the perfect route, because it was thought to be carried out following the criterion of not following circular routes.

Table 56 Integral Path Factor Matrix (Fr) B proposal 2

Path factor (fr)							
Route B	Capri	stop 1	stop 2	stop 3	stop 4	stop 5	
Capri	0	1.92895	1.56215	1.44814	1.65348	2.0141	
stop 1	1.9289	0	1.19817	1.23543	1.57905	1.92073	
stop 2	1.5622	1.19817	0	1.26398	1.73462	2.69764	
stop 3	1.4481	1.23543	1.26398	0	1.95703	1.6535	3
stop 4	1.57905	1.73462	1.95703	2.0141	1.92073	0	1.15761
stop 5	2.69764				3	1.15761	0

- ## Indicator matrix plotting speed between nodes i and j route B proposal 2

The plotted speed indicator matrix (Table 57) compares the route speed with the utopian route speed in a straight line, as this route is not circular it will tend to present the same values of the path factor matrix.

Table 57 Indicator matrix plotting speed between nodes i and j proposed route B 2

plotted speed index						
Route B	Capri stop 1 stop 2 stop 3 stop 4 stop 5					
Capri	0	1.92895 1.56215 1.44814 1.65348 2.0141				
stop 1	1.9289	0 1.19817 1.23543 1.57905 1.92073				
stop 2	1.5622	1.19817 0 1.26398 1.73462 2.69764				
stop 3	1.4481	1.23543 1.26398 0 1.95703 1.6535				3
stop 4	1.57905 1.73462 1.95703 2.0141 1.92073				0	1.15761
stop 5	2.69764			3	1.15761	0

- Indicator plotted speed of node i, Absolute Indicator Of Global time and integral path factor of node i proposal 2

The important thing about this Table (Table 58) corresponds to the results of column 5 *Ri,* the column 6 *sum indicator plotting speed between nodes,* column 8 *time* index *global.* The other columns are explained in detail in Chapter 5 (Chapter 5).

- Column 5 *Ri (Table 58):* The route has adequate accessibility, since no value exceeds 1.5, which makes it an accessible path.
- Column 6 *sum indicator plotted speed between nodes (Table 26):* The indicator plot speed remains low (less than 1.5), suggesting that the route bears an apt resemblance to the straight-line utopian route.
- Column 9 *global time index (Table 58):* the travel times over the network and another for travel times in a straight line to and from each of the nodes, are adequate, the longest time recorded is 47.47 minutes, therefore, his level of connectivity is adequate between nodes.
- The maximum route travel time for passengers is 13.67 minutes, that means that the time is less than 20 minutes.

Table 58 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i proposed 2

		Sum	ti-1	Ri		ti			
Capri	fifteen	8.61	0.07143	0.614772338 1.694 0.066666667			0.113	47.470 1.69387	
stop 1	eleven	7.86	0.1	0.786233552 1.564 0.090909091			0.142	31.921 1.56446	
stop 2	9	8.46	0.125 1.057070598 1.673 0.111111111				0.186	26.018 1.67324	
stop 3	9	8.90	0.125 1.113072986 1.487 0.111111111				0.165	26.018 1.48656	
stop 4	eleven	8.08	0.1	0.808178572 1.643 0.090909091 10.79			0.149	30.643 1.64256	
stop 5	fifteen	0.07143 0.770720138 2.113 0.066666667					0.141	34.575 2.11259	

