STD ROAD ENGINEERING,

CHANNELS AND PORTS

SUPERIOR TECHNICAL SCHOOL OF ROADS, CHANNELS AND PORTS

MASTER'S END PROJECT:

Development of Dgis tool, for the evaluation of the accessibility of collective public transport. App internship to Santiago de Cali (Colombia)

Presented by:

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Dedication

To the walkers of the world and to science

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THANKS

To the professors who with their knowledge contributed to the achievement of the skills that allowed the successful completion of the work consigned here. Especially to the tutors María Rosa Arroyo López and Ignacio Villalba Sanchis.

To my parents and sister, who with their support and accompaniment made it possible for me to reach the goal set from the beginning of the master's degree.

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1 Summary

The objective of this study was to develop a computer program aimed at facilitating transport planners to improve mobility in cities by measuring the level of accessibility of public transport. The methodology applicable by the user of the software was to measure accessibility in the different areas of the city through available public data and its own criteria.

To develop the software, the methodology consisted of seeking information on the concepts accepted as appropriate for modern urban planning and its central link with the accessibility of public transport to all areas of a city. From this information, programming in Matlab continued, obtaining a program that met the objective, which, once achieved, was validated, applied and proposed improvement measures in the city of Santiago de Cali (Colombia).

Indeed, the validation of the program was carried out in two phases, in the first, when it was used to study the accessibility of the southern area of Santiago de Cali, where the elaboration of transport routes is proposed that, if implemented, would help improve spatial accessibility in the area, and secondly, the spatial accessibility of 34 cities in the world was evaluated, including among them the 27 capitals of the 27 member states of the European Union

The main conclusion is the usefulness of the software to evaluate transport routes, transport systems and cities from the point of view of spatial and topological accessibility.

A relationship was found between the type of city and the spatial accessibility of transport in it, being low in cities built under the garden city model and the ideas of Le Corbusier, compared to the modern model of cities built for people, regardless of its historical context.

Keywords: Public transport; accessibility: mobility, GIS

Abstract

The objective of this study was to develop a computer program aimed at facilitating transport planners to improve mobility in cities by measuring the level of accessibility of public transport. The methodology applicable by the software user was to measure accessibility in the different areas of the city through available public data and their own criteria.

To make the software, the methodology used consisted of searching for information on the concepts accepted as appropriate for modern urban planning and their central link with the accessibility of public transport to all areas of a city. Based on this information, programming was continued in Matlab, to obtain a program that met the objective, which, once achieved, was validated, applying it and proposing improvement measures in the city of Santiago de Cali (Colombia).

Indeed, the validation of the program was carried out in two phases, in the first one, when it was used to study the accessibility of the southern area of Santiago de Cali, where the development of transport routes that would help to be implemented to improve spatial accessibility in the area, and, secondly, the spatial accessibility of 34 cities in the world was evaluated, including among them the 27 capitals of the 27 member states of the European Union

The main conclusion is that the utility of the software has been demonstrated to evaluate transport routes, transport systems and cities from the point of view of spatial and topological accessibility.

A relationship was found between the type of city and the spatial accessibility of transport in it, being low in cities built under the garden city model and the ideas of Le Corbusier, with respect to the modern model of cities built for people, independently of its historical context.

Keywords: Public transportation; accessibility: mobility, GIS

two Introduction

Getting from one place to another has always been a puzzle for people in the growing cities of the modern world. People are forced to travel for various reasons, both routinely and sporadically. The mobilization of people generates social and economic dynamics in each city and gives life. The challenge for the city government lies in how to achieve this mobility in the most efficient and friendly way possible, both for the people and for the city's own social, environmental and economic sustainability.

For people to move around in cities there are basically two means of transport, private and public. The layout of cities favoring the use of the automobile intensified its use, but its negative effects have been noted in problems of traffic jams, pollution, confusion, respiratory and even mental illnesses, before which the local governments and the citizens themselves they see the use of public transport as the most economical and effective solution, which, however, must be improved, to make people prefer it over individual transport.

Aiming to contribute to improving the perception and use of public transport by citizens, this work was undertaken with the aim of developing software that facilitates planning urban mobility based on the measurement of the level of accessibility of the different areas of any city. of the world for those who need to get around them using public and pedestrian transport.

To fulfill this purpose, the work was organized with a summary, the presentation of the indicated general objective and the partial ones that allowed it to be achieved, by establishing the guiding parameters that the urban planner must use to support mobility in public transport and on foot within the cities. different areas of each city, the design of the software and its validation.

The scope of the work was to structure a digital program, capable of facilitating urban mobility, applicable both to transport systems in operation or in project, which processes the information that is entered and throws data easily interpretable by developers, for on it. define the organization of public transport routes, defining planned stops in key places in each area of the city, so that people can take-leave the transport within 400 meters of their place of origin-destination.

The research method followed was based on studying the concept of the city, to understand what type of city people can live in better, in the city where people move in cars at 60 km/h or in which they can move on foot at 5 Km/h, in the words of the urban planner Jan Gehl, who in his studies managed to demonstrate that the friendliest cities for human life are those in which people can move on foot at this speed, for which cities must be equipped with a public transport system that allows the citizen to travel about 400 meters on foot between the boarding point and the public transport drop-off point, for which the stops must be located keeping at that distance the key sites that are of most common interest to the city dweller

On this basis, the following in the investigative method was to conceive the digital modeling that would allow this premise to be achieved, for which Matlab was used, as it is the appropriate system to address the task of collecting and processing massive matrix data to achieve the proposed objective, which, once achieved, required validation was carried out, taking the city of Santiago de Cali, located in the department of Valle del Cauca, in Colombia, as the primary scenario, seeking to verify that the software was capable of making it easier for the urban planner to establish travel routes by public transport and on foot that make cities more accessible to people.

Indeed, the method followed made it possible to achieve the central specific objective, designing and structuring the Dgis software, on the principle outlined by Jan Gehl, cities for people, thanks to the fact that the stops of the public transport system are planned focusing on the principle of fixing them in places within whose radius of 400 meters the key places required by citizens are found.

Thus, this work contributes by providing a digital tool capable of facilitating the urban planner to establish travel routes by public transport and on foot that make cities more accessible to people.

Once the objective of structuring a first model of the program has been achieved, the superior implication arises, encrypted in continuing to perfect the Dgis software over time, by gaining more knowledge about urban planning and citizen mobility, which will allow perfecting the solutions.

The physical infrastructure of a city makes sense as long as people can enjoy it because it is accessible, for this they must be able to move around it easily, so the developer, and his boss, the ruler, must plan to ensure that public transport Mass transit and walking are complementary, that is, they are harmonized, in such a way that people on forced walking routes can move within a maximum radius of 400 meters indicated.

The greatest limitation of the Dgis software is that the software does not take into account other factors when designing routes, such as the economic factor, satisfaction surveys, dangerousness of some streets, topography of the streets or the legal factor in the territory. . That is why a human being is always needed to operate it and analyze its results.

3 Objectives

This work has the following objectives:

3.1 Overall objective

Develop software that facilitates planning urban mobility based on the measurement of the level of accessibility of the different areas of any city in the world for those who need to get around them using public and pedestrian transport.

3.2 Specific objectives

To achieve this general objective, these specific ones must be achieved:

- Establish the guiding parameters to be used by the urban planner to support mobility by public transport and on foot within the different areas of each city.

- Generate software capable of making it easier for the urban planner to establish travel routes by public transport and on foot that make cities more accessible to people.

- Validate the software through at least one case study, where its functionality can be tested.

4 Scope of work

Urbanism is understood as an integrality, where transport is a fundamental aspect, to make the city vital, walkable, as modern urbanists and social scholars formulate in their concepts. On this basis, it is intended to generate a tool capable of measuring the topological and spatial accessibility of a transport system within each area in each city, as a means to be able to do better urban planning.

The tool envisioned is a digital program, capable of facilitating urban mobility, applicable both to transport systems in operation or in project, which processes the information that is entered and provides data that is easily interpretable by developers, to define the organization of urban areas. public transport routes, defining planned stops at key places in each area of the city, allowing people to take and leave transport within 400 meters of their place of origin-destination.

The software must work on both Windows and Mac OSx, as they are the most widely used desktop operating systems in the world.

5 Approach and justification of the problem

The aim of investigating public transportation in the city of Santiago de Cali and its effect on the population is based on the premise that transportation is an essential need for citizens, since moving within a large city, for economic or social, is a daily operation that must be supplied with own or public means or with a combination of both. (Ramirez-Cajigas, 2018).

To reaffirm the above, it is specified that "You must be aware that public transport has effects on the socio-cultural configurations of the city. Cities have emerged as strategic territories for a whole range of essential social, economic and political processes of our era: economic globalization, international migration, the affirmation of services and the financing of producers as the driving sector of growth 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, one can consider the representation of the social question in urban terms, the projection of the separation between marginalization and integration (Dubet, 1994; Rosanvallon, 1995)" (Sachs-Jeantet, nineteen ninety five).

Thus, transportation affects the daily lives of those who use it and those who lack it. access to it, that is why research on accessibility to public transport is justified. While there are various approaches to accessibility, this study focuses specifically on topological and spatial accessibility.

Therefore, not guaranteeing the mobility of citizens reduces the chances that they will have economic development and a better quality of life, but it also reduces the city's ability to generate social and economic dynamics, as a social conglomerate, which implies reducing its ability to attract tourism, investment and opportunities for economic action for its inhabitants (Ramirez Cajigans, 2018).

Consequently, the disadvantage limits access to 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 them and of course contributes to increasing exclusion. society among members of society. (Luke, 2011).

On the other hand, accessibility to transport, the type of city and the scale on which the city is built positively or negatively affect those who live in a city (Gehl, 2014). From this perspective arises the objective of developing software that facilitates planning urban mobility based on the measurement of the level of accessibility of the different areas of any city in the world for those who need to move around them using public and pedestrian transport.

For topological accessibility, the software must measure transport routes and evaluate their topology by means of equations defined by researchers of the past, for which the result is simple from the computational point of view, as they are matrices, whose values indicate the result to the researcher.

The spatial accessibility of an entire city is more complex to understand, since it is necessary to know city theories, concepts of well-being in the city, given by authors from different disciplines, such as Jane Jacobs and Jan Gelh, it is in this field where transport and urbanism they mix. The result is an application that integrates a concept capable of measuring the accessibility of any area of the world, this is achieved by applying the key concept of cities for people coined by Jan Gelh in his books, and giving it a global mathematical interpretation, which can be summarize in the area of influence, demarcated by a circle with a radius of up to 400 meters, which exists between each stop and the place of origin or destination of the user.

The software is valid for its function of finding topological accessibility, in the southern area of Santiago de Cali, Colombia, and in its function of spatial accessibility, evaluating 34 cities in the world.

6 Methodology

All research methods led to the study of the concept of the city, and within this, the historical city, recognizing that current cities are the result of historical processes that have led to having urban centers, aimed at getting people to live in them. in an increasingly better way in individual and collective terms.

Likewise, the predominant urban ideas or approaches were studied over the last centuries, leading to a clear understanding that the concept of the city and its implementation have been developed from different fields of study.

Once the main approaches on which urban planning and the mobility of the people born in it have been established, the concept of the 5Km/h city was chosen as the appropriate one for the intention of the work, this speed refers to the speed of a fast-walking pedestrian (Gehl, 2014), over the city concept of 60 km/h, this speed refers to a car going 60 km/h in a city, in cities around the world this is the maximum speed in others it is 50 km/h (Gehl, 2014), although the WHO has recommended a maximum urban speed between 40km and 50km, given that at higher speeds the pedestrian has a higher risk of death (World Health Organization, 2013) .

The average speed at which pedestrians move in summer is 14.2 minutes per km, which corresponds to 4.2 km per hour. In winter the average is 10.3 minutes per km, or 5.8 km per hour (Gehl, 2014).

The concept developed by the urban planner Jan Gehl, basing the decision that the friendliest cities for human life are those in which people can move on foot, which means that many people converge on its streets, who, for being so just walk side by side is socializing, and from that closeness, is more inclined to deepen that socialization through the possibility of dialogue.

Matlab was used to program the digital model, as it is the appropriate system to address the task of collecting and processing massive matrix data to achieve the proposed objective.

Once a designed and structured program capable of working was obtained, the obligatory validation was carried out, taking as a scenario the city of Santiago de Cali, located in the department of Valle del Cauca, in Colombia, seeking to verify that the software is capable of facilitating The urban planner establishes public transport and walking routes that make cities more accessible to people.

In Cali, the area of the city that is accessible to a pedestrian using collective public transport was evaluated, understanding that the pedestrian takes the transport service and when getting off has his destination at a maximum distance, which will be defined with the theory investigated. This process has been repeated in 34 other cities around the world, thus doing a second validation of the program in these, managing to test its computing power.

Thus, once the functionality of the program was completed, the methodological process was completed, in order to materialize the certain materialization of providing a useful tool to support the continuous exercise of urban planning.

7 Theoretical framework

This section contains the main theoretical references that support the work presented here. Starting from the state of the art, which contains elements of how to understand the city, land use planning, transport accessibility and segregation, mathematical urbanism and accessibility, healthy city transport and mass public transport and the environment.

7.1 state of the art

Research on urban planning and transportation has been carried out since the construction of the first cities, being a subject in which there is a wide state of the art, having faced the problem from mathematics, empiricism, observation as towards Willian H. Whyte, imagination and trial and error. Table 1 below summarizes the analytical racket on the matter:

Table 1 Bibliography used in the theoretical framework

Category and year of the edition used	Article	url (if you have one)	Author(s)	Publication year	abstract
Charter of Athens (1933 - 1942)			Le Corbusier, Jose Luis Sert	1942	It is a document resulting from the International Congress of Modern Architecture (CIAM 1933) and published in 1942, it stipulates criticism and ideas on how cities should be built, it was and is an urban planning guide. Guide that many authors consider contrary to the ideas of walkable cities, since in this one the automobile and monumentality are praised. It is an urban planning document that must be read, which helps to understand the reason for the existence of cities and neighborhoods. It is important to highlight that it is written in order to make cities hygienic, green and beautiful to look at.
Death and Life of Big Cities (1961)			Jane Jacobs	1961	Fundamental book for pedestrian urban planning, a book written by a journalist Jane Jacobs, here the author writes about her disagreement with the cities of architects, urban planners, engineers and politicians, I know that they moved away from common sense at the time of planning and they focused on building for their egos. He criticizes the garden city proposed by Howard, he criticizes the zoning that is also seen in the radiant cities of Le Corbusier, a green space in the city only makes sense if there is a reason to carry out a social activity in it. The city model that Jacobs proposes is based on the neighborhood, on the block in the neighborhood, she says that it is essential to promote good life in the city and with it security, a neighborhood where people can be friends, where there are reasons to be on the street at any time of the day, to generate civility and mutual respect among those who live there by creating places where time and ideas can be shared. Therefore, according to Jacobs, it is necessary to design urban environments where you can walk, over urban environments where you can drive a car. The street must be the space of relationship and not only a bridge between origin and destination, it is necessary to introduce shops, good chairs, public services, not to compete for the place but to share it. Jacobs also criticizes the gentrification to which neighborhoods are subjected. Include the experience and reality of the common human being, according to Jacobs, it should be included in the planning, the inclusive planning of the minorities
urban modeling			Michael Batty	1976	A mathematical book written by the famous Michael Batty, dedicated to urbanism, it is an excellent book to understand urban modeling, planning, land use, zoning, transportation, construction, projections, etc. Urban models are an aid for city prediction, try to save time, money and avoid urban failures.
The Social Life Of Small Urban Spaces			William H. Whyte	1980	It is an obligatory book in urban planning, it is generated from an investigation in which blocks, parks, green areas, acinated areas, areas with high density, etc. are studied. It was studied because people of all ages used a certain place. The questions that are asked What makes a place successful within the city? Why do some squares work and others don't? ¿ . I study in depth the pleasure of using places to chat about unimportant topics and how this makes people happier. The book is separated into interesting chapters about places in the city and activities that are carried out in them, there are interesting facts about the book, for example, where there are more women than men, urban space is better thought out, people walk faster in big cities, People generally choose to gather near pedestrian corridors where they see people passing by, seating spaces should be between 6 and 10 square feet (and leaving at least 1 foot line of chairs for every 30 square feet). Go to common sense, for example, the water sources of the parks should not have prohibitions on their use "you cannot put water in front of people and then pretend that you do not enjoy it".
accessibility indicators and their decision-making role in investments in transport infrastructure			Andres Monzon of Caceres	1988	This doctoral thesis, which deals with accessibility indicators, these are indicators that try to quantify the ease or difficulty that users of the transport system have to reach destinations. The study was carried out on the community of Madrid, a comparative analysis of three road plans in Madrid is made, evaluating them with the indicators.
Social Town Planning (1999)			Clara H Greed	1999	A very interesting book, which introduces the reader to the concept of social urbanism, through which it is hoped to teach that the planning process must be reflective of the people for whom the urban environment is planned, including gender, race, culture and opinions. The agenda of the "social aspects of planning" within urban planning. This inevitably leads to a consideration of issues such as urban governance, social policy, inequality, sustainability, and planning theory. This book further develops the theme of research into the construction of urban realities and, therefore, of social urbanism.

Table 2 Bibliography used in the theoretical framework 2

urban design compendium			Llewelyn-Davies	2000	This book is a compendium of recommendations for urban planning, although it was written in England, it has recommendations that can be applied anywhere, the book was born with the idea of complementing the design guidelines of the United Kingdom. It is very useful because it tries to show what kind of policies can be taken, for urban regeneration, it has instructions on transport, housing, walkable city, urban density, landscape, urban mobility, environment, etc.
Self-organizing pedestrian movement	Article in Environment and Planning B Planning and Design May 2001		Dirk Helbing, Peter Molnar, Illes J Farkas, Kai Bolay	2001	Studying the movement and behavior through observations of groups of pedestrians, it is pointed out in this document that pedestrian dynamics show various collective phenomena, for example, formation of lanes and oscillatory flows through bottlenecks and can be micro-modeled mathematically.
the humanization of urban space (2006)			Jan Gehl	2006	Modified edition of Life Between Buildings, in Spanish and summarized
European Landscape Architecture (2007)			Jens Balsby Nielsen, Torben Dam and Ian Thompson	2007	It is a compendium of recommendations when building gardens, parks and the urban planning that is related to these, always being old designs that are durable. Take nine European countries as an example and try to have case studies with photographs and plans of the gardens studied. It tries to teach the developer the importance of detail when designing, how aesthetics affects wear and tear from day to day, plan to last.
Representing Landscape architecture (2008)			Marc Treib	2008	It is a book that is made up of 14 essays, on how to design the landscape, how to correctly convey an idea in the design of the landscape, what tools to use in modeling the landscape. It is a call to link the representation to thinking, about the graphic representation, that is to say, it puts the idea first.
City Planning for Engineers, Environmental Engineers and Surveyors (2010)			Kurt W. Bauer	2010	It is an educational text for civil engineers that aims to inform about the urban planning process in the United States of America, the text is a basic manual on urban planning, focused on the areas of urban planning where civil engineers are required. It shows the concepts used in the planning of neighborhoods and cities, both new and classic. It shows the urban design in its entirety but not in depth.
Life Between Buildings (2011)			Jan Gehl	2011	The first edition was written in the 80s, however, for this work the 2011 edition is used, in this the deficiencies of the urbanism that existed in the 70s according to the author are pointed out, it tries to explain the importance of building a city for people, laying the foundations for the book "cities for people", then there are 3 types of human activities in the city according to Gehl: necessary, optional and social. Emphasizing the social ones as activities that only take place in a quality public space.
operations research			Hamdy A. Taha	2012	This is a book of mathematical models based on operations research, a discipline that began in the Second World War (United Kingdom), seeks to use the resources that are available in the most optimal way, in the cities they have a defined number of resources and with these resources it must be urbanized. This book has interesting examples where an urban planning decision has to be made and the solution is reached through a mathematical model, trying to arrive at the best possible solution.

Table 3 Bibliography used in theoretical framework 3

Cities for the People (2014)			Jan Gehl	2014	The author gives with this book a guide on how to build cities and urban spaces, focused on the walkable city of 5km/h and not the city for cars. It is here that Gelh generates the concept of cities for people. For this author, the city must be an environment that provides happiness, comfort and facilitates human relationships, he addresses the problem of urbanism from the basic concept that it is built for human beings, he gives us advice on how to generate safe, healthy spaces, with the human physical scale, designed for our senses in other words is to generate a "habitat for the beings that live there".
Cities Alive Towards a Walking World (2016)			Gregory Hodkinson	2016	This report shows the benefits of walkable cities (economic, social, environmental and political) and sets out measures to improve walkability, illustrating them through case studies. The report challenges decision-makers to be more aware of the direct and indirect benefits of more walkable cities and provides guidance on how these could be achieved.
theories and history of the contemporary city			Carlos Garcia Vizquez	2016	This book brings a historical account of the city, in a brilliant way it relates the historical facts, the different disciplines and the policies that were given over time. The author separates history with the formation of three types of city which he calls the metropolis, megalopolis and metapolis. The importance of history in urbanism, the same that is marked by urban anthropology, architecture and different philosophical worldviews. It is a must-read book for any urban planner, understanding the city as a historical and intellectual entity.
design of the spatial distribution of the routes of the mio system according to the quality of service perceived in the commune 18			David Alejandro Ramirez Cajigas	2018	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. The present degree work was carried out, which had as an analysis support the great mobility survey 2015, the basis of the study that allows issuing the report ¿Cali, how are we going?, additionally, a pilot test was applied, processed using the IBM SPSS Statistics 23 program. , 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 a broad and deep information collection, based on primary information provided by MetroCali, as the managing entity of the MIO transport system, and the pertinent secondary information, allowed reaching the indicated objective, to which was added the technical evaluation with topological measures. of accessibility of the existing routes and the proposals. Based on this, it was concluded that the routes and bus stops should be organized within the commune 18 of Cali, taking care that users find a bus MIO bus stop within a maximum radius of 300 meters, and that between bus stops the distance allows the bus driver achieve a greater speed in their displacements, which altogether allows the user to reduce the travel time, leading to a better perception of the service provided by the transport system. In this work, route travel times are improved without altering waiting times at bus stops and guaranteeing good accessibility.
Safer Cities Through The Design		https://publications.wri.org/citiessafer/es/	Ben Welle, Qingnan Liu, Wei Li, Claudia Adriazola Steil, Robin King, Claudio Sarmiento, Marta Obelheiro	2019	This freely accessible text on the internet addresses the challenge of providing road safety for pedestrians and drivers, designing safer cities. It is proposed in the urban design recommendations focused on the pedestrian city and mass transport, shortening travel times, reducing pollution, the possibility of having accidents and, in general, having cities that provide a better quality of life to those who live there.

7.1.1 Understanding the city

There are as many reasons for travel as the activities that a city offers, if you want to make software for public transportation, it is important to understand the city, because transportation helps its citizens to move around it.

7.1.1.1 Designing cities

"Man is man's greatest joy" says the Danish poem Hávamál,
with an anonymous author, who teaches, as the journalist Jane Jacobs wrote in her work Life and Death of Big Cities, and the architect Jan Gehl, in his work Cities for People, that cities have to be built with the dimension human, cities whose purpose is to achieve interaction between the inhabitants of the city, since, certainly, people are the ones who best give people happiness, which leads to moving away from the trends of the free-standing building, the one proposed by Le Corbusier.

But regardless of how the buildings where people are sheltered are distributed, designed and built, the transport of people continues to be the problem par excellence within cities, as can be seen by noting how since the 1960s the private automobile fleet , began to invade public space, displacing people to the background, which should have been assumed as a problem to be corrected due to the number of maleficences that it was empirically and scientifically proven to bring to citizens, for which it had to be recovered and returned. to incorporate the walk as a public policy, reinforcing the public space as a space for political, social and economic interaction. (Gehl, 2014).