6.3.3 Proposed Route C 2

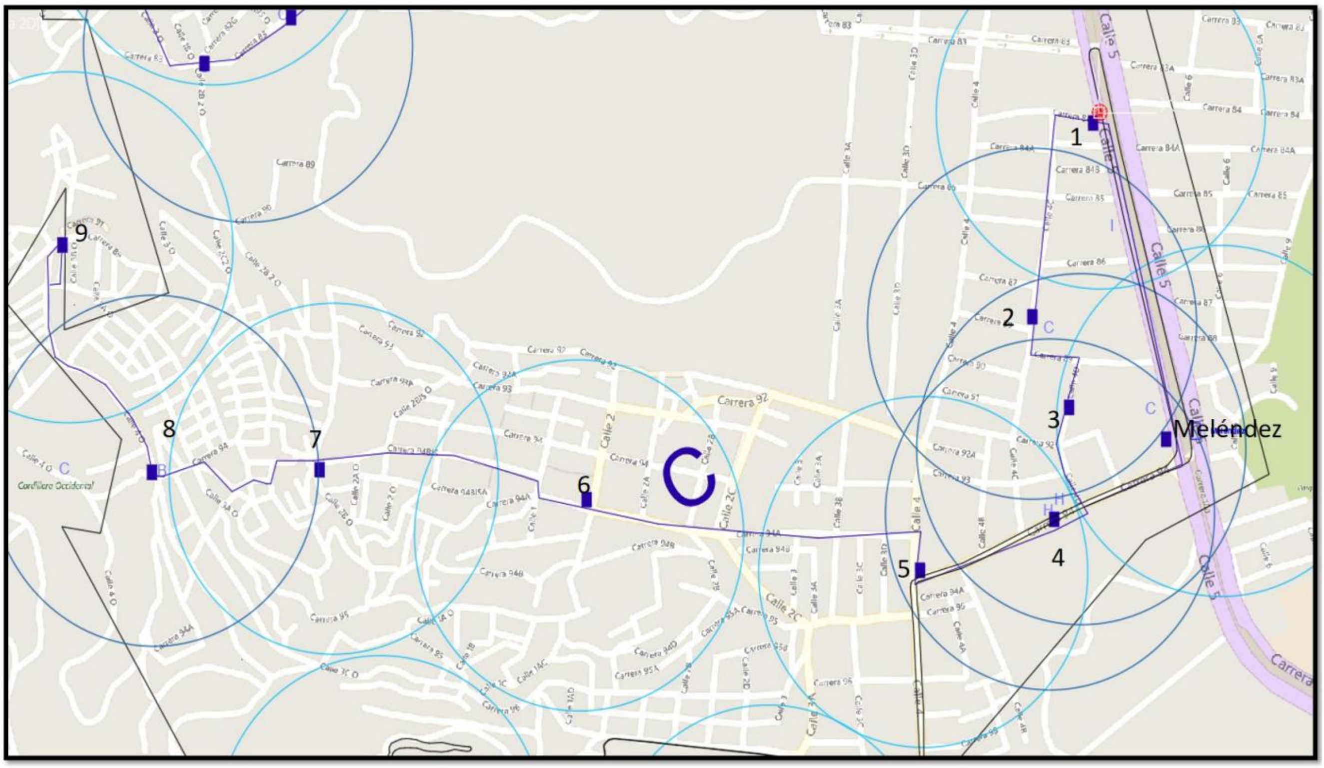

image 19 Route C Source: own elaboration

This route arises as an alternative proposal to part of route A12B (Numeral 5.3) Calculation of indicators (Image 19)

- Proposed Shimbel Route C Array 2

The Shimbel matrix (Table 59) shows that the maximum number of arcs between two nodes for a user is only 9, this means that its accessibility could be positively affected.

Table 59 Shimbel Matrix Proposed Route C 2

Route C	Shimbel matrix									
	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0	1	two	3	4	5	6	7	8	9
stop 1	1	0	1	two	3	4	5	6	7	8
stop 2	two	1	0	1	two	3	4	5	6	7
stop 3	3	two	1	0	1	two	3	4	5	6
stop 4	4	3	two	1	0	1	two	3	4	5
stop 5	5	4	3	two	1	0	1	two	3	4
stop 6	6	5	4	3	two	1	0	1	two	3
stop 7	7	6	5	4	3	two	1	0	1	two
stop 8	8	7	6	5	4	3	two	1	0	1
stop 9	9	8	7	6	5	4	3	two	1	0

- Distance matrix km on proposed route C 2

This matrix (Table 60) indicates that the maximum travel distance for said route is 3.64 kilometres.

Table 60 Distance matrix km on proposed route C 2

Route C	Distance en route									
Melendez	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0 0.28356 0.56926 1.2678 1.78356 2.13626 2.74455 3.018547 3.25955 3.64755									
stop 1	0.28356	0 0.2857 0.9842 0			1.5 1.8527 2.46099 2.734987 2.97599 3.36399					
stop 2	0.56926 0.2857		0.6985 1.2143			1.567 2.17529 2.449287 2.69029 3.07829				
stop 3	1.26776 0.9842 0.6985 1.78356			0 0.5158 0.8685 1.47679 1.750787 1.99179 2.37979						
stop 4	1.5 1.2143 0.5158 [illegible] 0.8685				0 0.3527 0.96099 1.234987 1.47599 1.86399					
stop 5	0.3527 2.744547 2.46099 [illegible] 3.018547					0 0.60829 0.882287 1.12329 1.51129				
stop 6	2.73499 2.44929 1.7508 1.23499 0.88229 3.259547 2.97599 2.69029						0	0.274 0.515 0.903		
stop 7	1.9918 1.47599 1.16475 43.12329 3.36399 3.07829 2.3798 1.86399						0.274	0 0.241 0.629		
stop 8	1.51129						0.515	0.241	0 0.388	
stop 9							0.903	0.629	0.388 0	