Emphasizing mobility on foot, a good public transport system, bicycles, and the integration of public spaces with these means of transport, brings with it significant advantages in people's happiness and health, reducing the personal, institutional, and social costs of a sick population. on an ongoing basis, whether mild or severe. (Gehl, 2014).

The volume of automobiles depends to a great extent on the city's capacity to offer roads for them, there is the example of Copenhagen, where an extensive network of bicycle lanes was introduced, which produced a significant increase in this means of transport. See Figure 1
Evolution of bicycle use in Copenhagen.

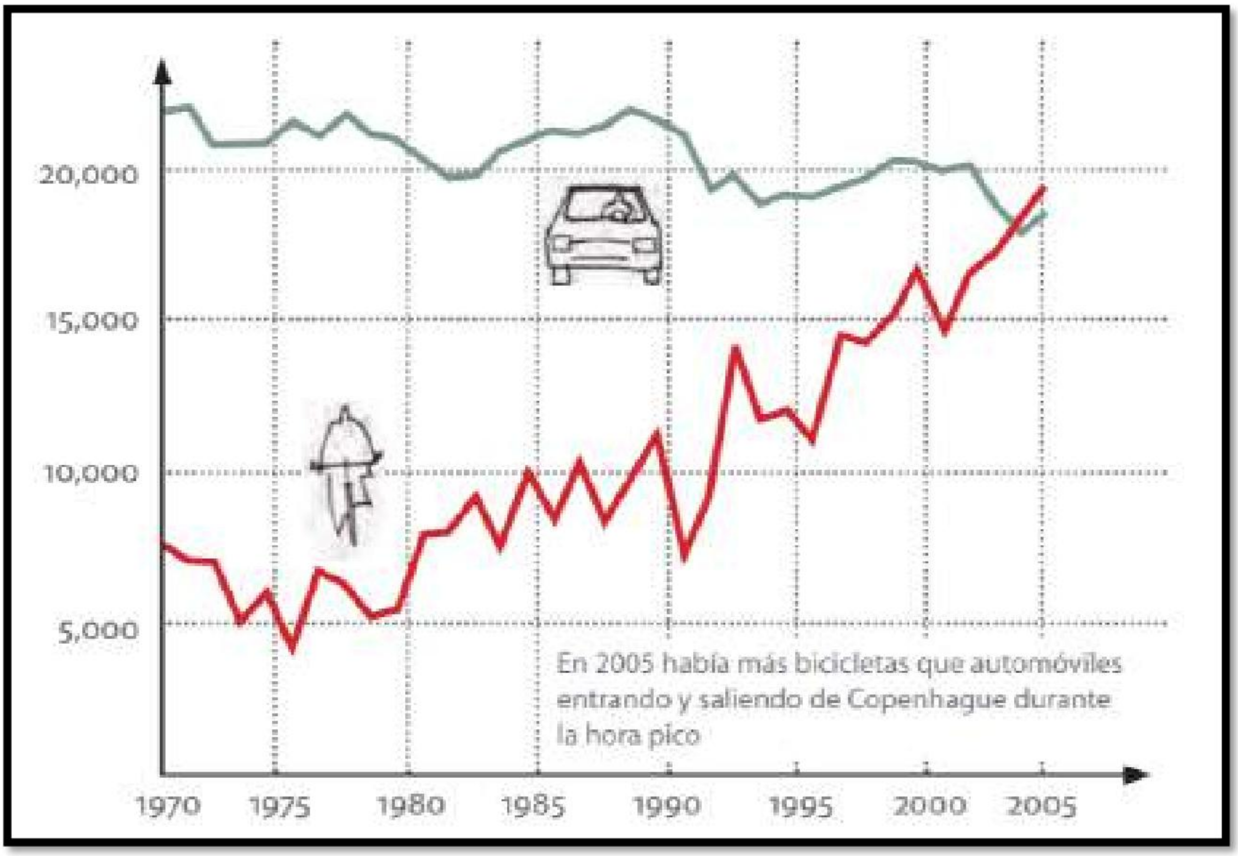


Figure 1 Evolution of bicycle use in Copenhagen (Gehl, 2014)

The reduction of traffic in the city center can go through various strategies, urban tolls, reduction of parking spaces, tax benefits for cyclists, streets only for pedestrians or cyclists, improving public space to facilitate interaction between people among other proposals that can be devised and implemented. Figure 2 Figure 3 (Gehl, 2014).

The pedestrianization of streets generates an economic change in the region, since businesses are generated and economic dynamics are made possible in them, for example, in Copenhagen and Melbourne a true revolution of small businesses has been experienced over the years thanks to the promotion of pedestrian streets and the use of bicycles. (Gehl, 2014).

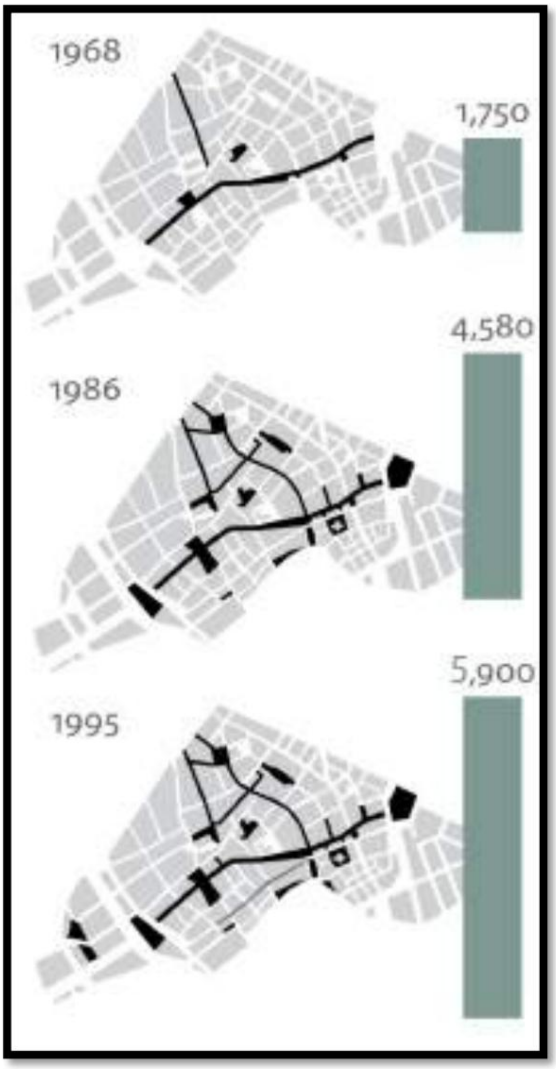


Figure 2 Permanence activities on summer days thanks to pedestrianization (Gehl, 2014)

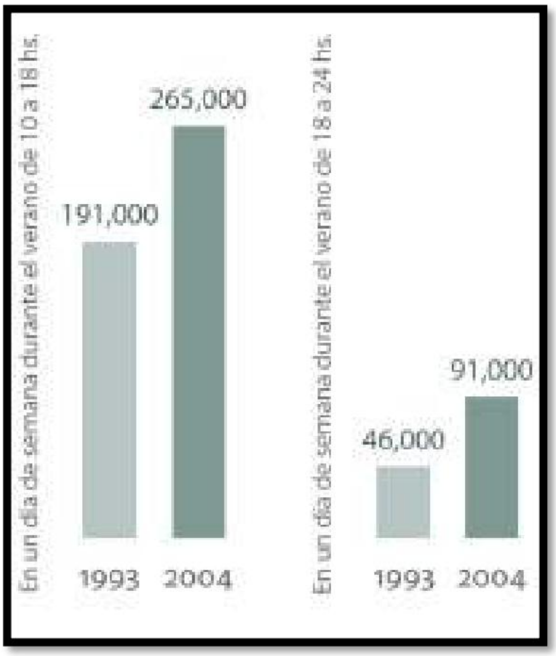


Figure 3 Pedestrian traffic in Melbourne (Gehl, 2014)

The following illustrations Figure 4, Figure 5, Figure 6 show as simple actions, how doubling the number of public seats manages to increase the number of people who visit a sector, which has been observed in Aker Brygge, Oslo, Norway, and in the boulevard del rio, in Cali, Colombia, where the number of people who frequenting these places increased.

Figure 4 Cali River Boulevard

Figure 5 Boulevard del rio Cali Colombia (the country, 2018)

Figure 6 Aker Brygge, Oslo Norway (visit Oslo, nd)

The quality of the urban built environment determines the type of activities carried out by people living in an urban area, as can be seen in Figure 7 High quality of the urban environment vs. low quality.

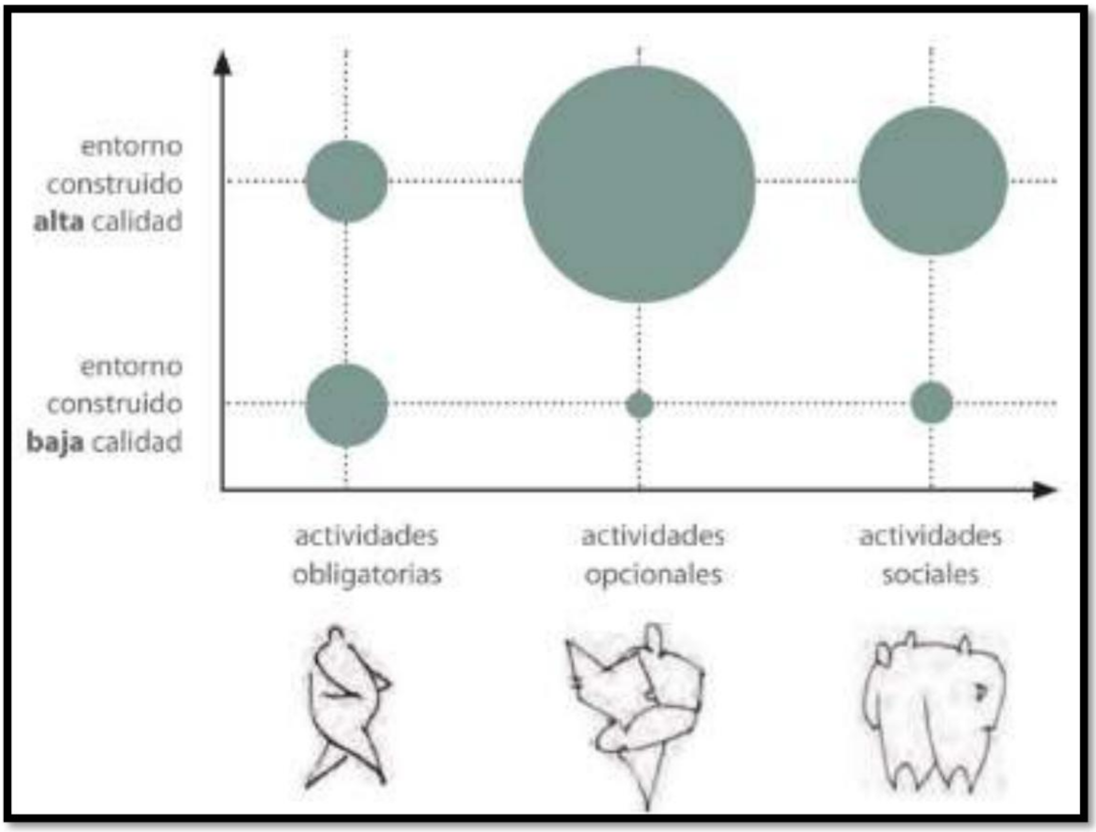


Figure 7 High quality of the urban environment vs low quality (Gehl, 2014)

When designing a city, one must think about the physiological aspects of the human being, the size, the ability to see, the speed with which one walks, the position in which people orient themselves and their type of locomotion, meaning this therefore the premise of working to scale and perspective human (Gehl, 2014).

Within the design of pedestrian places, the ability of the human being to see objects, distinguish objects, see easy expressions, distinguish people and the natural human-nature interaction must be taken into account. Contact with a building on the street occurs in normal situations only between the ground floor and the fifth floor, that is why the ground floor should be designed to attract the attention of the pedestrian, putting colors, designs, restaurants, shops , among other constructions that may be striking to us as human beings (Gehl, 2014).

Two classes of cities are then distinguished, the city to go by car, the 60km/h city, which is characterized by large avenues, signage with huge letters, separate buildings and sidewalks without anything that attracts attention when walking, an example of these cities is Dubai. On the other hand, there are the cities for 5km/h where you can see many shops and shelves accompanying the citizen while walking, these cities invite movement on foot, an example of this type of city is Venice (Gehl, 2014).

The scales must be designed according to daily activities, what Gelh calls materialized cities according to the human senses, automobiles and traffic generate problems for design on a human scale, since these two aspects require extensive areas for their operation. Buildings should not be designed to amaze from a distance, buildings and distances get bigger while the people who use them remain small.

The dispersion of people should be avoided, urban life is a process that feeds on itself, for this it must be planned with urban densification in mind. They seek to reduce the routes, think about the origins and destinations and have a basic hierarchy of importance.

The combination between attractive urban space and people enjoying those spaces is essential, a poorly planned high-density sector makes it difficult for people to want to go out and enjoy their neighborhood (Jacobs, 1961) (Gehl, 2014).

We must avoid building psychological barriers that prevent people from leaving, these barriers are dark streets, skyscrapers, narrow streets and not keeping proportion of urban space. The urban planner must try to achieve a daily environment in which there is permanence of the pedestrian on the street terraces. Figure 8 (Gehl, 2014).

Figure 8 On the left, correct examples of the city, on the right, examples of what not to do (Gehl, 2014)

The city has to be safe, so that people from different socioeconomic groups have the possibility of attending the same places, inequalities generate a tendency for certain sectors to hide from the rest of society, closed communities are generated, places with security guards private and hide behind bars and barbed wire, this hinders the ability to create safe places, for Jane Jacobs the same neighborhood where she lived offered security due to the ability of interaction between neighbors. (Jacobs, 1961).

Quote-"If we can strengthen urban life to the point of getting people to walk and spend time in public spaces, security, both perceived and real, will increase. The presence of others is always a good indicator that a place is considered safe and pleasant. There are "eyes on the street" and "eyes on the street" as well, meaning that whatever is happening is interesting and meaningful, both to the people on the street and to those watching from surrounding buildings. When people use public space, everything around them becomes more significant and important to look at. A vital city becomes a city that is valued and also safe"
(Gehl, 2014).

It is expected that urban centers will not exceed 1 km in diameter, so that people can reach the services offered by the urban center on foot. Direct routes, as short as possible for human beings, if it is possible to build bridges and tunnels for cars, so the pedestrian crosses the level, it is even possible to make connections between streets separated by buildings (Gehl, 2014).

We must avoid building cities like Brasilia, large green areas that do not invite you to do anything, buildings separated from each other, they are concrete islands. This is the city of Le Corbusier (Jacobs, 1961).

Principles of planning for the congregation of the people of Jan Gehl, are shown below in graphs quoted from his book cities for the people, indicating before the key principles of urban planning defended by this author:

1. *The different urban services must be located in such a way that it is not necessary to walk far to go from one to another and so that there are always people and events around them.* (Gehl, 2014).
2. *It is necessary to integrate city services until urban versatility, more diverse experiences, social sustainability and a sense of security are achieved in each of the districts* (Gehl, 2014).
3. *Design the public space so that people feel that it is a stimulating place and safe to walk or bike.* (Gehl, 2014)
4. *Work to strengthen incentives that encourage people to stay longer time in public space* (Gehl, 2014).

7.1.1.2 Designing a neighborhood for walking

Foot traffic increases sales to street retailers, in other words, it increases jobs in the city and improves the purchasing power of those who live there. In *New York City it was recently shown that transforming an underused parking area into a pedestrian plaza in Brooklyn has led to a dramatic 172% increase in retail sales* (Arup Group, 2016).

The pedestrian spends on average 65% more on purchases when leaving home than drivers, it is known that investing in cycling or in a pedestrian zone generates a return of 11.8 dollars for each dollar invested. (Arup Group, 2016).

When designing the urban layout of a city, the distance that the pedestrian will travel must be considered, considering the best way to connect the place with the pedestrian, the means of transport, providing direct links with the bus stops. (Arup Group, 2016).

A network should be created, generating access to the entire area, reducing the distance necessary to walk between two places, a network spacing between 80 and 100 meters seems to be the ideal size for countries with garden cities, however, for dense urban centers it should be 50 to 80 meters. (Davies, 2000). See Figure 9 for an aerial view of city blocks in 3 different cities, Portland, Philadelphia, and London.

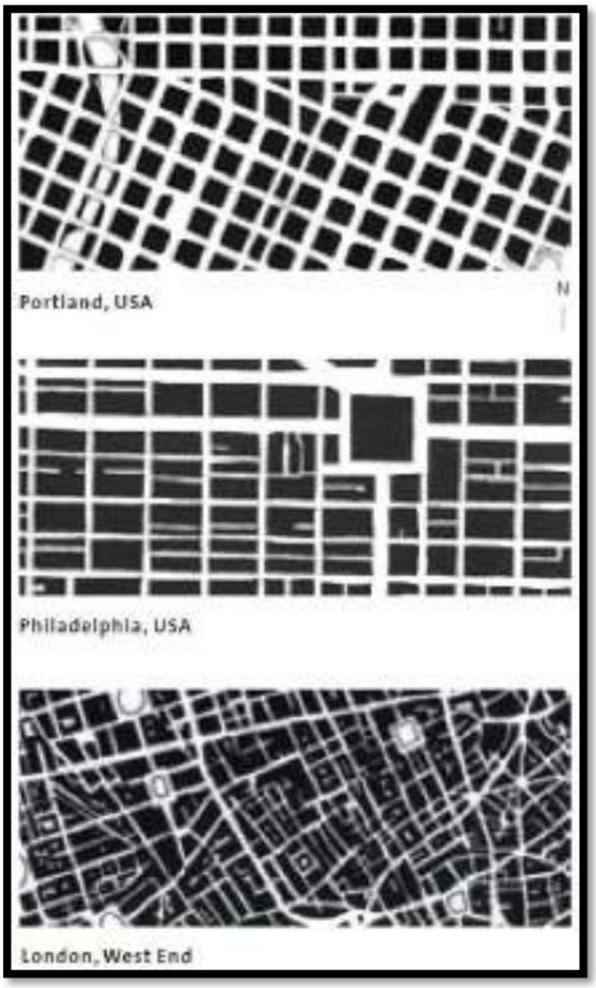


Figure 9 an aerial view of city blocks in 3 different cities, Portland, Philadelphia, and London (Davies, 2000)

The use of mixed land allows a greater opportunity for social interaction, traffic to work is reduced, a sense of security is generated, greater energy efficiency is generated and the lifestyle of the inhabitants is improved. It is very important to check the walking distance to facilities where daily activities take place, for example traditional Victorian and Edwardian suburbia (Davies, 2000).

The ideal distance has been established in locating sites of human concentration covering radii of 400 meters, which are covered in an average of 5 minutes on foot, that is, 400 meters should be considered as the section of the city that is most immediately related with a pleasant sensation for pedestrian performance once the public transport vehicle is abandoned to develop a dynamic of life, combining different uses, such as leaving and returning home due to work, study, shopping in stores, leisure, creeds, commerce, health centers and food, telling that yes that in those routes it is avoided put noisy and dirty places mixed with residential or business buildings.

The graphic sequence (Figure 10 walk radii in different possible situations) following gives a semblance on how to urbanize at 400 meters:

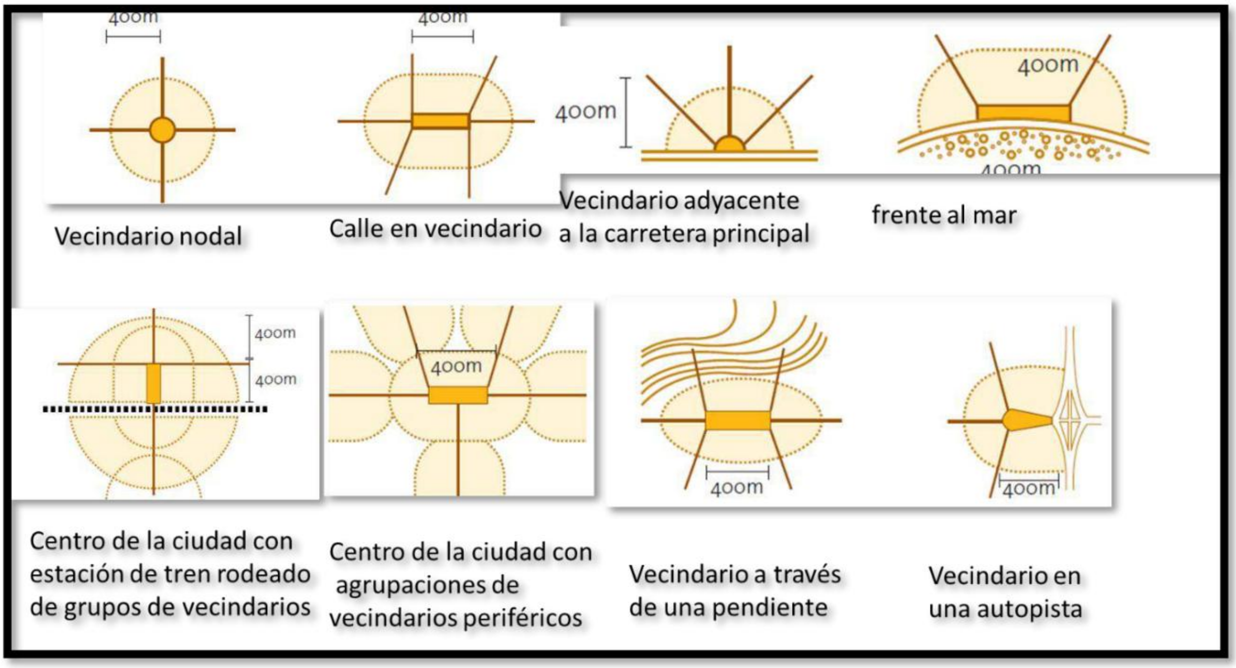


Figure 10 walking radii in different possible situations (Davies, 2000)

Mid-rise buildings between 3 and 4 stories are effective in ensuring adequate density without overcrowding, as illustrated below in Figure 11 (Davies, 2000).

		Option 1	Option 2	Option 3
Car Parking Arrangement		High 2 to 1.5 spaces os per unit	moderate or 1.5-1 space per unit	Under less than 1 space per unit
Predominant housing type		independent te and linked houses	Terraced houses and flats	mostly flats
Location	Configuration n			
Central area with accessibility factor d out of 6 and 4 4	Central			240-1100hr/ha 240-435 u/ha Ave. 2.7 hr / u
	Urban		200-450hr/ha 5 5-175 u/ha Ave. 3.1 hr / u	450-700hr/ha 165-275 u/ha Ave. 2.7 hr / u
	Suburban		240-250hr/ha 35-60 u/ha Ave.4.2 hr / u	250-350hr/ha 80-120 u/ha Ave.3.0 hr / u
Transport corridors and places close to the city center, an accessibility between 3 and 2	urban		200-300hr/ha 50-110 u/ha Ave. 3.7 hr / u	300-450hr/ha 100-150 u/ha Ave.3.0 hr / u
	Suburban	150-200 hr/ha 30-50 u/ha Ave. 4.6 hr / u	200-250hr/ha 50-80 u/ha Ave.3.8 hr / u	
Remote places accessibility 1	Suburban	150-200 hr/ha 30-65 u/ha Ave. 4.4 hr / u		

Figure 11 Urban density and collective public transport (Davies, 2000)

In the design of residential blocks it is important to have privacy for people, leaving the necessary height between the ground floor and the first floor for apartments and in houses leaving at least 21 meters between the house and the pedestrian curb. There are several ways to make the blocks, it is recommended that it be small between 60 and 80 meters, with the ability to adapt over time, very long blocks hinder pedestrian mobility and the setting up of transport stations. (Davies, 2000).

Below are some primary recommendations to organize the distribution and construction of blocks in order to facilitate the mobility of transport and pedestrian systems.
(Davies, 2000):

- The square subdivision of blocks offers the possibility of accommodating a greater variety of commercial and residential buildings.
- Rectangular blocks with depths of 110 meters are suitable for placing large buildings and large commercial factories or warehouses on them.
- Rectangular blocks with the short side oriented to the main street, brings as a benefit, the increase in connectivity of the surroundings, provides more crossings, and, therefore, slow down car traffic, facilitating the movement of pedestrians and cyclists.
- The irregular blocks adapt to the topography and the historical context of the city.
- Keeping plots small creates active failure, encourages the human scale Gehl talks about, and provides a flexible foundation for future growth. The excess space is reduced.

- Plots of 5 meters to 20 meters, generates a natural buffer for the uses of the low level.

The following graphic sequence (Figure 12 Housing blocks) illustrates the approaches, facilitating their understanding:

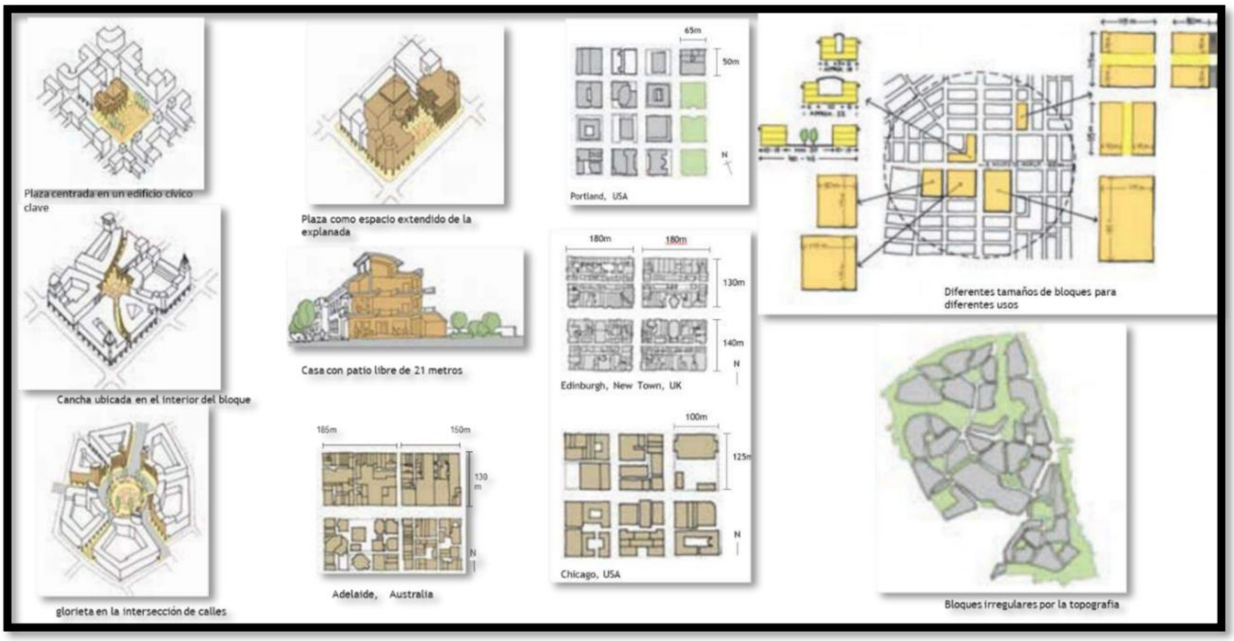


Figure 12 Housing blocks (Davies, 2000)

7.1.2 Land use planning

The land as a space cannot be used by people without transportation, the planning model of cities depends on the existing transportation technology at all times, the possibility of providing each area with public services, the cost of land and the average per capita income of the population, since this determines their purchasing power, including their ability to pay taxes and the services they receive, which in turn affects the quality of urban planning, since it indicates the quality and quantity of urban infrastructure with which each area of the city or the city in general can be provided (Kurt W. Bauer, 2010).

Land use planning in cities was studied mostly in the United States, where city land was separated into sections or areas, according to their use for residential, manufacturing, service, and retail use (Kurt W. Bauer , 2010).

From the distribution of these uses, the average transportation cost can go up or down, the idea is to maximize the number of residences within a short arrival time, generating a buffer around the industrial center, determining this of what has been called the model. mono-centric city (Kurt W. Bauer, 2010).

The sectoral model proposes the use of mixed land, although it is based on the monocentric model, which was proposed by Hoyt in 1939, the idea is not to depend on the industrial center as the only generator of trips (Kurt W. Bauer , 2010).

The external expansion model is based on the fact that the pedestrian becomes a user of trains and private cars and travel time no longer depends on distance but on technology, it is the beginning of dependence on the car (Kurt W. Bauer , 2010).

The polycentric model proposes a decrease in the cost of transporting goods, generating radial transport systems such as railways, the motor truck and the rise of the automobile, this is North America from 1960 to the present. The graphic sequence of Figure 13 illustrates some concepts of urban models (Kurt W. Bauer, 2010).

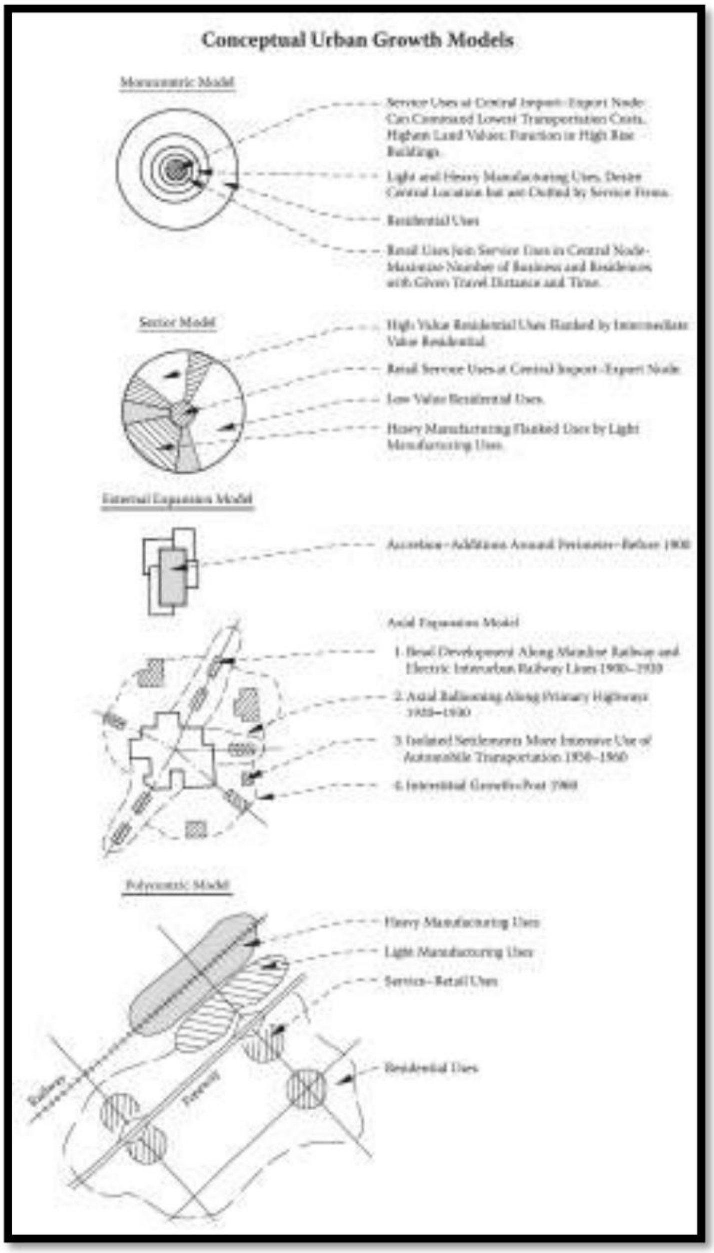


Figure 13 Models in city zoning (Kurt W. Bauer, 2010)

7.1.3 Accessibility, transportation and social segregation

Until now, it has been seen how the city should be developed based on authors specialized in urban planning, in all of them it has been possible to see how the city is related to transport.

The city's public transport not only shapes it, but also directly affects the lives of the human beings who live in it, causing exclusion for those who do not have means of transport. (Ramirez-Cajigas, 2018).

Measuring accessibility to public transport is important to have fairer societies, where people can live better, societies with cities for people, urban planning is directly related to transport (Gehl, 2014) (Cáceres, 1988)
(Ramirez-Cajigas, 2018).

An accurate definition is perhaps the following, which quoted verbatim says:

"Measure of ease of communication between activities or human settlements through the use of a certain transport system, allows explaining and measuring the ease or difficulty provided by infrastructures and means of transport in mobility. Three accessibility measures can be distinguished: 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 points that are in the same territory, and global accessibility, which is determined as the sum of the integral accessibility of all the nodes of the study area, which represents the degree of connection of the entire network and reflects the effects of any action on it" (Caceres, 1988) (dajome, 2016).

Regarding its importance, Cáceres would write "It can be said that the measurement of accessibility in its various formulations is an important contribution to the planning process of transport infrastructures. Its usefulness is confirmed, as a tool, to facilitate the understanding of transport dynamics and its interrelation with land use planning" (Caceres, 1988).

Spatial accessibility is nothing more than how accessible a point in the territory is, with respect to other points in it, points that are called nodes (Caceres, 1988).

The cities during the 20th century were planned thinking about the use of the car, generating segregation between the center of the cities and their neighborhoods, this produced a negative segregation among the inhabitants of these, generating an increase in the levels of local pollution and in turn this It represents a mortal danger for the inhabitants. (Vazquez, 2016).

Being a pedestrian or cyclist in the cities became so uncomfortable that people preferred not to go out unless it was by car, this brought with it physical and mental health problems for its inhabitants. These trends also affected the accessibility of different social groups (Gehl, 2014).

The transport planner traditionally considers that the correct way to deal with a transport problem is from mobility and not from accessibility, which has led to freeing up road space to combat vehicular congestion, a methodology that has not been entirely correct. (Gehl, 2014).

The predominant trend has been to "predict and provide", generating increasingly expensive projects, which result in infrastructures that after a few years will become insufficient to support the traffic, which is why the paradigm has to be changed to "predict and prevent", which is based on trying to predict future traffic demand and then taking actions to reduce that future demand. In order to minimize traffic on the roads, the emphasis must be on promoting the choice of trip, giving advantages to the collective, pedestrian and bicycle transport over individual transport by car. (Greed, 1999). To achieve this it is necessary:

- Improve multimodality and integration of all means of transport.
- The distances between origins and destinations must be as short as possible.
- Reallocate existing road space to prioritize walking, biking, and transportation collective.
- Carry out educational campaigns on the environmental damage of using combustion cars, the environmental damage of building new highways and promoting friendlier methods of transportation.
- Apply public policies that increase the cost of traveling by private car through circulation taxes.

According to (Greed, 1999) there are links between transport and equity, the unequal distribution of the planet's finite resources, unequal access to opportunities and an unequal distribution of the negative impacts of transport.

The transportation planner must think and resolve how transportation can exclude or make unhappy population sectors, among these there are groups that require special attention, as opposed to those who have access to private transportation by car, which is strongly linked to the level of income, age and gender, therefore, the policy, that is, the principles on which public transport is planned and drawn up, must be profoundly inclusive, that is, it must be such that, when applied, it must ensure that rich and poor They want to use public transport because it is inclusive and efficient, which means that old and young people who are poor can go about their daily activities, of all kinds, which has a direct impact on their happiness and the economy. of the city; while for their part the rich find it valid not to use their private vehicles, since they can get anywhere in the city quickly, comfortably and without negatively impacting the environment (Gehl, 2014).

To assume public transport in all its important social dimension, it is enough to think that families with medium and even high-income incomes must be covered by it, since in a family of four with the availability of two or three vehicles when used by those who should have left first, two or one person is excluded from their right to move if they do not have public transportation available (Delbocs, 2011).

The public transportation fare must be cheap, because transportation becomes a necessity, and those who are excluded due to its high cost lose employment and recreation opportunities and gain in frustration, negatively impacting society as a whole, so This exclusion must be avoided by implementing subsidized transportation for young people, the elderly and the unemployed (Greed, 1999).

The development of cities must be generated in places close to the areas covered by transportation systems (Gehl, 2014).

Finally, to ensure that public transport is social, that is, it is beneficial to the majority of the inhabitants of a city, the urban planner must focus on structuring a model capable of reaching all areas of the city, providing stops that are a maximum of 400 meters (Davies, 2000) from crucial sites of social concentration, with the frequency of passage of a few minutes on each route, with low collection rates as a percentage of the national legal basic salary, but all this must be accompanied by well-equipped streets in terms of paving, sanitation, lighting and security, (Jacobs, 1961) remaining to be resolved the individual will of the people to value public transport as positive, for which the developer must get people to use the public transport service.

A wide range of research has now shown that transport disadvantages can act to limit access to social and economic activities and that this can reduce quality of life and exacerbate social exclusion (Delbocs, 2011).

There were very clear differences in mobility and car dependency between geographic locations. Trips per day and distance trips per day peaked at marginal locations (Delbocs, 2011).

Correlations between transportation disadvantage and well-being were fairly consistent and were higher in the regional sample (and to a lesser extent in the marginal sample). The strongest correlations were between the frequency of difficulty accessing activities and subjective well-being (Delbocs, 2011).

Recent work has suggested that the socially excluded may not report as many transportation problems because they do not go out as much (Delbocs, 2011).

At the end of the 20th century, sociology began to examine gender inequality, generating social awareness of the existing problems between men and women, having a broader understanding of how people live in their habitat (city)
(Greed, 1999).

The existence of gender marginalization in rural society was found, observing that women have a particular difficulty in finding employment and performing activities.
(Greed, 1999)

In many cases, households had only one means of transport and this was used by men, isolating women from life, as if that were not enough, there were no public transport routes (Greed, 1999).

Although the rural environment is not part of the urban environment, the accessibility that exists in the connection between a rural and an urban area can be measured. (Caceres, 1988).

Living for many years is a relatively new phenomenon, which was generated after the Second World War by improving living conditions. The population of developed countries tends to be older, therefore, it is on the way to face a world of old people, generating evident obstacles in urban planning (Greed, 1999).

After retirement there is no generality or homogeneity only due to age, there is a generational difference between each age group, cultural difference and different preferences, so urban planning for these people cannot be addressed as a single vision
(Greed, 1999).

The classic key factors addressed in planning for the elderly are housing, social services, health, and the elderly are kept in their home, receiving what they need there, as if when they reach old age, human beings leave their humanity and cannot leave for the things they require and thus share with other members of society for having become a waste of the city (Greed, 1999).

In general, it is acceptable that cities are built for those who by age are in their productive stage, that places for sports and recreation are provided for the young and athletic, but these sites can be planned so that the old can walk in them and still, sit down to pleasantly observe the course of the lives of the youngest (Greed, 1999).

Elderly people, having less physical abilities than young people, need accessible transportation systems, with stations close to their homes, generating the possibility of living in the city regardless of their advanced age (Greed, 1999).

7.1.4 Urban planning, mathematics and accessibility

The mathematical modeling of urban situations seems to be the best method to plan cities and save money in the attempt using current computing power, which reached the capacity to handle large amounts of data several years ago.

There is a classic problem found in Taha's operations research book (Taha, 2012), chapter 2, subscript 2.4.4 called “Urban development planning”. The problem narrates how a city that faces a budget cut, seeks a solution to improve its tax base with a new housing project, where restrictions on house size, price, street size, costs and, in general, real aspects are proposed. that can only be solved from matrix mathematics.

The interesting thing is that this type of problem can occur in real cities, and the solution is not complex, since it is solved with a linear programming model (matrix equations with equalities). With the current possibility of computing power, it is possible to solve
many similar problems in a matter of seconds.

The arrival of computer science brought the possibility of using mathematics as a tool for the analysis of solutions and urban predictions. Always be attempts to arrive at mathematical simplicity, in order to solve the real complexity, the rule of clarity of Simon and Chase.

Urban mathematical modeling was born in the 1950s, with the hope of giving rigor to urban planning, giving rise to the conviction that urban phenomena have a degree of complexity that can only be addressed from mathematics. The following chart summarizes three modeling systems:

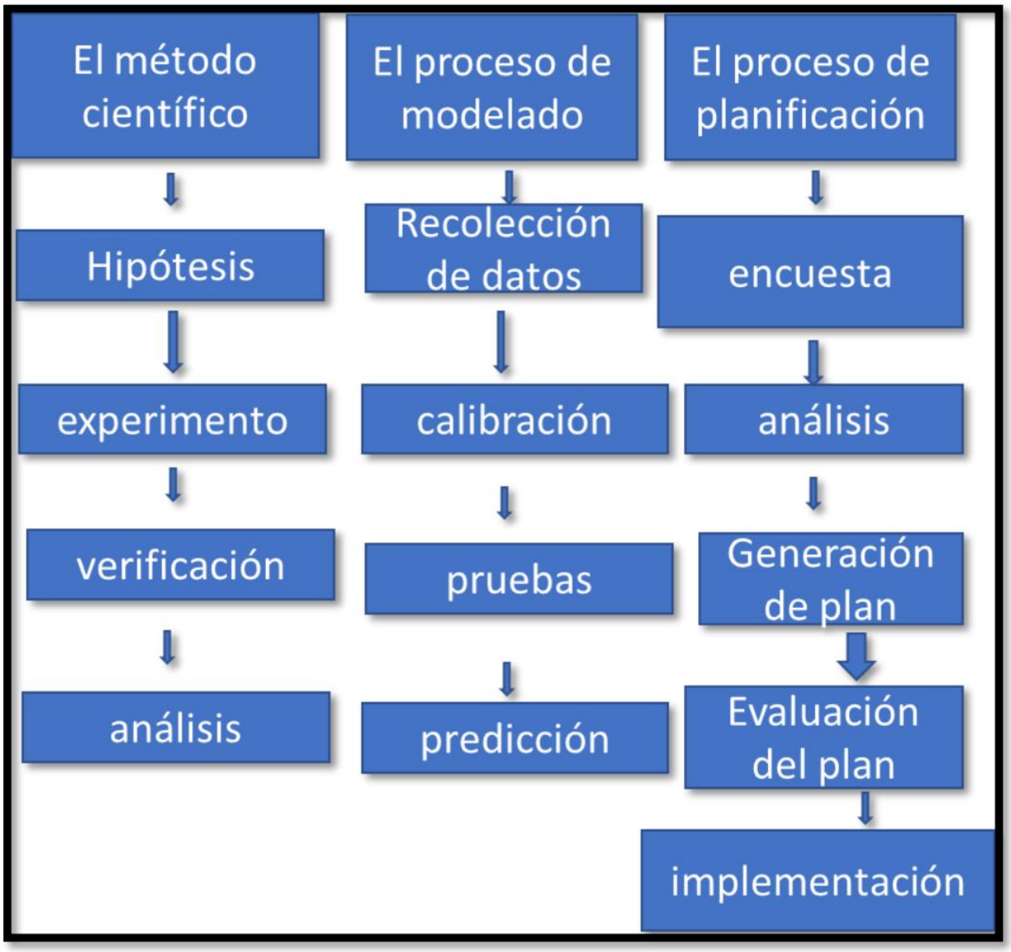


Figure 14 Scheme planning (Leslie Martin, 1976)

Using one of these methods, or another derived from them, it is possible to model a city urbanistically, including all the infrastructure that allows the social and economic interaction of a resident community and those who visit it.

These models are based on the simulation of a single subsystem within the city, such as a specific commercial activity or a residential area, the theories of the models are hand in hand with hypotheses of economic and statistical science. The micro-theoretical approach is more difficult to prove than the macro-theoretical approach, because in the micro, human behavior is more present (Leslie Martin, 1976).

Lowry (1968), poses urban modeling as a mechanism for conflict resolution between different groups who require territory for different purposes, separating the urban system by activities and transactions, always with a macro approach. (transportation, retail, residential, industrial) (Leslie Martin, 1976).

Chapin (1965) analyzes the activities as interactions within the study area, considering each activity as a sum of integration, the space adapts to the activities.

For population estimation, any formula of economic science can be used, a general formula is given here (Leslie Martin, 1976):

(+ 1) = (1 + ÿ +) ( ) = ( )Equation *1 (Leslie Martin, 1976)*

P= population.

t= time.

q= growth factor.

d= mortality rate.

b=birth rate.

m= net migration rate.

It must be understood that urban modeling has several aspects, it is not possible to speak of a single urban model but of the set of different models that can provide a solution to urban planning (Leslie Martin, 1976).

A problem can be modeled in a system of equations as seen in the example cited by (Taha, 2012), thus subregional models of impact on a decision, predictive models, optimization, spatial design, activity models, residential models are available. , urban dynamics, transport dynamics and of course complex dynamic simulations that relate the above.

The economic-based models are simpler, they are seen by the following functions: the population P is expressed as a function of employment E, and the service S is a function of the population, la = , > 1, Equation 4 = + , Equation 6, are economic equations and = , 0 < < 1, Equation 5, relation between basic employment for any closed and defined city system (Leslie Martin, 1976):

= ( )Equation *2*

= ( )Equation *3*

= , *> 1, Equation 4*

= , 0 < < 1, *Equation 5*

= + ,Equation *6*

= – , , = *Equation 7*

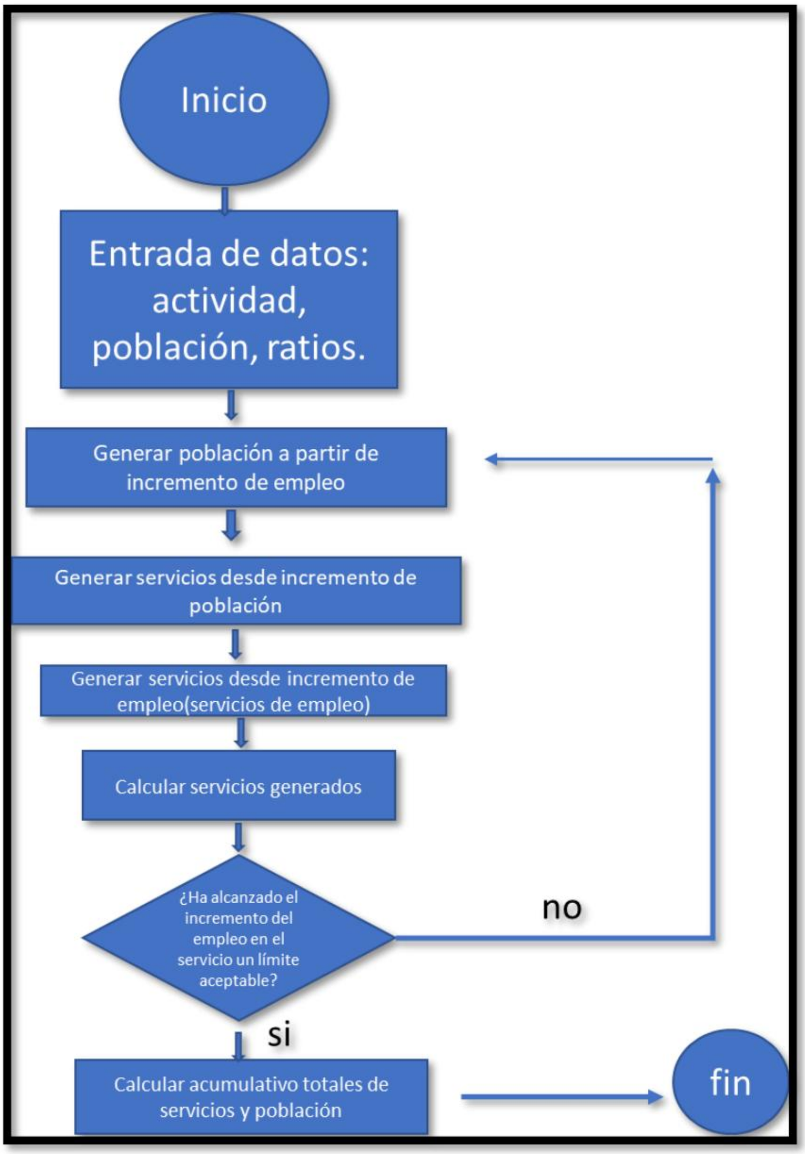


Figure 15 The sequence of operations in the generation of population and services from basic employment. (Leslie Martin, 1976)

Within all the models that can be run to evaluate some aspect of the city, in this work the accessibility models focused on public transport are taken as a basis, because the idea is to achieve cities for walking or, in the words of Gehl, cities for the people:

Some classic models study the different activities in different areas, in the study region (Hamburg and Young 1965), the problem with these models is that they go against each other to the idea of a city for walking, this is based on classifying each activity in order of importance in the daily life of the people of a region, thus generating biunivocal origins and destinations (Leslie Martin, 1976).