- ## Distance matrix km on line route C proposal 2

It is observed what would be (Table 61) the measurement of the distance, if a route could be built hypothetical and utopian between two nodes, this matrix is generated for further calculations

Table 61 Distance matrix km in line route C proposed 2

Route C	Straight line distance									
	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0	0.251 0.505 1.6 0 0.257 0.856			1.544	1.855	2.051	0.181 0.315 0.194		0.54
stop 1	0.251	0.257 0 0.625 0.856			1.353	1.648	1.868	0.349 0.3980.8991		0.673
stop 2	0.505	0.625 1,353 1,1091,6492 1,409			1.109	1.409	1.66	0.882 1.3681.6326		0.828
stop 3	1.6	0.797 1,8680.1398 1,0697 0.1949 0.492 0				0.797	1.067	1.63 1.855 10772		1,119
stop 4	1,544	0.491 0.882 0.673 0.82,119				0.309	0.61	0.1625		1,321
stop 5	1.855				0.309	0	0.414			1,823
stop 6	2.051				0.61	0.414	0			1,889
stop 7	0.181				1.368	1.68	1.855			0.487
stop 8	0.315				1.326	1.63	1.772	0.1625 1.889	0	0.345
stop 9	0.54				1.321	1.823	0.487		0.345	0

- ## Matrix of time traveled en route minutes route C proposal 2

It shows (Table 62) the time that the bus would take to travel from one node to another, the speed used are 13km/h because it is the minimum speed recorded by commune 18 in some of their routes.

Table 62 Matrix of time traveled en route minutes route C proposal 2

Route C	time en route									
	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0	1.30874 2.62735 5.8512 8.23182 9.85966 12.6671 13.93176 15.0441 16.8348								
stop 1	1.3087385	0	1.31862 4.5425 6.92308 8.55092 11.3584 12.62302 13.7353 15.5261							
stop 2	2.6273538 1.31862		0	3.2238 5.60446 7.23231 10.0398 11.3044 12.4167 14.2075						
stop 3	5.8512 4.54246 3.22385			0	2.38062 4.00846 6.81594 8.080555 9.19286 10.9836					
stop 4	8.2318154 6.92308 5.60446 2.3806 9.8596615				0	1.62785 4.43532 5.69994 6.81225 8.60302				
stop 5	8.55092 7.23231 4.0085 1.62785					0	2.80748 4.072094 5.1844 6.97517			
stop 6	12.66714 11.3584 10.0398 6.8159 4.43532 2.80748						0	1.264615 2.37692 4.16769		
stop 7	13.931755 12.623 11.3044 8.0806 5.69994 4.07209 1.26462 15.044063 13.7353							0	1.11231 2.90308	
stop 8	12.4167 9.1929 6.81225 5.1844 2.37692 1.112308 1548308 16.832 .2075 10.984 8.60302								0	1.79077
stop 9	6.97517 4.16769 2.903077 1.79077									0

speed of 13km/h.

- Matrix of time traveled in a straight line minutes proposed route C

two

The straight line travel matrix (Table 63) shows the time it would take for the bus to travel the distance between two nodes, a hypothetical and utopian distance, is used for subsequent calculations

Table 63 Matrix of time traveled in a straight line minutes route C proposed 2

Route C	time in a straight line									
	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0 1.15846 2.33077 7.3846 7.12615 8.56154 9.46615 0.835385 1.45385 2.49231									
stop 1	1.1584615	0 1.18615 3.9508 6.24462 7.60615 8.62154 0.895385 1.61077 3.10615								
stop 2	2.3307692 1.18615		0 2.8846 5.11846 6.50308 7.66154 1.836923 2.26615 3.82154							
stop 3	7.3846154 3.95077 2.88462			0 2.27077 3.67846 4.92462 4.121538 4.07077 5.16462						
stop 4	7.1261538 6.24462 5.11846 2.2708 8.5615385				0 1.42615 2.81538 6.313846				6.12 6.09692	
stop 5	7.60615 6.50308 3.6785 1.42615 62154 7.66154 4.9246					0 1.91077 7.753846 7.52308 8.41385				
stop 6	2.81538 1.91077 0.8353846 0.89538 1.83692 4.1215 6.31385 7.75385						0 8.561538 8.17846 8.71846			
stop 7	8.56154 1.4538462 1.61077 2.26615 4.0708 .52308 8.17846 2.4923077 3.10615							0	0.75 2.24769	
stop 8	3.82154 5.1646 6.09692 8.41385 8.71846 2.247692 1.59231							0.75	0 1.59231	
stop 9										0

speed of 13km/h.