The Lowry model organizes the spatial economy into activities and also classifies into land use (employment, services, residential, industrial, etc). The activities are studied and the land is divided into activity ratios, it also classifies the regions in basic employment (exports outside the region) and non-basic employment (only regional), takes into account the population density of each area and tries to ensure that never exceed an urban density threshold (Leslie Martin, 1976).

There is an inherent problem in cities and that is that they grow little by little over time, this generates a problem called "The problem of location attraction", it is very difficult to measure the attraction generated by a place, since modifies over time, the variables in the spatial models can be divided between extensive and intensive, the extensive ones change as the zoning system alters, while the others do not, in theory the attraction measure should only be altered relatively. The normal thing is to make population prediction models, for this work a stable population with the ability to move randomly between the zones of the study area will be assumed (Leslie Martin, 1976).

Transport is transversal to urban planning, people could live in caves and still need to be transported, at the beginning of the history of cities, you had to walk very little, you could go from one end of the city to the other using the feet, over time the cities grew and with this the need to plan the city for public and individual transport was generated to reduce travel times (Leslie Martin, 1976).

There is a mathematical methodology to measure and study a transport network (accessibility indicators) in all its aspects, transport policies directly influence people's lives and the organization of city neighborhoods, transport is then a matter that cannot be left to chance (Leslie Martin, 1976).

Transport should be planned together with land use, thus saving money and always thinking about the impact of any modification of the network. The transport network defines the accessibility that citizens have, the quality of the environment and of course how attractive the city is for investment (Leslie Martin, 1976) (Caceres, 1988) (Kurt W. Bauer, 2010).

7.1.4.1 Topological measures of accessibility

Maximizing accessibility improves current and future individual and collective well-being (Caceres, 1988). Accessibility can be measured in several ways, measuring the distances between a location and other points, measuring the travel time and comparing it with the minimum possible distance, the possibility of a population group to access an area, benefit that people obtain by having access to transportation and other alternatives. accessibility is

“Freedom to decide whether or not to participate in different activities (work, shopping, recreation, etc.) (Caceres, 1988) citing Burns.

Figure 16 shows some ways to measure accessibility.

Figure 16 Accessibility indicators (Caceres, 1988)

Topological measurements are based on graph theory, representing the road network as a mesh, each section of the mesh joins two nodes, a scalar is taken into account that represents distance, time, cost, etc. (Caceres, 1988).

Travel measurements focus on the itinerary and the number of times a moving particle travels in a system (Caceres, 1988).

The aggregate measures take into account the relationship that exists between transport and land use, the nodes of the mesh are considered as a group. On the other hand, the disaggregated ones consider the element that moves in the network (person, car) (Caceres, 1988).

The measures based on public transport are a subset of the disaggregated ones, these are important because they take into account the means of transport of the most vulnerable population (Caceres, 1988).

Accessibility studies are classified into 3 groups: macro accessibility, which studies the entire study region, meso accessibility, a significant part of the total area, and micro accessibility, which goes on an individual scale, studying certain groups (Caceres, 1988).

There is relative accessibility, the degree of connection that two places located in the same territory have, and integral or absolute accessibility, which is the degree of interconnection that a point has with the rest (Caceres, 1988).

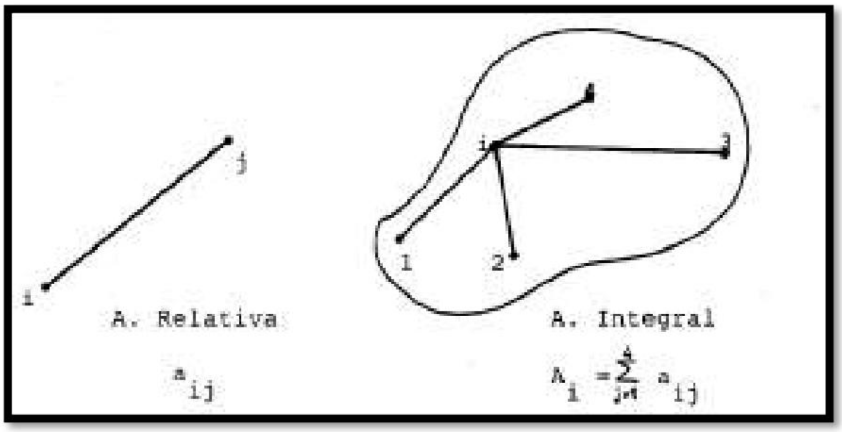


Figure 17 Relative and integral accessibility. (Caceres, 1988)

Topological accessibility measures Shimbel index (IS), path factor (tracing), index of speed ( ) and absolute indicator of global time (Tg).

Shimbel Index (SI):

"The Shimbel index calculates what is the minimum number of paths necessary to , connect a node or stop, with another node of a network or route".- (dajome, 2016) citing (Fernandez Santamaria, 2000.). Ingram in 1971 and Vickerman (1974), generalized the Shimbel model, arguing that the model should be able to show the urban grid as it is, for this it develops a series of formulas based on the general Shimbel equation adding, the factor

$$\frac{1}{(\quad)}. \text{ (Caceres, 1988)}$$

$$IS = ÿ(1)$$

path factor ( )

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

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

Where:

= minimum distance through the communications network between i and j.

0 = geographical or straight line distance from i to j.

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

Adjusted to generalize all routes takes into account the geography of the route.

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

original unadjusted equation does not take into account the geography of the route.

$$= \frac{ÿdij}{ÿdÿij} \qquad (4)$$

= 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) will reflect better performance the closer it is to number 1. The reason why this is very simple, the number 1.5 indicates that the route is only 50% above the perfect standard, it is necessary to remember that the roads are traced over a city and pre-existing topography, so having an ideal indicator of "1", it is just a utopian idea, which is far from reality (Cáceres, 1988).

Absolute indicator of global time ( ).

"This indicator measures the sum of the time it takes to travel each vehicle of the transport system, from each node to all the others, thus, the point with the lowest sum is the best communicated" (dajome, 2016) citing (Izquierdo, 1991).

$$= ÿ \sum_{=1}^{=} \qquad (5)$$

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

n= number of nodes.

Plot index – speed ( ).

“It is a variety of the route factor, the highest values correspond to the most inaccessible areas. It is calculated with the construction of two matrices, one for travel times over the network and another for travel times in a straight line to and from each of the nodes,” (dajome, 2016) citing (Izquierdo, 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 average speed of circulation.

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:

= Plotting indicator of speed of node i..

n = number of nodes in each zone.

Gravity Models:

These models assume that the population behaves under the laws of classical mechanics, then it states that for there to be interaction there must be communication between the areas, each individual exerts the same influence or capacity for interaction, the influence is proportional to the difficulty of communication from its location and a transport friction is generated depending on its distance (Cáceres, 1988).

Pi.Pj " population of areas y and j, respectively.

Dij - distance from node i to j.

$$= \frac{f(Pi, Pj)}{f(Dij)}$$

A population potential can also be associated, measuring the influence of a group of inhabitants on a point in the territory.

Vij = potential created in i by the population of j.

Pi. ,Pj " population of areas y and j, respectively.

Dij - distance from node i to j.

$$= K ÿ (\frac{pj}{\text{I said)}}$$

Accessibility and public transport.

In public transport, not only the influence seen in the topological measurements should be attacked, but also the waiting time, since this is the biggest difference between those who have a private car and those who do not.

$$= ÿ_{1} \frac{\text{hey dj}}{(\,)}$$

Ai = absolute accessibility of node i

Oi = variable that expresses the influence of the origin

Dj = variable that expresses the attraction of the destination

fídij)= variable that reflects the opposition to displacement

The variables are modified according to the type of study to be carried out, for example, it can be traffic, the respective population, the number of trips, also the number of jobs, the number of businesses, etc. (Caceres, 1988).

Table 4 shows accessibility measures in transport, the table has been extracted from the reference (dajome, 2016)

Table 4 Topological measurements table extracted verbatim without modifying the reference (dajome, 2016)

Topological Measurements They are the oldest, are based on graph theory and only consider the transport network in the study area, simplifying it and representing it by a mesh, where each of its sections joins two nodes.				
Index	**Author / Year**	**Description**	**Pro / Con**	**Formulation**
density indicator	Left, R. (1994)	Measures the density of communication infrastructures in an area in km/km2	It allows obtaining information on the availability of road infrastructure in each neighborhood to subsequently generate descriptive maps on the behavior of the network in the territory. / It can have many variations depending on the weighting of roads or services of different categories.	$D = \frac{km\ de\ red}{Área\ zona\ de\ estudio}\ (\frac{km}{km^2})$
density gauge Kansky	Potrykowski M. and Taylor, Z. (1978)	Measure the density using the quantification of the infrastructure endowment and the number of nodes of the graph or study area	It involves the road infrastructure sections of the system in relation to the stops or stations that connect them, allowing visualization of the availability of the entrances that users have to the system. quantify the density numbering the sections in the area without taking into account account their length, allowing more uncertainty in their results.	$\beta = \frac{e}{v}; \gamma = \frac{v}{3(v-2)}; \alpha = \frac{e-v}{2v-5}$ Donde: β, γ, α= Indicadores de densidad e= Numero de arcos o tramos de la red v= Numero de nodos

Absolute indicator of global time	Sarmiento, I., Munoz, J. and Angel, C. (2000)	(neighborhoods) of the network from a road.	allows visualize the speed with which users can move from a specific neighborhood to all the territory taking in Measures the sum of displacement times nodes counts the length of the dot to all others. It tends to favor points located towards the center of a network by its geographical location.	$T_i = \sum_{j=i}^{n} t_{ij}$ Donde: t_{ij} = Tiempo mínimo de recorrido de i a j utilizando la red
Factor of route	Left, R. (1994)	Measures the quality of the layout, that is, its degree of approximation to the straight line	Since the straight line is the better path of connection between two points, the road network can be weighted based on this characteristic. / When having routes with the same start and finish point, other conditions must be taken into account in order to use it.	$r_{ij} = \frac{\sum_{j=1}^{n} d_{ij}}{\sum_{j=1}^{n} d^0_{ij}}$ Donde: r_{ij} = Factor de ruta entre los puntos i y j; d_{ij} = Mínima distancia por la red de comunicaciones entre i y j; d^0_{ij} = Distancia geográfica o en línea recta de i a j
Trace rate and speed	Left, R. (1994)	based on the map of the route factor, territory. where of the factor represent the route, it is also necessary curves conditions of use for isochronous the paths with and arrival. I know	The results thrown by the isochronous curves allow a better view of the condition of the road network of the system thanks to the fact that the generated graph is their / results Being a variant to graphically vary the using the same point of departure	$Itv_i = \frac{\sum_{j=1}^{j=n} t_{ij}}{\sum_{j=1}^{j=n} t^0_{ij}}$ Donde: t_{ij} = Tiempo mínimo de recorrido de i a j utilizando la red; t^0_{ij} = tiempo ficticio que se tardaría en recorre la distancia i-j a la velocidad media

Added Measures:
They are based on the interrelationship between transportation and land use, they provide joint information on a group of nodes in the road network, and their relationship with others.

Index	Author / Year	Description	Pro / Con	Formulation
severity indicator	Left, R. (1994)	It includes the number of inhabitants of each node, and is restricted with an impedance value, which is defined as the difficulty of move from iaj	It includes a social type variable, which is the number of inhabitants in each node (neighborhood), allowing analysis that includes the population census and its social stratum based on the indicator. / The displacement impedance must be defined, which can vary according to the criteria with which it is done, generating uncertainty in the result.	$$a_{ij} = \frac{P_j}{e^{\beta d_{ij}}}, \forall_i \neq j$$ Donde: P_j= Población del nodo de destino β= Impedancia entre *i* y *j* d_{ij}= Distancia en km entre los nodos *i* y *j*
indicator Hansen	Hansen, W.G. (1959)	Evaluate the attraction of the population for an area, considering the number of areas areas with ... It does not take into account ... accessibility zone with study ... between the node and areas	It allows to see the possible displacements of the inhabitants of a node (neighborhood) taking into account the development for development and of the conditions infrastructure availability of displacement ... the development area.	$$A_i = \sum_{j=1}^{n} t_{ij}$$ $$A_{ij} = \frac{E_j}{d^{b}_{ij}}$$ Donde: A_i = Nivel de accesibilidad de la zona *i* respecto a la zona *j* E_j = Total de empleos en la zona d_{ij} = Distancia entre las zonas *i* y *j* n = Número de zonas del área de estudio *b* = Parámetro de calibración

indicator Hirshman Y Henderson	Barcellos, V., Goncalves, A., Lopes, F. (2000)	Measure weights with respect to growth population of an entire region and depending on the accessibility of a subregion compared to the region from which it is divided	Separate and give weight to accessibility each of subregion (neighborhood) of the territory when analyzing the behavior of population growth of the entire territory (Cali). / Due to social inequality in the territory, the growth rate population can vary in areas of the territory, generating uncertainty when giving a weight to the accessibility of each node (neighborhood) with respect to the growth rate of the entire territory (Cali)	$G_j = G_t \frac{L_j * A_j}{\sum_{i=1}^{n} L_j * A_j}$ Donde: G_j = Incremento de crecimiento de la población asignada en la subregión j G_t = Crecimiento total proyectado para la subregión j A_j = Accesibilidad entre la subregión i y la subregión j
Public transport provision index (IPTP)	Jaramillo et al (2012)	It quantifies the the amount of public transport in an area, and uses infrastructure variables who qualify access to the service	It is directly related to the road infrastructure, stations and stops found in each neighborhood allowing analyze the accessibility of the users to the system.	$A-IPTP_j = \frac{1}{A_j}\sum_{i=1}^{n} S_{ij} W_{ci} W_{fi}$ Donde: $W_{ci} = C_i / C_{min}$ $W_{fi} = f_i / f_{min}$ n= # de servicios de transporte publico S_{ij}= # de paradas para el servicio i en j W_{ci}= factor de peso de capacidad de i W_{fi}= factor de peso para frecuencia de j A_j= área del distrito j P_j= población del distrito j

7.1.5 Transport in the healthy city

The use of public transport must become an option as good as private car transport, the difficulty lies in the fact that there are already years of urban planning focused on this option and also the public transport system in many, perhaps the Most cities in the world do not enjoy the best perception, due to their multiple failures (Ramirez Cajigas, 2018).

To start or reorganize a public transport system, there are some important questions that the urban planner must ask, and by obtaining assertive answers, you will be able to achieve optimal results within the restrictions imposed by reality: all the questions are obtained from various authors (urban desing compendium, 2000) (Davies, 2000) (Kurt W. Bauer, 2010) (Gehl, 2014).

- How wide is the sidewalk?
- What is the flow of people between areas on each day of the week?

- What is the most suitable public transport system for the city based on the geological condition of the land where it is built and the existing building system in it?

- What is the territorial extension of the city?
- What are the main streets that lead to the places of greatest concentration Social?
- What are the key places where social concentrations are generated?
- How many neighborhoods make up each area?
- Is the width of the streets sufficient to separate lanes exclusively for public transport?

- Does the pedestrian have to wait long to cross the streets?
- In how many areas is the city subdivided?
- Is the material from which the pavement is made comfortable?
- Are there guide signs?
- Is there visibility?
- Is the street mixed use?
- Does the city's infrastructure allow the organization of public transport stops within a radius of 400 meters based on the key places of origin and arrival of passengers?

- Do existing routes connect origins and destinations?
- Are the routes labyrinthine?
- How accessible are the streets to public transport vehicles?

- Is there space available in front of houses and buildings, that is, in the streets, to support the installation of small businesses that encourage the concentration and socialization of people?
- Clean public environment.
- Cars parked in a place other than the bicycle lane, clearly demarcate the spaces for cars.
- Streets with between 500 and 1000 vehicles per hour, require the pedestrian to wait a while to cross the street.
- Streets with more than a thousand vehicles per hour require assistance so that the pedestrian can crossing.
- Streets of 30 kilometers per hour if it is a vehicular street.
- Streets where people can be seen by other citizens.
- Lanes defined if the speed is greater than 30 kilometers per hour.
- Densities of 80 people per hectare, will attract up to 2000 people per stop, this number increases as the density rises.
- Bicycle storage should be included in public building policy.
- The bus should have priority at intersections and turns.
- The bus is successful if the necessary density exists within a radius of 400 meters or 5 minutes walk.

- The path should lead where people want to go, modifying the path if necessary.
  street geometry
- Eliminate pedestrian barriers.
- It is inefficient to have incomplete sections for cyclists.
- Streets with up to 500 vehicles per hour (in two directions) offer pedestrians
  opportunity to pass the street.

Notwithstanding the emphasis of this work on taking mass transit as the axis of approaches when considering public transport systems, the following table (Table 5) presents the "catchment areas for public transport" encompassing several alternative systems, as appropriate. action by the developer: (Davies, 2000)

- To get people to walk in the city.
- To promote the use of bicycles.
- To promote and achieve the use of the bus, the following must be considered:
- Bicycle parking spaces in the city encourage their use.
- Narrow radii at crossroads, spend the minimum amount of time possible in the car lanes.
- Slowing down traffic increases the feeling of safety.
- Lanes are recommended for cyclist use from 1.5 to 1.75 meters, since on many occasions the user is accompanied by their small children, who go by their side.
- Stops are recommended at intervals of 200 meters to 300 meters on buses See
  Table 5

Table 5 Public transport catchment areas, this table shows a recommendation to take into account when designing collective public transport systems, however, the service area used in this work is 400 meters and not 800 meters source: (Davis, 2000)

Catchment areas for public transport					
Transportation	minibus	buses	guided bus	Train light	train
interval of stop	200m	200m	300m	600m	1,000m+
of service area	800m	800m	800m	1,000m	2,000m+
Catchment people per stop	320 - 640	480 to 1760	1680 to 3120	4800 to 9000	24000

In front of private cars and their parking should be considered when urbanizing (urban desing compendium, 2000) (Davies, 2000) (Kurt W. Bauer, 2010) (Gehl, 2014) :

- Car parking cannot be allowed to dominate the urban landscape.
- Keep the number of public parking lots low, so that people prefer to use public transport.

- It is recommended to have only one car space per household.
- Community parking spaces.
- The parking lots should preferably go under the streets and locations, it should be avoided to have cars in front of the facade, as it makes pedestrian and cyclist passage uncomfortable.
- Parking space may be available at the rear of the building if underground parking is not possible.
- The layout must be logical to the driver. •

Avoid leftover spaces.

7.1.6 Mass public transport and the environment

The anthropogenic contamination of the environment is a reality, it is generating a legitimate concern worldwide, due to the problems for health and general well-being that it entails (Arup Group, 2016).

The vehicle fleet in cities today is made up almost entirely of combustion cars, which in turn release gases such as Co2 (Figure 18), Nox, Co, lead residues, sulfur dioxide, among others. particulate matter.

A consistent way to combat polluting emissions in cities is to eliminate their source, automobiles, although it is not feasible to expropriate them from their owners, it does seem to be a good option to design cities designed so that the user in as many cases as possible , choose to make their short trips on foot, by bicycle and on an electric skateboard and in addition to this, they should have mass public transport systems for long, accessible, fast and efficient trips. That generate a decrease in private traffic (Arup Group, 2016).

Shifting the focus from a city for cars to a city for people, urban and transportation planning can mitigate impacts and foster environmentally and economically sustainable development. Instead of the efficiency of roads, parking, and pollution, cities now strive for activity, nature, and vibrancy. Adapted to Spanish from (Arup Group, 2016).

Figure 18 CO2 emissions from transportation (% of total fuel combustion) (World Bank, 2021)

It is estimated that there are at least one billion people exposed to urban air pollution per year, it is estimated that the medical cost and repair of facades will be 2% of GDP in developed countries and 5% for underdeveloped ones and also that at least 90% of air pollution in cities is caused by combustion cars (Arup Group, 2016).

There is a history of improving air quality in pedestrianized streets in cities such as Istanbul where a 32% reduction of NO2 was found in these streets and in some campaigns such as the day without traffic carried out in Paris, 40% less than nitrogen dioxide (Arup Group, 2016).

8 Design and development of software to measure topological and spatial accessibility

The master's degree in transport, territory and urbanism has as a fundamental requirement to propose an improvement in some front of the study area by the student in the final master's project, in that horizon, the first intention with this work was to make a comparative analysis of the urban organization of some cities in order to derive a city organization model, but when collecting information, studying it and observing the mobility situation in different cities on the internet, it was decided that it could be a better contribution to propose specialized software so that the urban planner can plan urban mobility based on measurements of the level of accessibility of city areas for those who move in them using public transport and on foot. This section presents the results achieved for this purpose. The Dgis software has had the following creative process Figure 19.

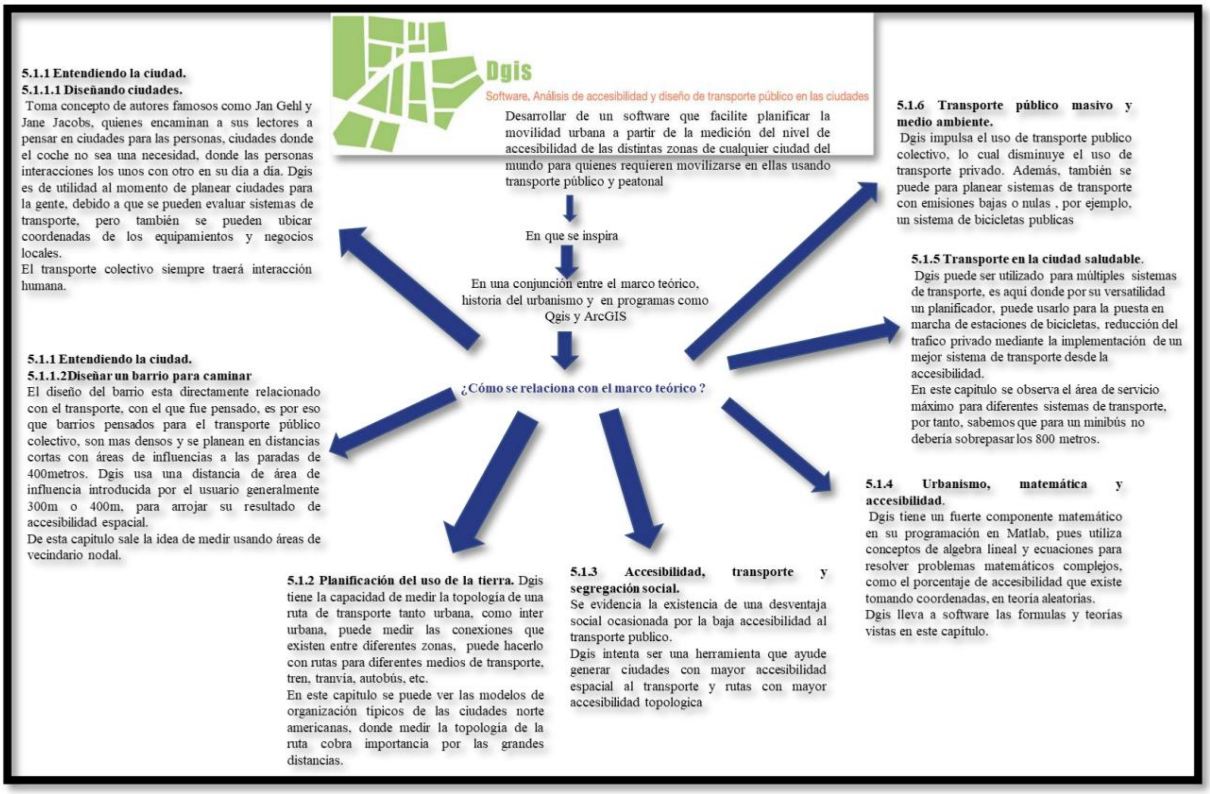


Figure 19 Dgis creative process

Cities are dynamic because people move in them in order to satisfy their interests, and the desires and ambitions of living people never stop, so cities, even if they are already built, are continually modified, on the surface or underground. , all aimed at people reaching their legitimate goals by moving around in them in the most agile way possible, which means making cities more accessible to people, which can be achieved if urban planners can do their job by measuring that accessibility using a software, point of arrival of the present work.

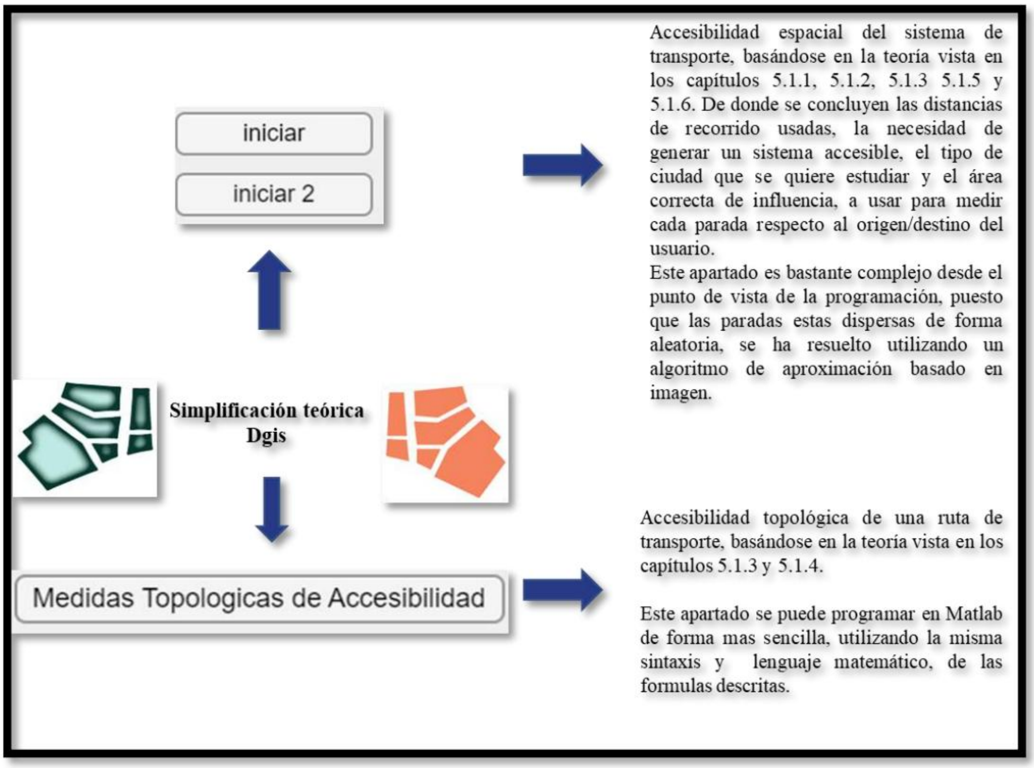


Figure 20 Dgis theoretical simplification

At first, it was valued not to make independent software, but rather to create a tool in Python that ran using computational tools such as: Qgis, arcgis, autocad in conjunction with Google Earth, however, weighing the need for urban planners to plan in the said task in a more specific way, but having the overall vision, it was defined that a program focused on fulfilling the indicated purpose was needed:

Design software capable of facilitating urban mobility planning based on measurement of the level of accessibility of the different areas in each city of the world for those who need to move around them using public transport and on foot, a broad theoretical framework on transport, accessibility and the city was investigated, whose concepts were used in transport and can be seen in Figure 20.

The program should be able to provide truthful and easy-to-interpret information for the urban planner, since urban planning is not only planned by engineers with mathematical training, but also by topographers, geographers, architects, sociologists and even journalists, as is the case by Jane Jacobs. Having this clear, the task is to create a program capable of being used in any development office, in any classroom and even presentable on the Internet.

The scheme of the program can be seen in Figure 21, its code in annex 1 at the end of this document and its programming guidelines followed were these:

- The results of the program must be output in an already generalized format to avoid compatibility problems, which is why the xlxs (Excel) format is used.
- The results cannot have visible mathematical formulas that complicate the use of these.
- The results must be modifiable.
- The results must be obtained from global, free, easily accessible data. Data that can be obtained without the need to request them from the urban development agencies in the city.
- The input data must be in an easy and commonly used format, in this way SHP data is not needed as in Qgis, but simple coordinate data (numbers) would suffice.
- The parameters of the program must be modifiable, since urban regulations change worldwide.
- Obtaining the coordinate points of the program should be able to be obtained from free, public or private sources. Even so, the coordinate points for the development of this work will be taken from OpenStreetMap, since the data that is on that platform is free and freely usable.

8.1.1 Program structure

The usefulness of the program is centered on the objective of making it easier for the urban planner to establish travel routes by public transport and on foot that make cities more accessible to people, since naturally the streets of the cities and everything that they are endowed with are for the benefit of the people and that endowment makes sense as long as it is used by the people.

In this perspective, the public transport service must have routes in each area of the city that allow users to reach key sites such as museums, educational and recreation centers, private companies and official institutions, leaving the pedestrian within a radius of 300 meters. 400 meters away, which must also be fulfilled in the initial place that originates the user's displacement, that is, from his residence.

The data required by a program that fulfills this task can be seen simplified in Figure 21 and are roughly:

Input information:

- Geospatial coordinates of the points to be evaluated (stops, stations, businesses, institutions, etc.)
- Coordinates of the ends of the area to be evaluated.
- Area of influence from each specified coordinate to be evaluated. For this work, 400 meters is used, but you could put whatever is necessary in meters.
- Lower and upper limit, of separation between coordinates to be evaluated, if required by the researcher.

- Public or private database file in Excel xlsx format.
- Map of the place studied in OpenStreetMap format for public access.
- If you want to measure an existing or planned route, using topological indicators, you must enter the average speed in the program, an xlsx file of coordinates and another with the matrix of distances along the route, which is done simply by measuring the distance of route route between each stop.

Output information:

- Allows you to set existing stops between the lower and upper limit.
- It allows knowing the distance between stops to decide to remove the very close ones, changing them where they are more useful depending on the key sites that need to be covered.
- Results in the corresponding menu, in a window where you can see a graphical representation of the data and buffers, representing the area of influence reached in white, and the area not reached in black.
- A file named results.xlsx containing the results to be analyzed by the urban planner.
- Allows you to find coordinates, which it outputs in a .xlsx file.
- Allows visualization of the study map.
- It allows to measure routes through the meter of topological measures of accessibility. (For this, the user must know the transport route to be evaluated and its nodes.), the results are given in an .xlsx file.
- Useful matrices to analyze path, make path comparisons, modify nodes and evaluate their performance.
- Time travel.

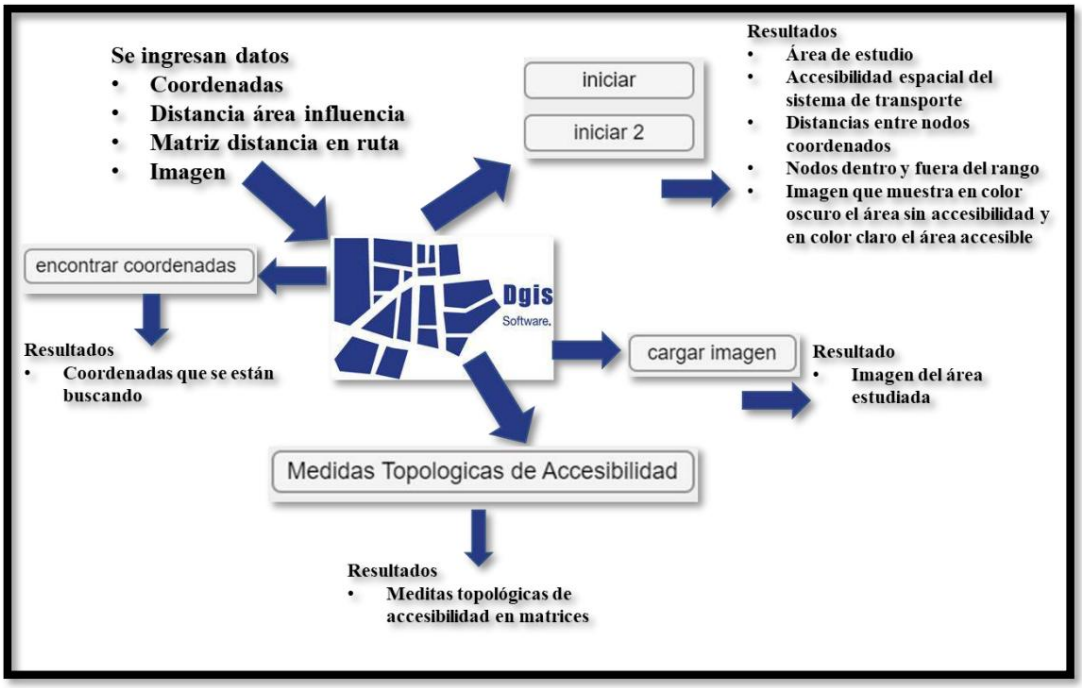


Figure 21 Simplified diagram of the operation of Dgis

8.1.2 Instructions for use of the software

Next, the reader finds the obligatory tutorial, which facilitates the correct use of the program, by indicating the data that must be supplied, the data that it throws and the interpretation or analysis of these, taking as an example a random sector of the city of Santiago de Cali, in Valle del Cauca, Colombia, to demonstrate its applicability in any city on the planet with easy and free availability of the basic information available generically on the web in administratively organized cities:

Installer program download link, copy and paste the link into the address bar of your preferred web browser:

Link for operating system **Mac OSx 10.14** =

https://drive.google.com/file/d/1EQLW9KBiO0rTNM56npzMevAqlctIihOW/view?usp=sharing

Link for **Windows 10** OS = https://drive.google.com/file/d/1m-U1b_e QoXIKg9_gBeMqmA6qkj1WqUs/view?usp=sharing

1. Double-click on the file named Dgis Figure 22 First you must double-click
   Click on the program icon.

Figure 22 First you must double click on the program icon for its installation

2. Once the program starts on your computer you will see something like Figure 23 ·

Figure 23 Screenshot of the start window of the Dgis program

3. Now coordinate data must be obtained, for this example, the OpenStreetMap database will be used, since it is free to use.
4. Go to the web address https://www.openstreetmap.org/.
5. Select the export button, then click manually select Figure 24 capture.

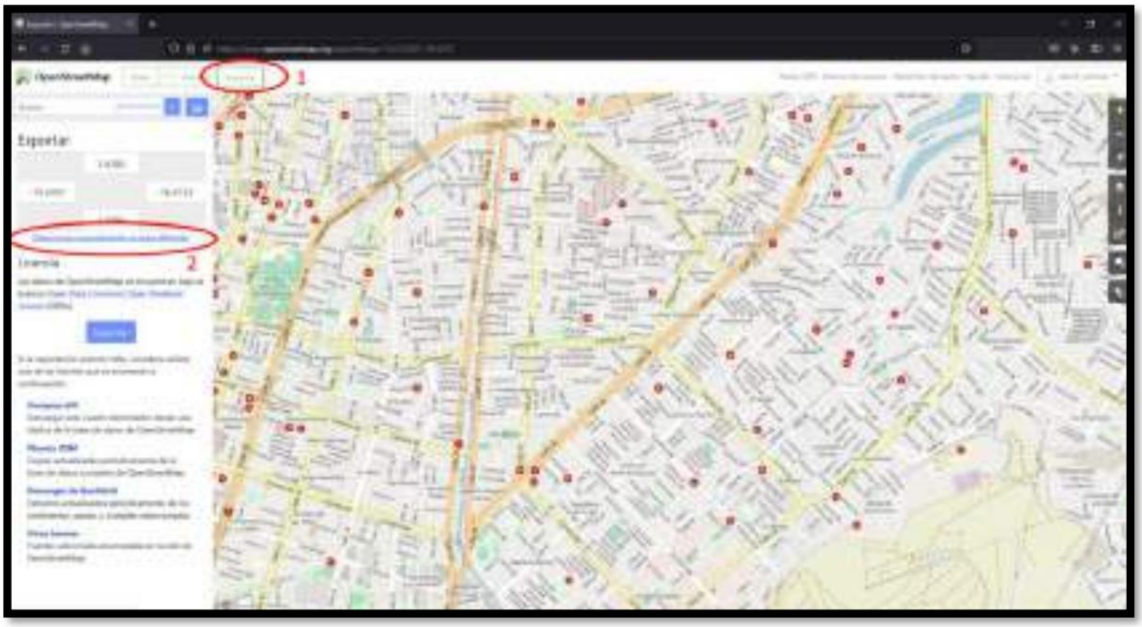


Figure 24 screenshot showing an example of a map seen in the openstreetmap viewer

6. The area to be studied is chosen and the database file is downloaded by clicking on export and an image file as seen in Figure 25 .

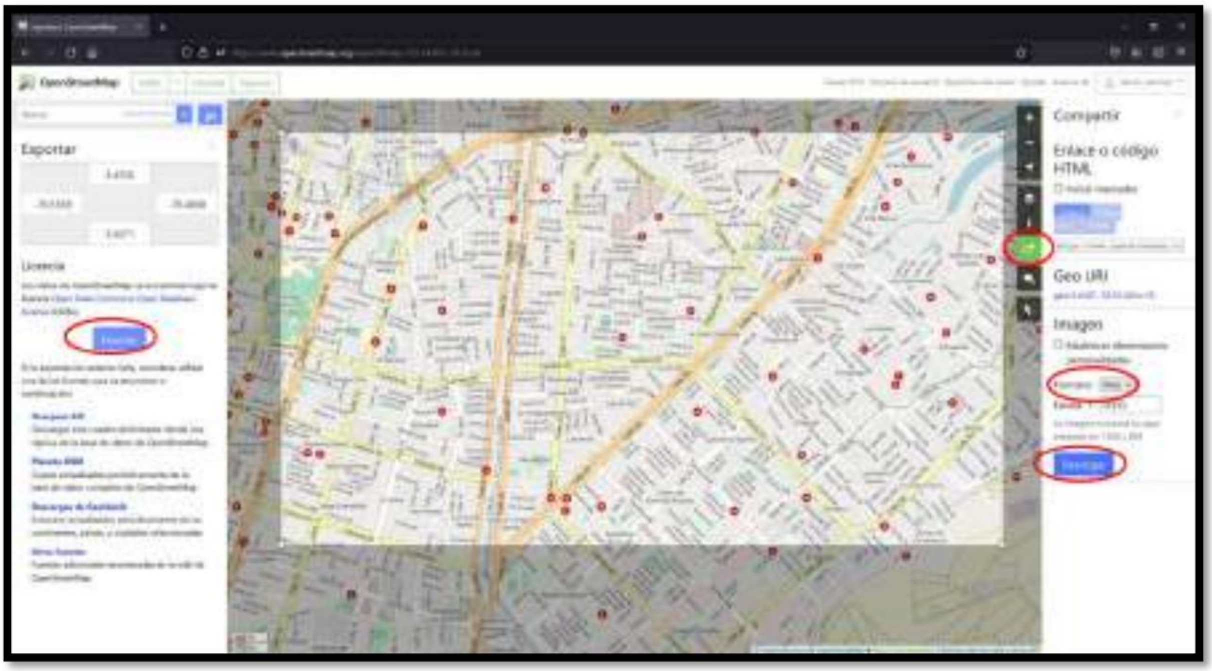


Figure 25 instructions for use within the Openstreetmap page

7. It is very important that you save the coordinate information of the image crop, which is located in the upper left corner Figure 26 .

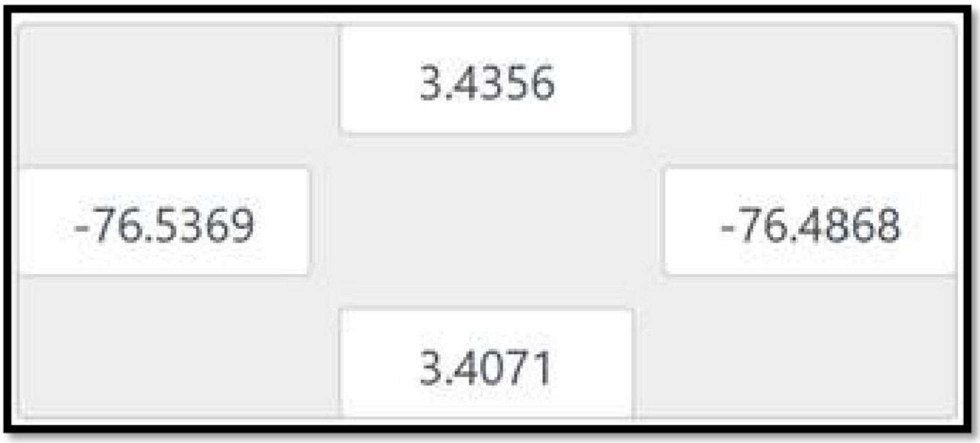


Figure 26 Coordinates to take into account, these numbers must be entered in the Dgis program window

8. You will obtain two files, one with an .osm extension and the other with a .png extension, you can rename these files as you wish as long as you respect the extension, do not use spaces and make use of letters or numbers contained within the English alphabet, that is say do not use accents, umlauts, quotation marks, apostrophes, matches or special letters such as Ñ.

9. Now enter the downloads folder and proceed to open the file with the .osm extension with Excel, Libre office Calc, Open Office, Google Sheets, numbers or any other spreadsheet program, in this example it will be explained how to use the Excel because, despite being paid, it is an application that many people are familiar with.

10. Right click on the File, Archive. osm that I downloaded from https://www.openstreetmap.org/, remember that you can rename the file as you like with English characters and no space, choose to open with your favorite spreadsheet program; Excel Figure 27 is used for this example.

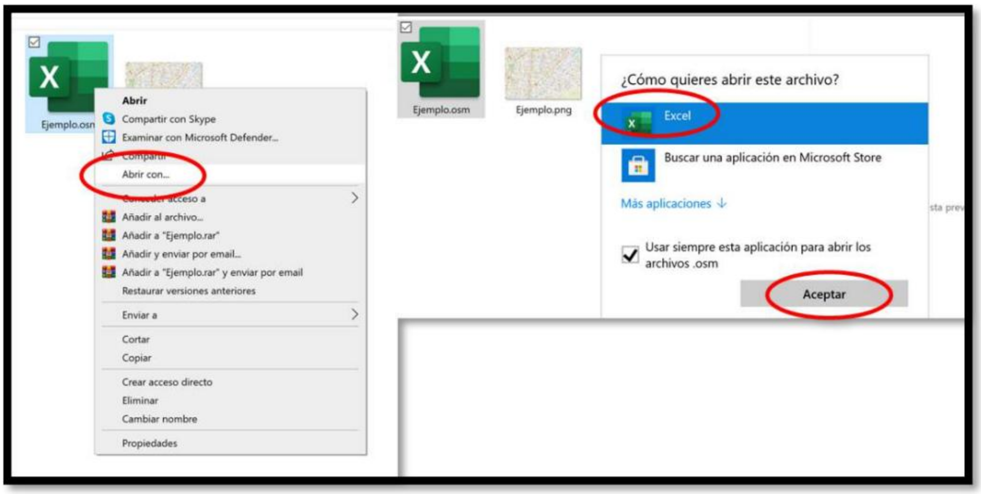


Figure 27 How to correctly open the osm file downloaded from the openstreetmap website

11. When opening with the spreadsheet program, have it take the data as a table XML, and it is accepted. Figure 28 ·

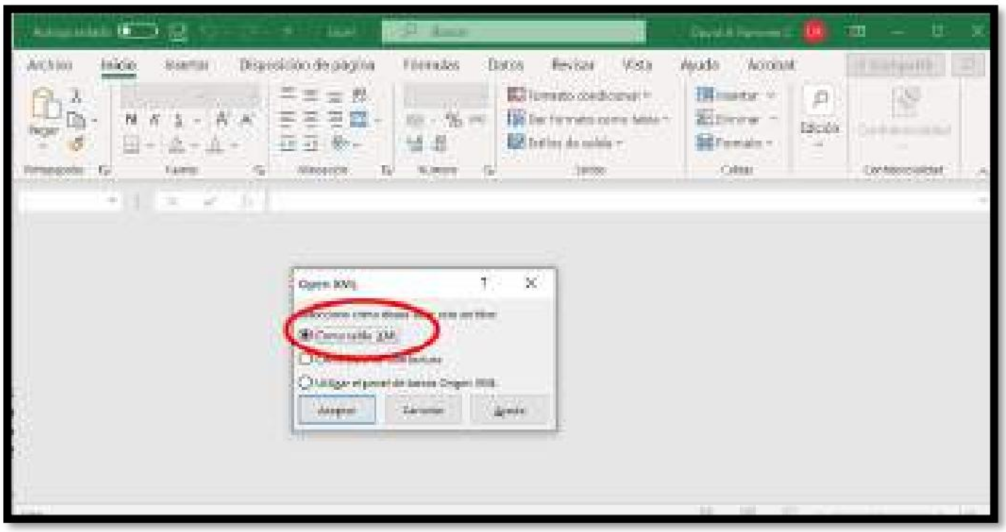


Figure 28 The document must be opened as an XML table

12. Once the program opens, you will see that there are several columns, each one with a title, the column that is named with: “v” (corresponds to the name), “lon” (corresponds to the length), “lat” (corresponds to the altitude), once these columns have been identified, the filter is used to extract all the data that is needed. For this example, in the city of Cali, the public transport stations and stops are needed. Public transport stops have a name that begins with the word "MIO", so the user is located in the name column "v" and there selects the filter "MIO". Figure 29 .