- Integral Path Factor Matrix (Fr) proposed path C 2

The route factor matrix (Table 64) shows how much difference there is in the route traced between two nodes and the utopian path in a straight line. It can be stated by looking at the results that the route presents a good similarity to the perfect route, because it was thought to be carried out following the criterion of not following circular routes.

Table 64 Integral Route Factor Matrix (Fr) route C proposal 2

Route C	Path factor (fr)									
Melendez	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0	1.12972 1.12725 0.7924 1.15516 1.15162 1.33815 16.67706 10.3478 6.75472								
stop 1	1.1297211	0	1.11167 1.1498 1.10865 1.12421 1.31744 14.09787 8.52718 4.99849							
stop 2	1.1272475 1.11167		0	1.1176 1.09495 1.11214 1.31041 6.153987 5.4792 3.71774						
stop 3	0.79235 1.14977 1.1176			0	1.04837 1.08971 1.38406 1.960568 2.25826 2.12671					
stop 4	1.1551554 1.10865 1.09495 1.0484 1.1516226				0	1.14142 1.57539 0.902768 1.11311 1.41104				
stop 5	1.12421 1.11214 1.0897 10.141342 31744 1.31041 1.3841					0	1.46929 0.525171 0.68913 0.82901			
stop 6	1.57539 1.46929 16.677055 14.0979 6.15399 1.9606 0.90277 0.52517						0	0.147709 0.29063 0.47803		
stop 7	0.14771 10.347768 8.52718 5.4792 1.0131 2.01131 .68913 0.29063 1.483077							0	1.48308 1.29158	
stop 8	6.7547167 4.99849 3.71774 2.1267 1.41104 0.82901 0.47803 1.291581 1.12464								0	1.12464
stop 9										0

- Indicator matrix plotting speed between nodes i and j path C proposal 2

The plotted speed indicator matrix (Table 65) compares the route speed with the utopian route speed in a straight line, as this route is not circular it will tend to present the same values of the path factor matrix.

Table 65 Indicator matrix plotting speed between nodes i and j route C proposed 2

Route C	plotted speed index									
Melendez	Melendez Stop 1 Stop 2 Stop 3 Stop 4 Stop 5 Stop 6 Stop 7 Stop 8 Stop 9									
Melendez	0	1.12972 1.12725 0.7924 1.15516 1.15162 1.33815 16.67706 10.3478 6.75472								
stop 1	1.1297211	0	1.11167 1.1498 1.10865 1.12421 1.31744 14.09787 8.52718 4.99849							
stop 2	1.1272475	1.11167	0	1.1176 1.09495 1.11214 1.31041 6.153987 5.4792 3.71774						
stop 3	0.79235 1.14977 1.1176			0	1.04837 1.08971 1.38406 1.960568 2.25826 2.12671					
stop 4	1.1551554 1.10865 1.09495 1.0484 1.1516226				0	1.14142 1.57539 0.902768 1.11311 1.41104				
stop 5	1.12421 1.11214 1.0897 1.14142 1.3381507 1.31744					0	1.46929 0.525171 0.68913 0.82901			
stop 6	1.310841 1.3 57539 1.46929 16.677055 14.0979 6.15399 1.9606						0	0.147709 0.29063 0.47803		
stop 7	0.90277 0.52517 0.14771 10.347768 8.52718 5.4792 2.2583 1.11311 0.68913							0	1.48308 1.29158	
stop 8	0.76833 71.2906 .7547167 4.99849 3.71774 2.1267 1.41104 0.82901 0.47803 1.291581 1.12464								0	1.12464
stop 9										0

- Indicator plotted speed of node i, Absolute Indicator Of Global time and integral path factor of node i proposal 2

The importance of this Table (Table 26) corresponds to the results of column 5 *Ri,* the column 6 *sum indicator plotting speed between nodes,* column 8 *time* index *global.* The other columns are explained in detail in Chapter 5 (Chapter 5).

• Column 5 *Ri (Table 66):* The route has adequate accessibility, since no value exceeds 1.5, which makes it an accessible path.

• Column 6 *sum indicator plotted speed between nodes (Table 66):* The indicator plot speed remains low (less than 1.5), suggesting that the route bears an apt resemblance to the straight-line utopian route.

• Column 9 *global time index (Table 66):* the travel times over the network and another for travel times in a straight line to and from each of the nodes, are of only 83.25 minutes, therefore, its level of connectivity is adequate between nodes.

• The maximum route travel time for passengers is 16.83 minutes, that means that the time is less than 20 minutes.

Table 66 Indicator plotted speed of node i, Absolute Indicator Of Global Time and integral path factor of node i

Melendez	Four. Five	40.47 0.0227 0.919858808 2.116				0.022222222 0.0470 86.357 2.1161			
stop 1	37	34.57 0.0278 0.960139261 2.207				0.027027027 0.0597 75.887 2.20729			
stop 2	31	22.22 0.0333 0.740831539 2.023 12.93				0.032258065 0.0652 67.975 2.02251			
stop 3	27	0.0385 0.497207514 1.432 10.55 0.0417				0.037037037 0.0531 55.080 1.43247			
stop 4	25	0.439619283 1.156 9.13 0.0417 0.380488027				0.04 0.0462 50.318 1.15589			
stop 5	25	0.943				0.04 0.0377 50.318 0.9427			
stop 6	27	9.31 0.0385 0.358119889 0.919				0.037037037 0.0340 55.933 0.91907			
stop 7	31	43.24 0.0333 1.441326253 1.831				0.032258065 0.0591 60.992 1.8307			
stop 8	37	31.31 0.0278 0.869805702 2.016				0.027027027 0.0545 67.666 2.01593			
stop 9	Four. Five	22.73 0.0227 0.516635475 1.968				0.022222222 0.0437 81.992 1.96841			

6.3.4 Maximum travel time for each route, taking into account the property unity of the routes of both directions

Next, (Table 67) is read, where the maximum travel times are expressed that can have a person for each of the current routes and the new routes. It is important note that 4 old routes become 3 new routes, route A12D is not modifiable by geometry of the road so this would become route 4 for the two proposals of this document.

Both routes are valid because they respect the conditions of being accessible and improving the moved in the commune, based on the perception of the users.

Table 67 Maximum travel time for each route, taking into account the unit property of both-way routes

current routes	maximum travel time minutes (speed see Table 17)	maximum travel time minutes 13km/h	Proposal 1	maximum travel time minutes 13km/h	Proposal 2	Maximum time of route minutes 13km/h
12A	28.31	30.2	Route A	8.55	Route A	13.38
A 12 B	20.52	20.7	Route B	10.38	Route B	13.67
at 12C	9.86	12.3	Route C	12.72	Route C	16.83
At 12 D	21.8	25.17				
78A	20.69	24.04				

7 CONCLUSIONS AND RECOMMENDATIONS

Based on the results obtained, the conclusions show compliance with the general objective, verifying the achievement of the specific objectives.

- In general, all the activities of the users of the MIO transport system are seen affected by the cost and efficiency of the system, with the time category being the one with the greatest affectation generates, although the cost as a value to pay for transportation is high relative to the average income of the population.

- The current route system is highly accessible because the values found in the studies show this, but contradictorily, users manifest themselves dissatisfied, negative perception of the MIO transport system originated in the slowness in the coverage of the route by the buses, but it is clear that the study It also shows that this perception has been changing over time.

- Travel time on routes can be reduced by eliminating the need for the feeder leave people at the main station, that is, they can leave the people near the station but not in it, thus avoiding additional travel, such as that is currently generated on Calle 5, however, the risk has to be reduced to the citizen building bus stops with adequate bays.

- Linear routes are more time efficient than circular routes, but circular routes cancel the possibility of travel between different areas within the commune 18.

- It is advisable to organize the number of stops, considering the distance of a radius of 300 meters (equivalent to a 5-minute walk) between the location site (origin) from the user to the whereabouts, and from the destination whereabouts to the place where the user goes, complementing this with a distance between stops that allows to recognize in the MIO transport system a collective and not an individual system. In this way it will improve the location of bus stops and thereby improve the perception of the service that reaches users due to delays in travel time.

- Although this research did not deal with the topic of bus frequency due to the whereabouts, if it can be observed that there is a possibility that the solution at the time of waiting in stations is none other than tracing routes in a straight line, which allows obtaining shorter total travel times.

- The proposal to redesign the spatial distribution of stops and modification of routes, based on topological indicators of accessibility, can improve the quality of the service, to give the MIO transport system a perceptible profile as equitable and functional.

- Travel times for the user were considerably reduced with the new proposed routes, thus, the old routes have the following travel times: A12C with 9.86 minutes, A12A with 28.31 minutes, A12B with 20.52 minutes, A12D with 21.8 and A78A with 20.69 minutes, while in the new two proposals are presented old times ranging between 8 and 16 minutes.

- There will always be a disadvantage for poor people, but the transportation system can help to reduce this disadvantage, if it is possible to provide the community with a more efficient public transport system that reduces the total cost of travel and time invested in it, which will result in greater well-being for MIO users and in the end it will bring greater prosperity for the families and thus for the city.

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