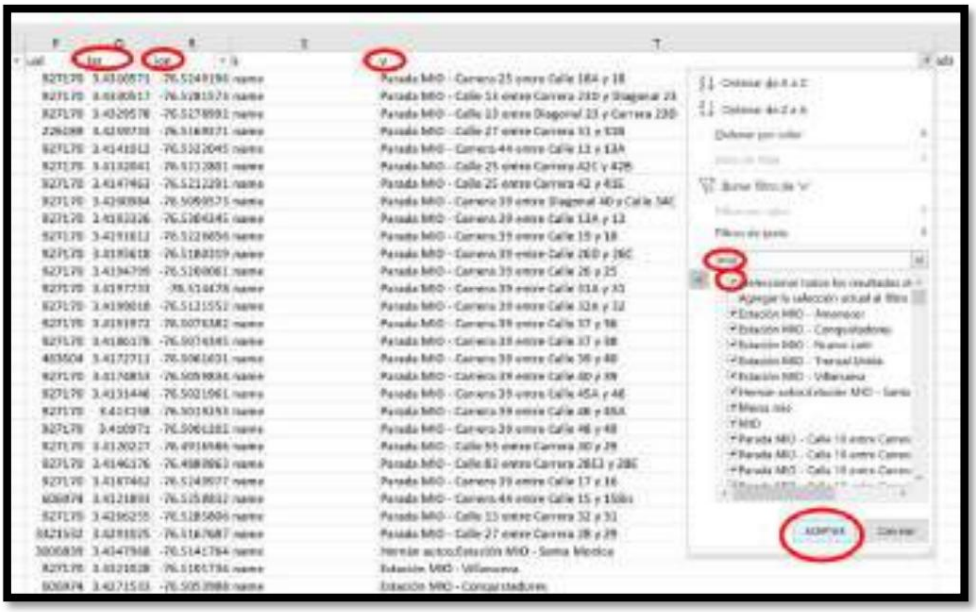


Figure 29 Use of the filter in the spreadsheet program

13. Now it is simply transferred by copying and pasting the column named "v", "lon" and "lat", to a spreadsheet document and saves it as an .xlsx extension, it is important not to put accents, spaces, umlauts, apostrophes or non-English language symbols. Figure 30
.

This document is important because it is the document from which the program will take the necessary data to return the results, in fact, you will be able to put new coordinates for existing points or future points from points of longitude and latitude that you can obtain from topographic stations, from Google maps, google erath, bing maps, OpenStreetMaps or any other coordinate provider.

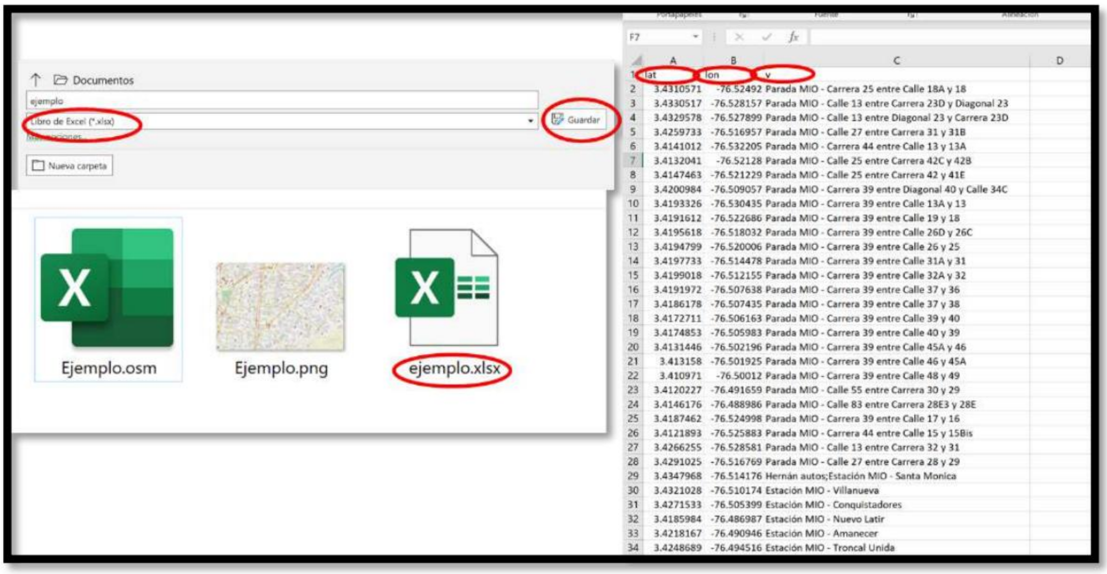


Figure 30 Format in which the filtered data should be saved

14. Now the program must be started, once it has finished loading, some data must be entered for its operation, which are the longitude and latitude coordinates that were obtained from the openstreetmap and can be seen in Figure 26 , you must also enter the size of the buffer to be measured in meters in addition to the limit lower and upper limit that denotes the range to be evaluated between stops, the range is important to eliminate stops that are very close to each other, then the evaluation of the program is shortened, however the program can be set to evaluate between 1 meter and 400 meters following the example described. Figure 31.

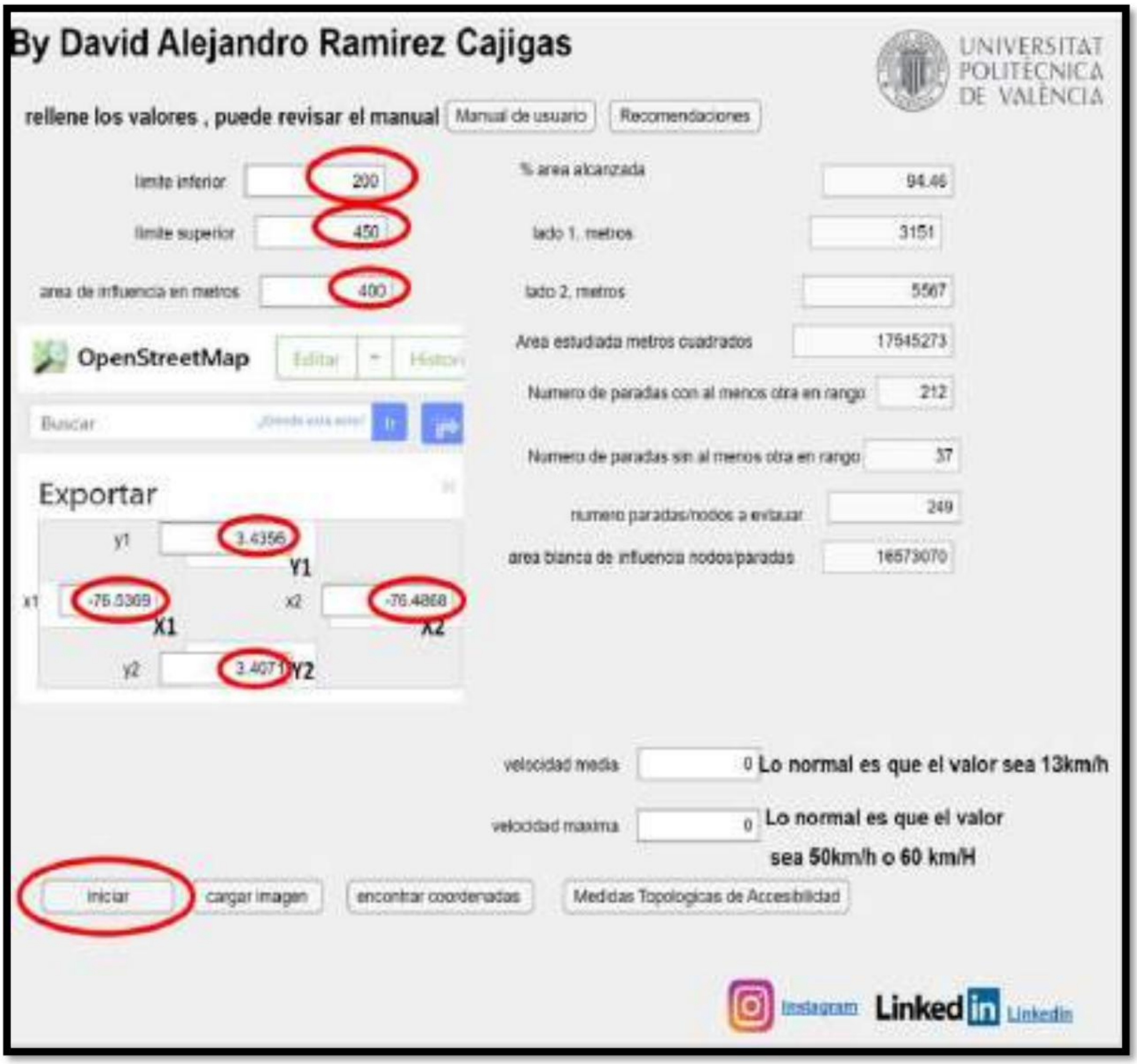


Figure 31 Where to enter the input data to the program?

15. Now you should click on the "start" button, once clicked the program will ask you to choose the .xlsx file that was generated in point 13, select the file and click on open, then you simply have to wait for the program to run. Figure 32.

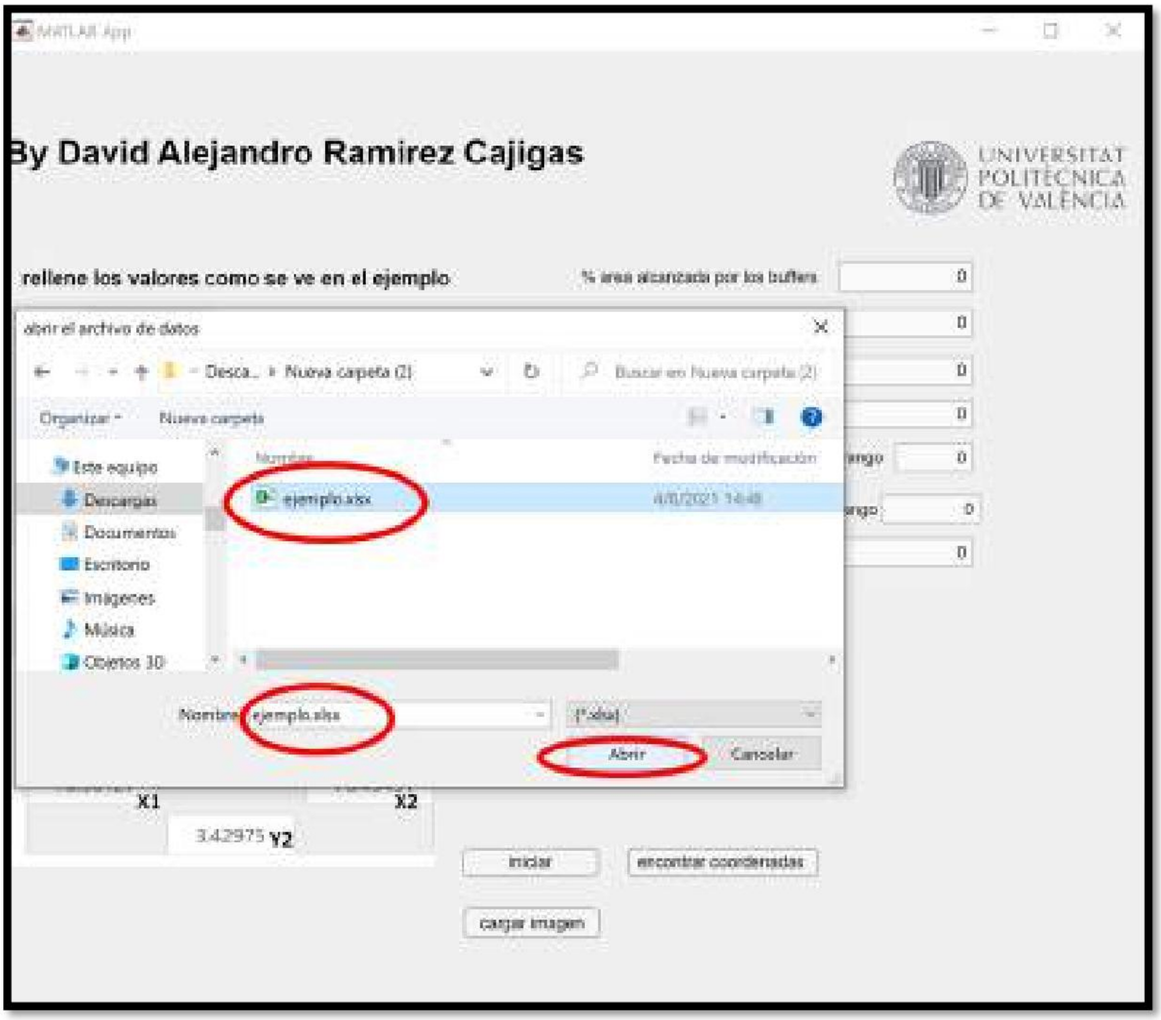


Figure 32 How to add the database that has been filtered

16. Now the program will process the information and display the results in the corresponding menu, in a window where you can see a graphical representation of the data and buffers, representing the area of influence reached in black, and in target, the not reached, and, finally, it will throw a file with the name results.xlsx in which the results to be analyzed by the urban planner are contained. Figure 33

Figure 33 Results obtained when executing the program shows on the left the numerical results as a summary, and on the right, the graphic scheme of the area that the collective public transport reaches, in white the area that was reached and in black the one that was not, in blue the limit of the studied area

17. The file results.xlsx shows information that can be seen in Figure 34

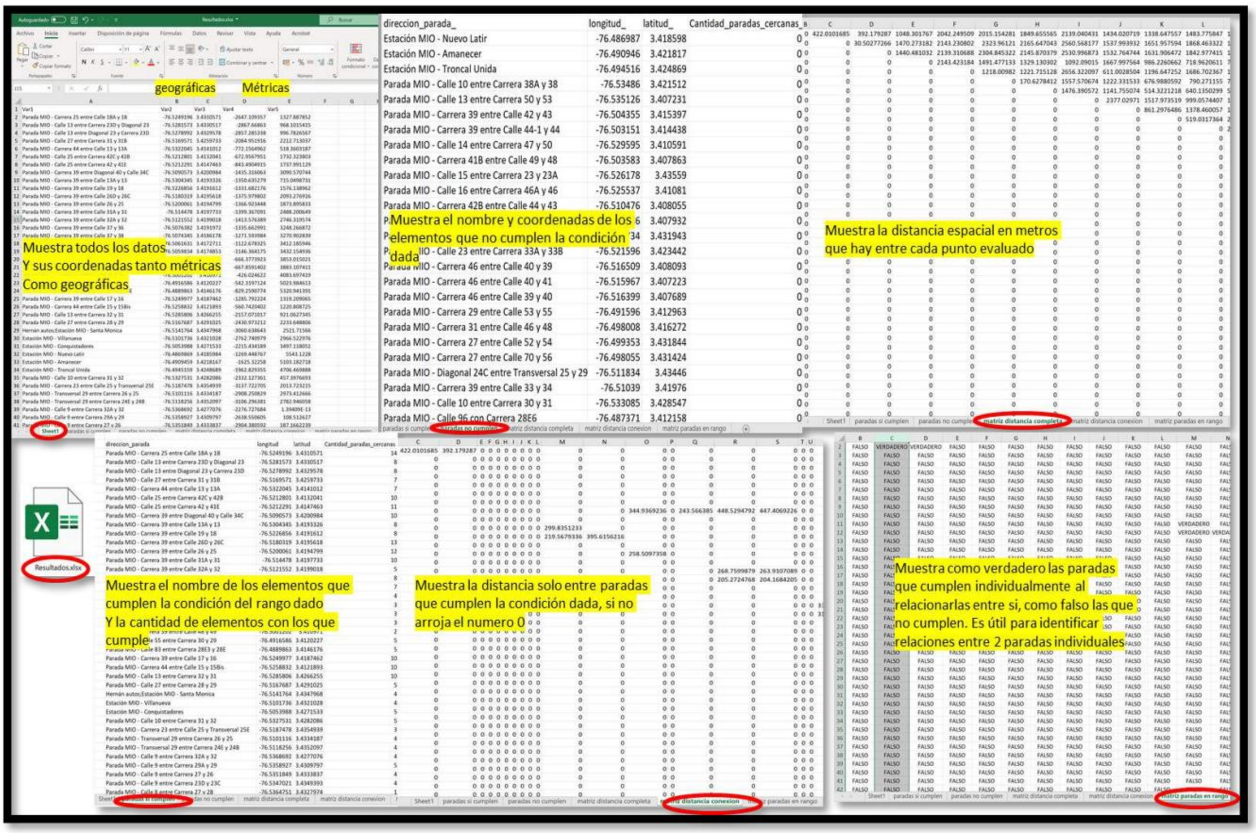


Figure 34 Specific results in xlsx format are generated by the program

18. The file generated in point 13, the data entry file can be modified at the user's whim by removing or adding coordinates and points according to the study that must be done, these coordinates could be obtained in various ways as seen above, even so, the program brings a function to find points automatically, the button is called "Find Coordinates". By clicking on this button, a window will be displayed where the program asks for the file. osm and the .NPG file that was downloaded in point 6. See Figure 35

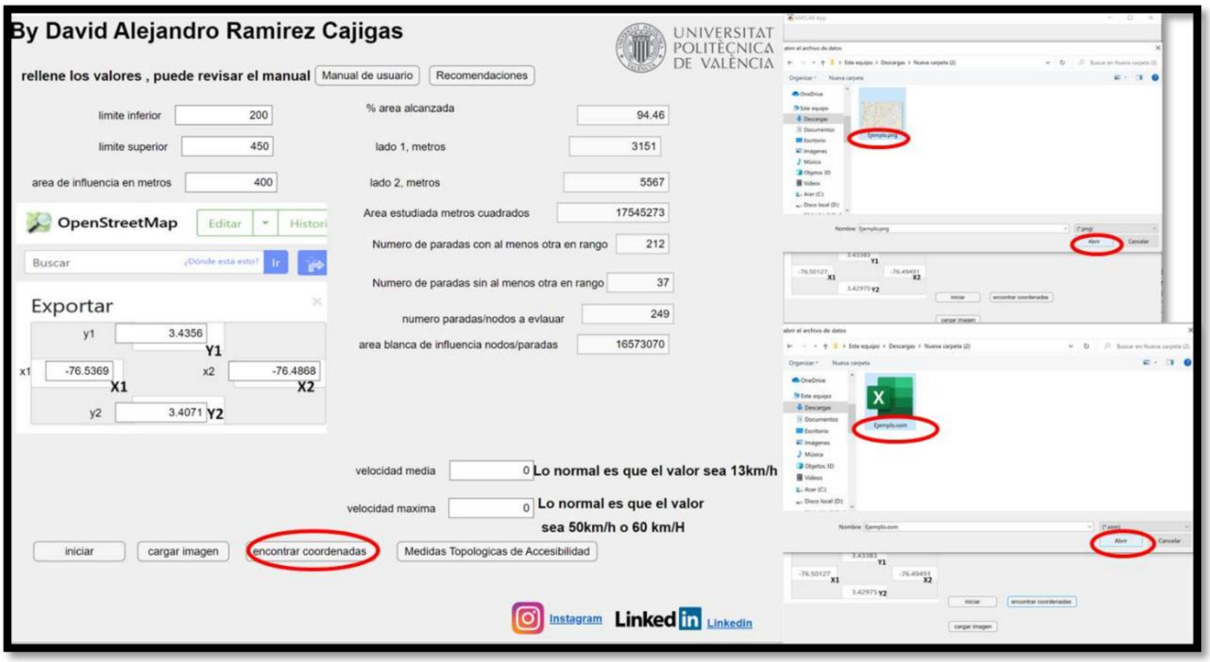


Figure 35 Correct use of the find coordinates button

19. The program will process (this takes time according to the size of the file) the information and will display a map with a pointer. Where the user clicks with the pointer will save a coordinate, when you finish taking the necessary number of points, just close the window and a file will be automatically generated with the coordinates taken, these coordinates can be saved to be evaluated as those obtained in point 13. See Figure 36

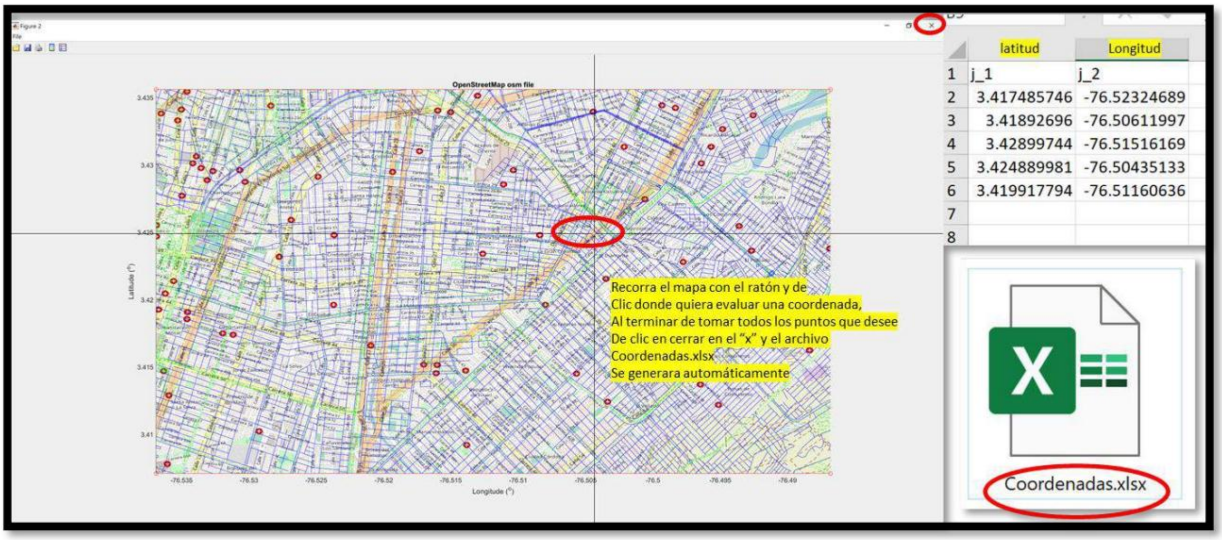


Figure 36 Finding coordinates with the program, capture of its execution

20. There is a button where you can view the study map, the same data from point 18 must be loaded, but first clicking on the "load image" button see Figure 37 .

Figure 37 Using the Upload Image Button

21. The accessibility topological measurement meter has been implemented to measure routes, for this the user must know the transport route to be evaluated and its nodes.

22. The average speed with which the system to be evaluated moves along the route must be entered. In general, this speed does not exceed 15km/h, but this can vary and must be entered by the researcher or user of the program.
23. You can measure an urban or interurban route, the minimum number of nodes must be 2 (origin and destination), there is no node limit, however, the researcher can eliminate repetitive nodes or nodes that are on the same street, in parallel , thus avoiding evaluating the same node twice.
24. For this example, data from an urban public transport route within the city of Santiago de Cali will be used. The researcher needs data that is not publicly accessible in many cases.

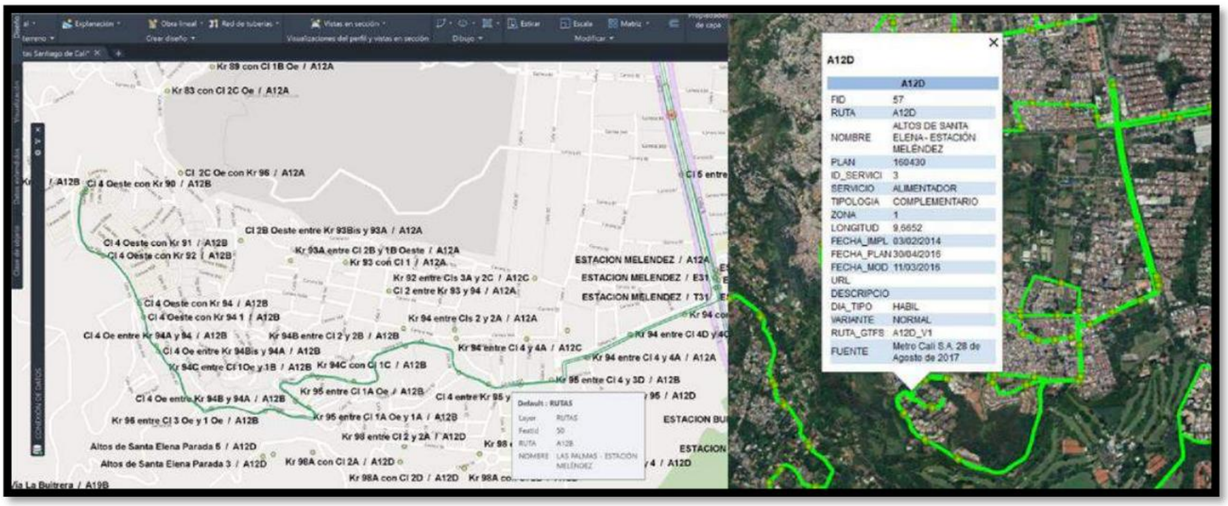
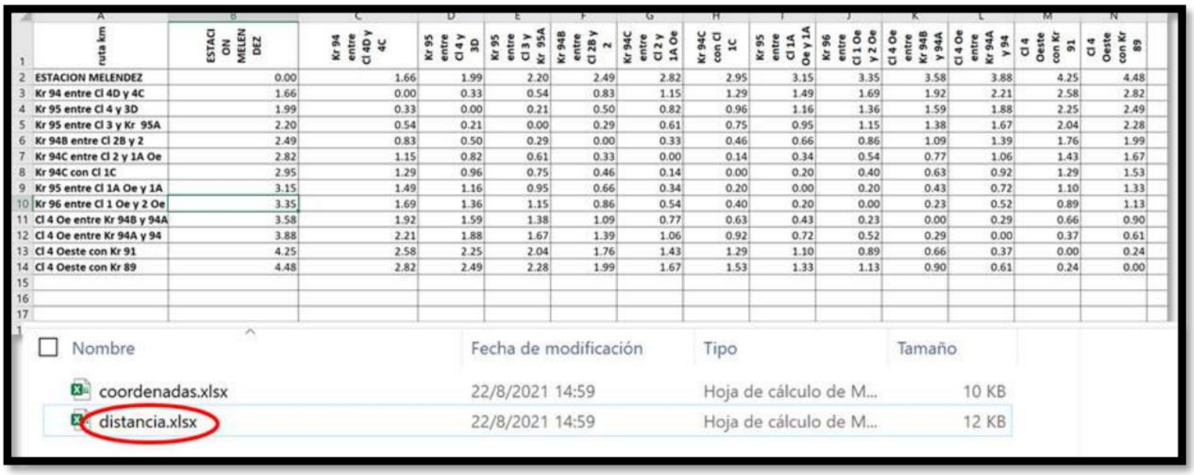


Figure 38 Capture of the route, using AutoCad Civil and Google Earth, data provided by the municipality

25. Once the researcher has the route in mind, he must measure the distance between each node he wants to evaluate and the next, always using kilometers, for this he can use multiple programs, AutoCad, Arcgis, Qgis, Google maps, Freecad, LibreCad , Qcad, Dragsight, BricsCad, etc. Figure 17 Capture of the route, using AutoCad Civil and Google Earth.
26. You will need to create an .xlsx file like the one seen in Figure 39

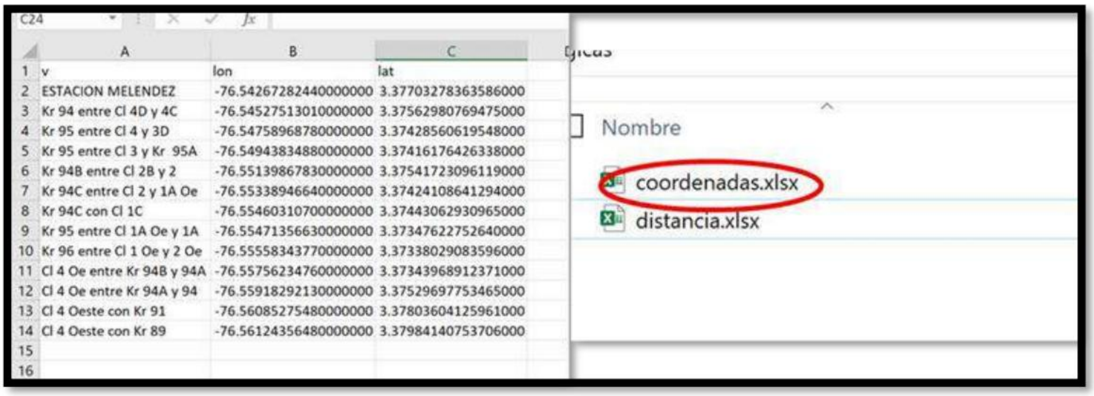


ruta km	ESTACION MELENDEZ	Kr 94 entre Cl 4D y 4C	Kr 95 entre Cl 4 y 3D	Kr 95 entre Cl 3 y Kr 95A	Kr 94B entre Cl 2B y 2	Kr 94C entre Cl 2 y 1A Oe	Kr 94C con Cl 1C	Kr 95 entre Cl 1A Oe y 1A	Kr 96 entre Cl 1 Oe y 2 Oe	Cl 4 Oe entre Kr 94B y 94A	Cl 4 Oe entre Kr 94A y 94	Cl 4 Oeste con Kr 91	Cl 4 Oeste con Kr 89
ESTACION MELENDEZ	0.00	1.66	1.99	2.20	2.49	2.82	2.95	3.15	3.35	3.58	3.88	4.25	4.48
Kr 94 entre Cl 4D y 4C	1.66	0.00	0.33	0.54	0.83	1.15	1.29	1.49	1.69	1.92	2.21	2.58	2.82
Kr 95 entre Cl 4 y 3D	1.99	0.33	0.00	0.21	0.50	0.82	0.96	1.16	1.36	1.59	1.88	2.25	2.49
Kr 95 entre Cl 3 y Kr 95A	2.20	0.54	0.21	0.00	0.29	0.61	0.75	0.95	1.15	1.38	1.67	2.04	2.28
Kr 94B entre Cl 2B y 2	2.49	0.83	0.50	0.29	0.00	0.33	0.46	0.66	0.86	1.09	1.39	1.76	1.99
Kr 94C entre Cl 2 y 1A Oe	2.82	1.15	0.82	0.61	0.33	0.00	0.14	0.34	0.54	0.77	1.06	1.43	1.67
Kr 94C con Cl 1C	2.95	1.29	0.96	0.75	0.46	0.14	0.00	0.20	0.40	0.63	0.92	1.29	1.53
Kr 95 entre Cl 1A Oe y 1A	3.15	1.49	1.16	0.95	0.66	0.34	0.20	0.00	0.20	0.43	0.72	1.10	1.33
Kr 96 entre Cl 1 Oe y 2 Oe	3.35	1.69	1.36	1.15	0.86	0.54	0.40	0.20	0.00	0.23	0.52	0.89	1.13
Cl 4 Oe entre Kr 94B y 94A	3.58	1.92	1.59	1.38	1.09	0.77	0.63	0.43	0.23	0.00	0.29	0.66	0.90
Cl 4 Oe entre Kr 94A y 94	3.88	2.21	1.88	1.67	1.39	1.06	0.92	0.72	0.52	0.29	0.00	0.37	0.61
Cl 4 Oeste con Kr 91	4.25	2.58	2.25	2.04	1.76	1.43	1.29	1.10	0.89	0.66	0.37	0.00	0.24
Cl 4 Oeste con Kr 89	4.48	2.82	2.49	2.28	1.99	1.67	1.53	1.33	1.13	0.90	0.61	0.24	0.00

Nombre	Fecha de modificación	Tipo	Tamaño
coordenadas.xlsx	22/8/2021 14:59	Hoja de cálculo de M...	10 KB
distancia.xlsx	22/8/2021 14:59	Hoja de cálculo de M...	12 KB

Figure 39 With the data supplied, you must measure the distance that exists within the path of the route (normally a polyline) from each node, thus obtaining a matrix of distance along the route, use kilometers as a measure of length.

27. Now you must generate an .xlsx file with the coordinates identical to the one in the previous steps, which columns are named v (for the name), lon (longitude) and lat (latitude), it will be very important that you respect the order you entered in the distance matrix. The coordinates can be obtained using the special function of the program for it or any other software or database. Figure 40 .



v	lon	lat
ESTACION MELENDEZ	-76.54267282440000000	3.37703278363586000
Kr 94 entre Cl 4D y 4C	-76.54527513010000000	3.37562980769475000
Kr 95 entre Cl 4 y 3D	-76.54758968780000000	3.37428560619548000
Kr 95 entre Cl 3 y Kr 95A	-76.54943834880000000	3.37416176426338000
Kr 94B entre Cl 2B y 2	-76.55139867830000000	3.37541723096119000
Kr 94C entre Cl 2 y 1A Oe	-76.55338946640000000	3.37424108641294000
Kr 94C con Cl 1C	-76.55460310700000000	3.37443062930965000
Kr 95 entre Cl 1A Oe y 1A	-76.55471356630000000	3.37347622752640000
Kr 96 entre Cl 1 Oe y 2 Oe	-76.55558343770000000	3.37338029083596000
Cl 4 Oe entre Kr 94B y 94A	-76.55756234760000000	3.37343968912371000
Cl 4 Oe entre Kr 94A y 94	-76.55918292130000000	3.37529697753465000
Cl 4 Oeste con Kr 91	-76.56085275480000000	3.37803604125961000
Cl 4 Oeste con Kr 89	-76.56124356480000000	3.37984140753706000

Figure 40 File with the coordinates and direction of the stops, it is important to use the correct name in the row "v, lon, lat".

28. Now you must mark the average speed at which the transport moves on the route to be evaluated, fill in the fields from the previous steps, optionally fill in the coordinates field and after that you must click on accessibility topological measures Figure 41

Figure 41 It is important to introduce the average speed with which the evaluated means of transport moves in the city, in general, buses go on average at 13 km in urban sectors. You will also need to enter the data files in the correct order as seen in the picture.

29. When clicking on Topological accessibility measures, a load menu is displayed, where you must first load the coordinates and then the distance matrix, the load order is very important.
30. Now the program will make the necessary calculations and then present the results on the screen and in a file named Topologicas.xlsx Figure 42 .

Figure 42 The programmed Dgis generates an Excel file named Topologicas.xls where the results are found.

31. The generated file is composed of 13 pages, which contain useful matrices for the researcher to analyze the route, now the researcher can compare many routes or modify their nodes and evaluate their performance, the last page is a summary

where, among other things, you can see data such as the travel time Figure 43 Capture.

Figure 43 Screenshot showing the results summary table

32. It is important to note that this feature is for researchers with access to route data and broader mathematical knowledge.
33. Guide Recommended read the complete of https://wiki.openstreetmap.org/wiki/ES:Caracter%C3%ADsticas_del_mapa#Transp Learn what each keyword means within the database, so you can evaluate what you need without making mistakes.
34. It is recommended to watch a video on YouTube called How to use Dgis? In the next link https://www.youtube.com/watch?v=FVs8sLwRb8g
35. You can see the Dgis software code in annex 11.2 Dgis program code.

8.1.3 Utility of the software within urban planning

This software helps urban planning, as it facilitates decision-making on where to put stops and stations within the city, it is also capable of measuring the topological accessibility of transport routes and has some functions such as:

- Measures the percentage of area reached by public transport within the area of study.
- It is possible to eliminate or add stops in a transport network and evaluate their area of influence.
- You can add to the simulation, other transport items different from public transport stops, such as parking for bicycles, parking for electric scooters, parking for cars, and, in addition, you can modify the

study buffer as the user wishes, therefore, what the user needs can be studied.

- You can measure how accessible its transport network is for the inhabitants of a building, since you can put the coordinates as explained in the previous title, and thus evaluate how accessible that building is to the network.
- You can measure the accessibility of an area with respect to other areas, thanks to the location spatial coordinates offered by the program.
- You can put the coordinates of a series of customers to whom merchandise must be delivered, through the find coordinates function, and thus make decisions in the distribution of goods, observing their spatial position on the map and organizing more efficient routes in the consumption of fuel, through the percentage comparison function of routes found within the results of topological accessibility measurements.

- You can evaluate the connectivity that a new urban project has, as you can be a park, a convention center, a stadium, etc.
- It could plan evacuation locations within cities where there is an earthquake risk such as Santiago de Chile, Mexico City, Los Angeles, California, Tokyo or Cali, through its coordinates and maps section, something similar to the spatial planning of programs such as Qgis, using the start button, with the coordinates of the refuge zone and its area of influence.
- It is a tool with multiple uses, it is an open letter for professionals, urban planners, students and professors to use it within their research area.

8.1.4 X CIOT 2021 10th International Congress on Spatial Planning

Dgis has been designed for this master's thesis, even so, it was presented as a proposal to the "X CIOT 2021 10 International Congress on Spatial Planning", held in Valencia Spain on November 17, 18 and 19, 2021, within of the category AXIS C: Urban and metropolitan agenda; towards healthier cities and territories, AXIS C-3: Sustainable intra-urban and metropolitan mobility. Within the poster category and the presentation/communication category.

Dgis has been chosen in both categories, its poster was exhibited during the exhibition days and can be seen in the annex, corresponding to chapter 11.2 of this document, while the communication can be read in the congress book called "10 ciot recovery, transformation and resilience: the role of the territory".

Accessible from the official page of the event: https://www.10ciot.org/libro or from the following link to Google drive https://drive.google.com/file/d/1HDJiD7TC_jc7FIOeC hppkVXbM6_4Gn2/view?usp=sharing Fragment of the index Figure 44.

EJE C.3: Movilidad sostenible intraurbana y metropolitana

Figure 44 fragment of the index of the congress book where Dgis has been shown (Fundicot, 2021).

8.2 Practical application to Cali (Colombia)

Taking a recount of the ideas and concepts considered so far and using the computer program developed in this work, improvements will be proposed for an area of the city of Santiago de Cali, in Colombia, and future recommendations will be formulated, following as a horizon turn this city into a city for the people in terms of Gehl.

In 2018, the study "Design of the spatial distribution of the routes of the mio* system according to the quality of service perceived in commune 18" was carried out, focused on an area of the city of Santiago de Cali Colombia. In this study, a satisfaction survey was carried out, a survey of origin destination and subsequently topological accessibility indicators were used to try to improve it in the commune, as a result, the redesign of 4 routes was obtained (Figure 45 result study of 2018) of public transportation and the spatial reorganization of the nodes/stops, allowing the study to conclude:

*The MIO (Massive Integrated of the West) is the public transport system of Cali, capital city of the department of Valle del Cauca, with 2,228,000 inhabitants (2018), which replaced the old system of multiple private urban transport companies that it was inefficient and costly in terms of the pollution it generated, urban congestion, and poor service to citizens.

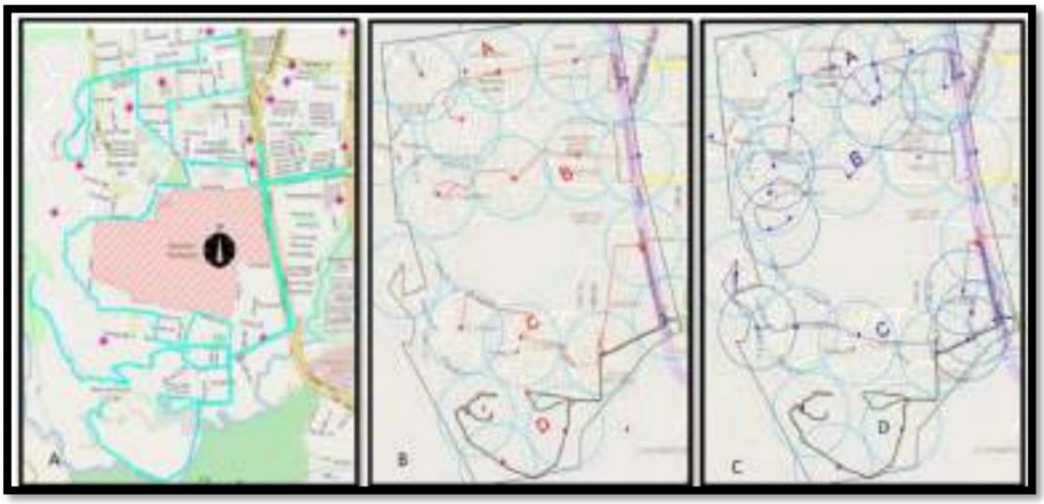


Figure 45 results of the 2018 study (Ramirez Cajigas, 2018).

- The origin-destination survey turns out to be inappropriate because the users of the transportation system could not indicate that they were going to a place that was inaccessible by it. (simply due to the absence of this service until the end, even though it was good in the rest of the city), therefore, accessibility design must be separated from design by demand (Ramirez Cajigas, 2018).
- People who do not access a place because the system does not allow, lose job, educational and recreational opportunities (Ramirez Cajigas, 2018) (Dajome, 2016).
- People have a wrong view of reality, for example, when the survey asked a quantitative question about the quality of the transport service, they scored it with ratings greater than 50%, but when asked the same question qualitatively, they answered that the service is bad (Ramirez Cajigas, 2018).

- The surveys carried out in 2018 did not reflect the numerical reality of the system. (Ramirez-Cajigas, 2018).
- There will always be a disadvantage for poor people, but the transport system can help to reduce this disadvantage, if it is possible to provide the community with a more efficient collective transport system that reduces the total cost of the trip and the time invested in it. , which will result in greater well-being for users of the public transport system and in the end will bring greater prosperity for families and thus for the city (Ramirez Cajigas, 2018).

The 2018 study concluded with a good result for the commune, demonstrating the effectiveness of route design using topological accessibility and as a consequence of this improving the lives of the people who live in it, the biggest problem when doing a study like this is that you need to have the routes and routes that are in the transportation system (Ramirez Cajigas, 2018).

The Dgis software created in this project is used together with public access tools. such as open street maps and data to which you have access as a researcher, supplied by Metro Cali, the entity that is in charge of transportation in the city. To analyze an area of the city.

As if it were a joke against modern urbanism, one of the neighborhoods of the 22nd commune is called a garden city, and in general, these neighborhoods seem to be a mix between the North American garden city of the 20th century and the ideas of Le Corbusier with your radiant city. That is why in the sector there are blocks of houses isolated from each other, and when this does not happen, residential complexes of buildings highly separated from each other are observed, with access to parks that end up being little used or whose greatest attraction is be taking the pet for a walk. In other words, quite the opposite, to what is recommended in the theoretical framework by authors such as Gelh, Jacobs and Kurt.

8.2.1 Data on the commune studied

The population data that we have of this commune come from two parts, firstly, we have the information provided by the entity DANE (Entity responsible for the planning, survey, processing, analysis and dissemination of official statistics of Colombia).
And on the other hand you have the information from the database of the public transport system, Curiously, the data is not identical, despite the fact that it is from 2018, the year of the last population census.

The Figures between Figure 46 and Figure 53, try to put the reader in context with the population, routes, stops and urban planning of the commune, apart from the fact that they are the stops that were evaluated with the Dgis software.

Área en Cali	Comuna	Total personas CNPV 2018	Total personas CG2005	Variación porcentual
Cabecera municipal	01	49.214	61.999	-20,6%
Cabecera municipal	02	98.702	102.080	-3,3%
Cabecera municipal	03	27.000	44.308	-39,1%
Cabecera municipal	04	45.112	55.965	-19,4%
Cabecera municipal	05	92.171	99.844	-7,7%
Cabecera municipal	06	123.740	169.392	-27,0%
Cabecera municipal	07	57.720	77.775	-25,8%
Cabecera municipal	08	80.504	97.335	-17,3%
Cabecera municipal	09	29.887	48.382	-38,2%
Cabecera municipal	10	84.127	103.671	-18,9%
Cabecera municipal	11	89.305	98.361	-9,2%
Cabecera municipal	12	56.192	67.439	-16,7%
Cabecera municipal	13	116.359	169.829	-31,5%
Cabecera municipal	14	127.918	151.789	-15,7%
Cabecera municipal	15	102.224	126.709	-19,3%
Cabecera municipal	16	79.555	94.445	-15,8%
Cabecera municipal	17	143.978	104.544	37,7%
Cabecera municipal	18	99.376	100.339	-1,0%
Cabecera municipal	19	89.256	98.735	-9,6%
Cabecera municipal	20	48.405	65.207	-25,8%
Cabecera municipal	21	108.790	92.336	17,8%
Cabecera municipal	22	31.366	9.082	245,4%
Centro poblado	98	12.398	22.514	-43,9%
Rural disperso	99	9.570	13.240	-27,7%

Figura 46 Comuna 22 y población (DANE, 2018).

Tabla 6 Población Comuna base de datos red de transporte "MetroCali" 2018.

ID_BARRIO,C	BARRIO,C,254	COMUNA,C,2	ESTRA_MOD	AREA,N,19,10	PERIMETRO,N,19,10	X,N,19,10	Y,N,19,10	ID_GIS,C,254	POBLACION,N,16,6	POB_M,N,16	POB_F,N,16,6	NUM_VIVIEN,N,16,6	PERIMETER,N	HECTARES,N,	Nombre_ZAT	Num_nueva,N,4,0
2299	Club Campestre	22	6	634792.7021	1534436.575	1059323.784	864344.309	2299	0	0	0	0	5144.515	63.479		2299
2298	Ciudad Campestre	22	6	201957.1534	236580.0708	1059808.612	864425.636	2298	787	326	461	258	1707.884	20.196		2298
2201	Urbanizaci¾n Ciudad JardÝn	22	6	1700171.156	967450.534	1060109.202	863642.551	2201	3488	1475	2013	966	6792.132	170.017		2201
2297	Urbanizaci¾n Rio Lili	22	6	225354.618	250463.1714	1061107.458	863819.851	2297	391	198	193	110	2128.263	22.535		2297
2296	Parcelaciones Pance	22	6	7840132.864	1662588.104	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2296
2201	Urbanizaci¾n Ciudad JardÝn	22	6	1700171.156	215983.0599	1060109.202	863642.551	2201	3488	1475	2013	966	6792.132	170.017		2211
2201	Urbanizaci¾n Ciudad JardÝn	22	6	1700171.156	463701.363	1060109.202	863642.551	2201	3488	1475	2013	966	6792.132	170.017		2212
2296	Parcelaciones Pance	22	6	7840132.864	877899.9394	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2213
2296	Parcelaciones Pance	22	6	7840132.864	1041135.186	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2214
2296	Parcelaciones Pance	22	6	7840132.864	1961175.909	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2215
2296	Parcelaciones Pance	22	6	7840132.864	235951.845	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2216
2296	Parcelaciones Pance	22	6	7840132.864	642336.9854	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2219
2296	Parcelaciones Pance	22	6	7840132.864	561119.4063	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2221
2296	Parcelaciones Pance	22	6	7840132.864	769794.2071	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2222
2296	Parcelaciones Pance	22	6	7840132.864	67361.30736	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2220
2296	Parcelaciones Pance	22	6	7840132.864	76953.59132	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2217
2296	Parcelaciones Pance	22	6	7840132.864	202322.6379	1060101.562	861726.298	2296	3437	1647	1790	873	11996.345	784.013		2218
	Bochalema								8971	8971	8971					
				92404079.45				38753	49449	23066	26383	12869	161316.853	9240.404		

8.2.2 Public transport routes in the study area

Figure 47 Public transport routes in pink route name and stops in green source, Shp database in Qgis.

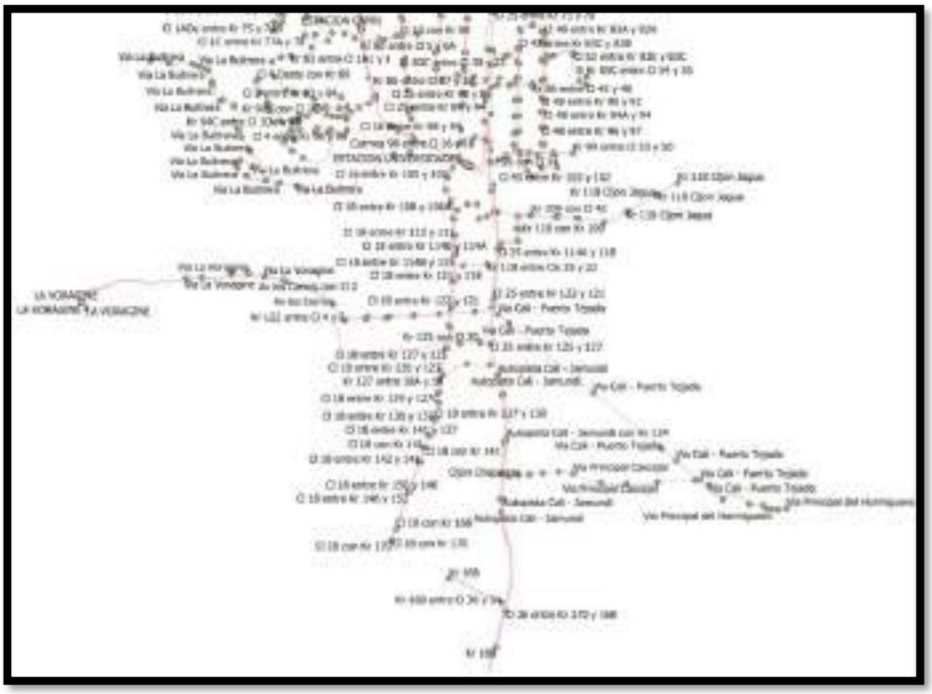


Figure 48 48 Public transport routes in pink and stops in green with direction by stop. source, Shp database in Qgis.

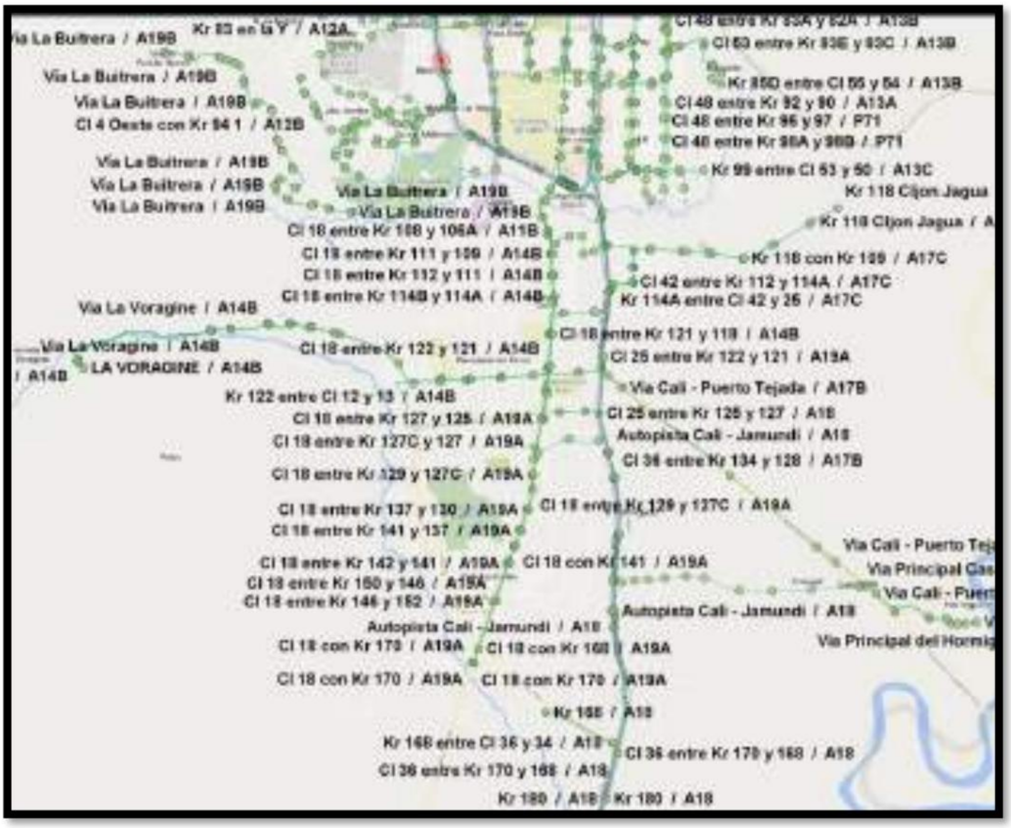


Figure 49 Routes and stops under a Bing map using AutoCAD Civil.

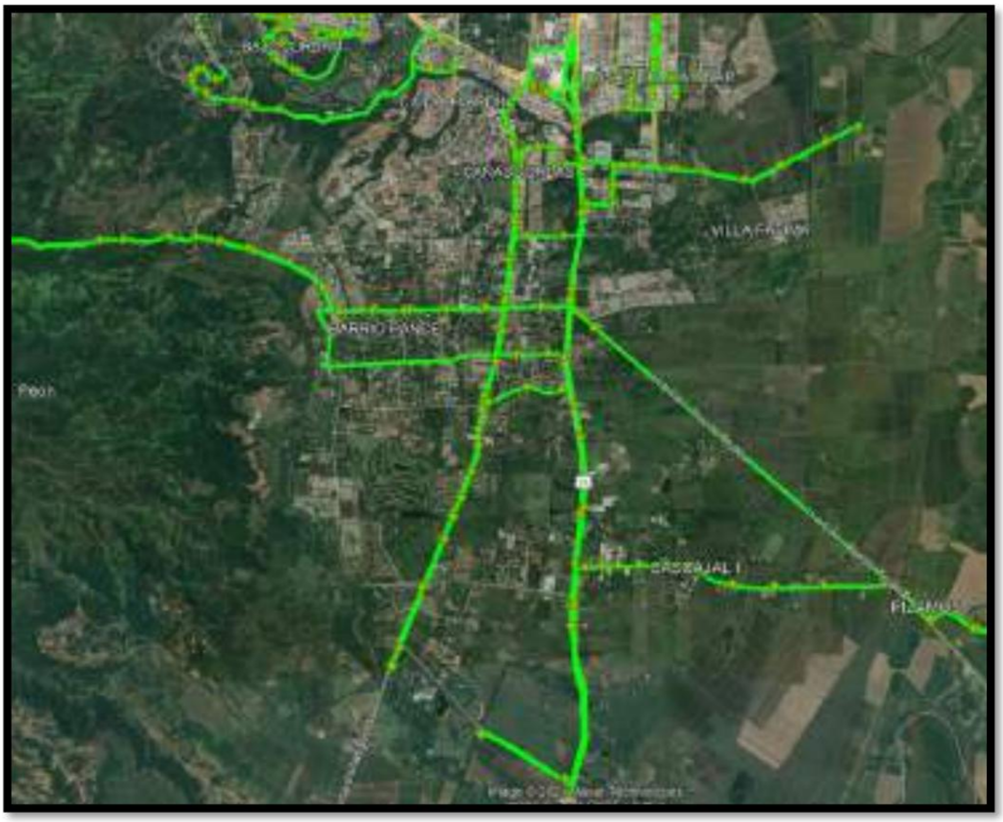


Figure 50 Commune 22 public transport routes in Google Earth.

Figure 51 Typical 3d view of buildings in the Source Google Earth area.

Figure 52Typical 3d view of buildings in the Google Earth Source area.

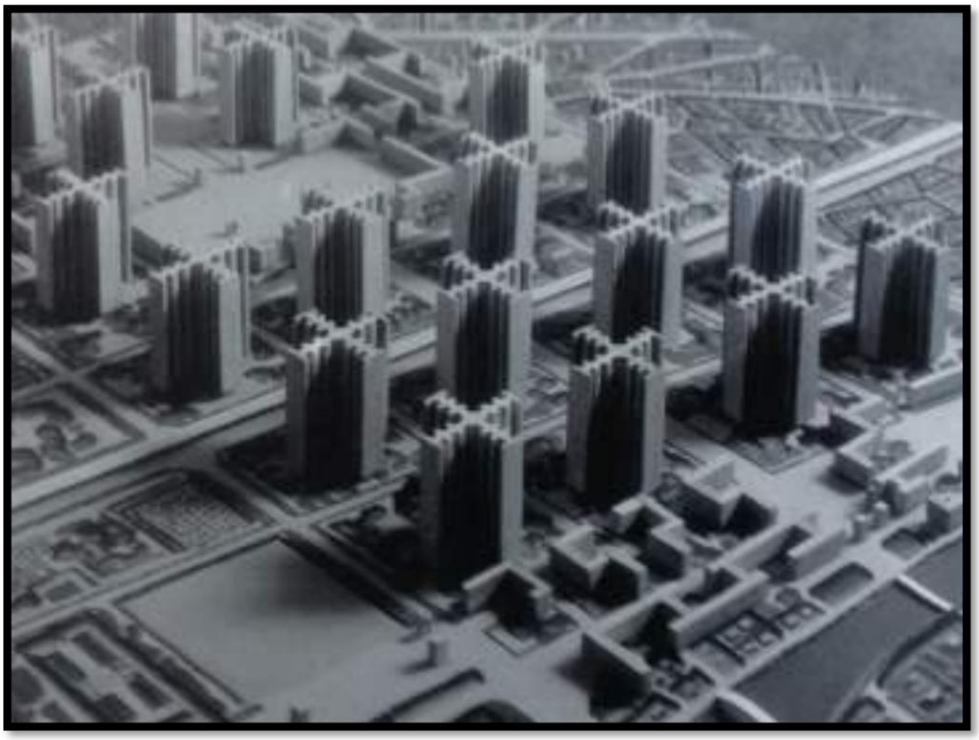


Figure 53 Curiously similar to the ideas we now know were wrong from Le Corbusier Source: (Wikipedia, 1925).

8.2.3 Development and analysis within the commune 22

Authors seen in the previous chapters argue that the optimal walking distance should be a maximum of 400 meters, assuming that a human being walks at a speed between 4.5 km/h and 5 km/h, it means that the average person would walk 400 meters between 4, 8 minutes to 5.33 minutes. (Gehl, 2014) (Davies, 2000).

Now we proceed to run the data of the study area in the software evaluating 300 meters and 400 meters of influence area.

The results are not surprising when they show that the area reached by the public transport system in the commune ranges between 26.42% and 34.27%. This shows that most of the area is inaccessible, unless there is private transportation. See Figure 54 Commune 22 public transportation system, area of influence 300 m and Figure 55 Commune 22 public transportation system, area of influence 400 m.

Figure 54 Commune 22 public transport system area of influence 300 meters.

Figure 55 Commune 22 public transport system area of influence 400 meters.

A model was also run with the entire public transport system of the city of Santiago de Cali, whose results are 50.

84% for the measurement at 300m and 56.2 for 400m (See Figure 56 and Figure 57). Here it is important to emphasize that there is no theoretical limit to the calculation capacity of the program by default, the only limit that can exist is that of the RAM memory and processor of the pc where it runs. In order to obtain the calculation of the entire city system, the program consumed a total of 25 gigabytes of Ram, it was run on a PC with 32 GB ram, Core i7 at 3.4 mhz and a graphics card dedicated Nvidia 1070 8GB of Vram.

The foregoing expresses that in theory a model could be run that covers the transport system of an entire country or even the entire planet, if enough RAM capacity is reached.

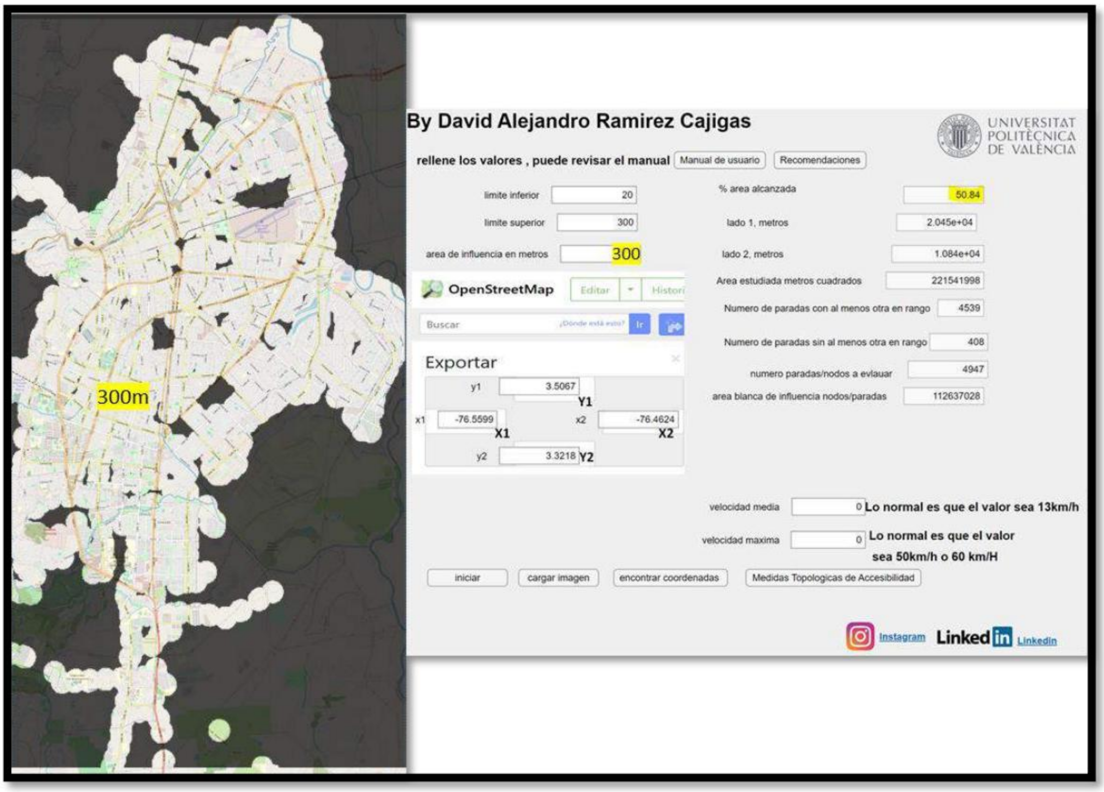


Figure 56 Public transport system throughout the city of Cali area of influence 300m

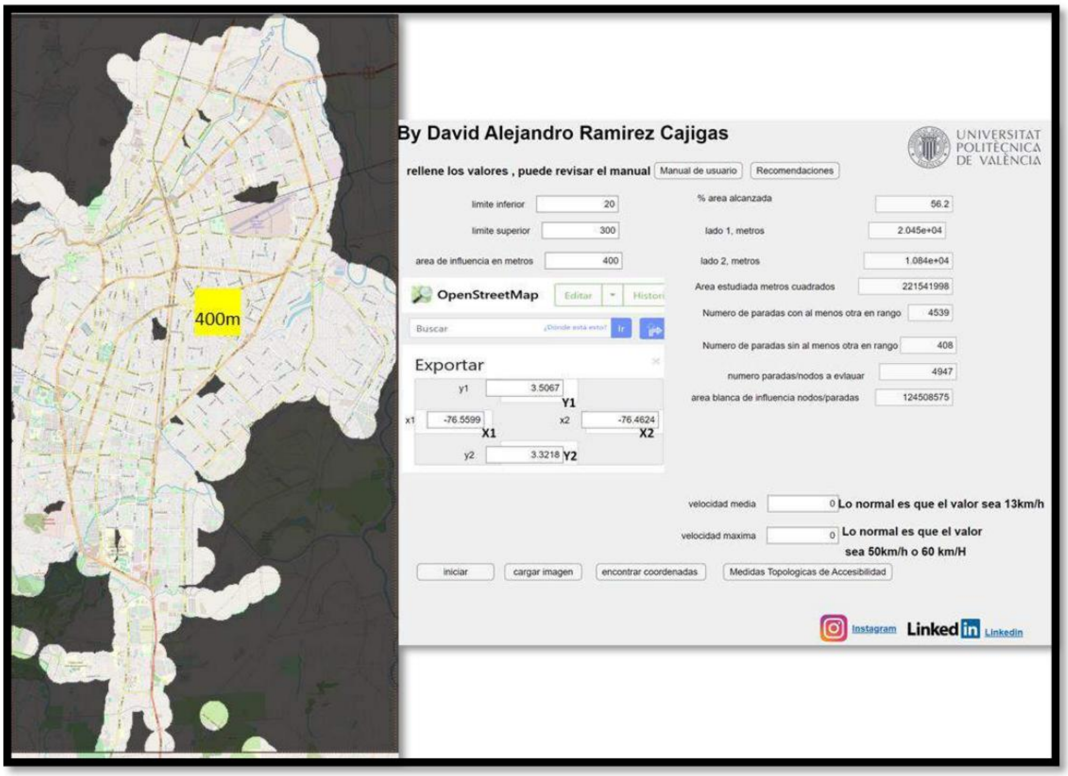


Figure 57 Public transport system throughout the city of Cali area of influence 400m

8.2.4 Analysis of a new neighborhood in the commune

The interesting thing about this commune is that it is located in the expansion zone to the south of the city of Cali, in which new urbanizations and neighborhoods arise at such a surprising rate that, according to DANE, there is a record of demographic explosion 245.4% between the 2005 and 2018 census.

The neighborhood is called Bochalema, it has approximately 8,971 inhabitants and is characterized by being mostly residential, with a small commercial area, people live in apartment buildings protected by bars and separated from each other, large parks and sidewalks from 90 to 150 centimeters wide.

The neighborhood itself is an adaptation of Le Corbusier's radiant city, a neighborhood that is not designed for the enjoyment of the human being, focused on automobiles, focused on the industrialized production of residences and that has not taken into account the recommendations of authors such as Jane Jacobs, Jan Gehl, William H. Whyte, Clara H Greed and Llewelyn Davies.

It is a neighborhood that synthesizes the failure of urbanism in commune 22, it is new because it began to be built in 2015 and is still growing with new housing projects in a closed unit, the glory of the fear of terrorism, imposed on the world since the 9/11 attacks (Kurt W. Bauer, 2010).

What hurts is the fact that it is new within the city, commune 22 in its oldest neighborhoods even lacks sidewalks, it is a commune designed 100% for private transportation where citizens are deprived of opportunities, see Figure 7 High quality of the urban environment vs. low quality.

It is designed with ideas from a decadent past that has become obsolete, which shows that Colombia is essentially a country of absurdities.

Figure 58 Aerial view of the neighborhood, large empty parks, blocks of buildings separated from each other and enclosed by bars Source Google Earth.

Figure 59 Aerial view of the neighborhood, large empty parks, blocks of buildings separated from each other and enclosed by bars Source Google Earth.

Figure 60 Sidewalks between 90 cm and 150 cm wide, with light poles in the middle Source Google Earth.

Figure 61 Large and numerous parks, empty sidewalks that do not invite walking Source Google Earth.

Figure 62 Distances Source Google Earth.

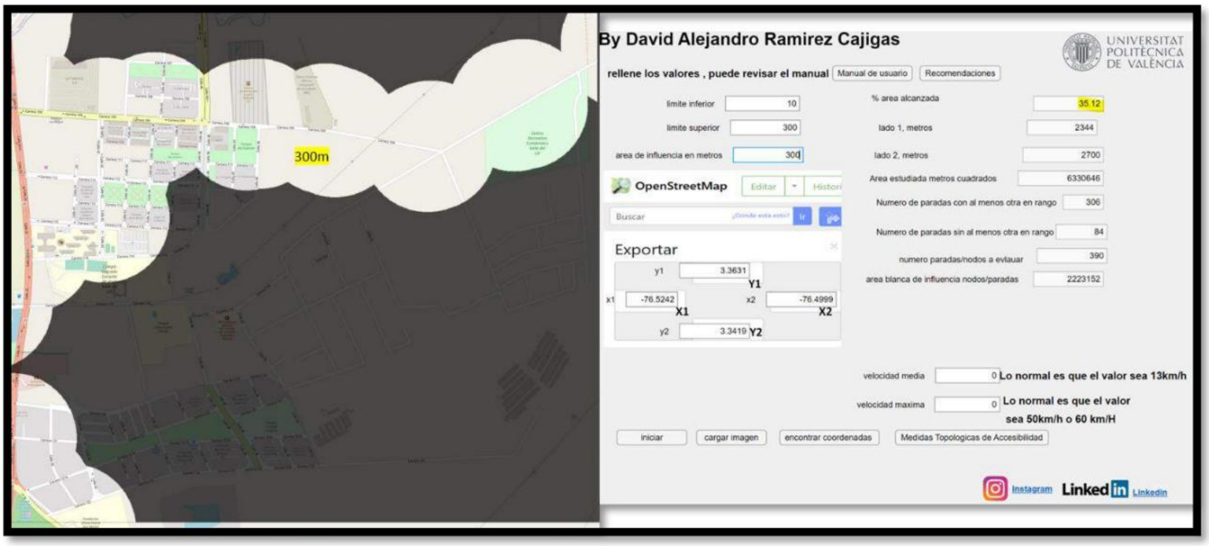


Figure 63 Bochalema neighborhood public transportation system area of influence 300m.

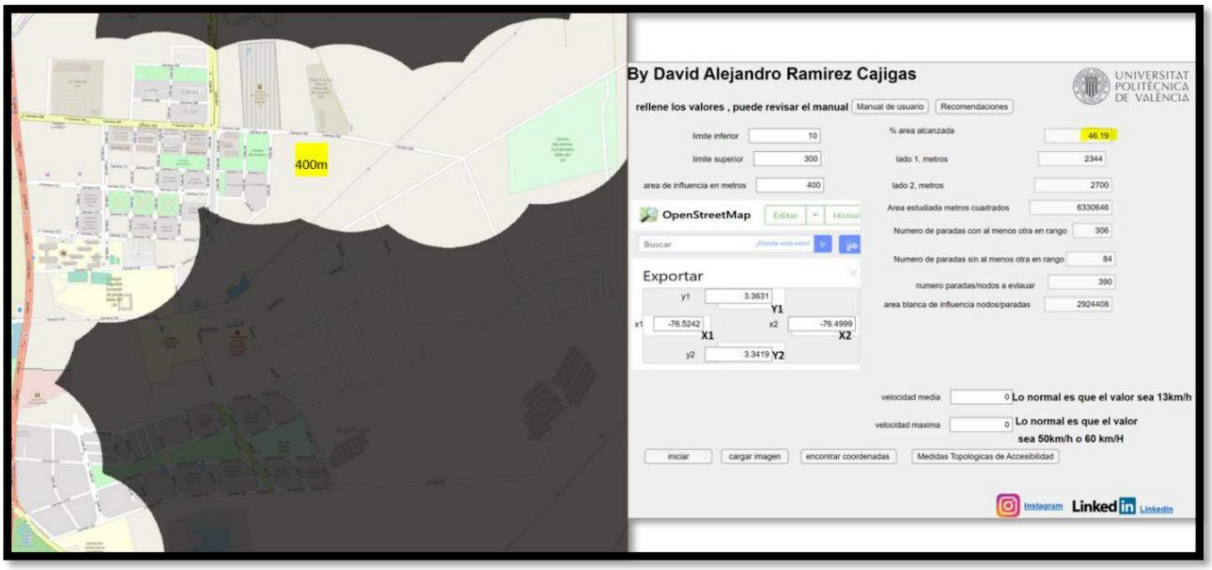


Figure 64 Bochalema neighborhood public transportation system area of influence 400m.

In this area of the city, there is a transport coverage of 35.12% for an area of influence of 300 meters and 46.19% for an area of influence of 400 meters (see Figure 63 and Figure 64) which corresponds to a deficient area. Streets not suitable for pedestrians with long walking distances are observed (see Figure 59 to Figure 62).

To extract the coordinates of the facilities and businesses in the area, use the button to find coordinates (see Figure 65) of the Dgis Software, the area lacks a large number of notable facilities, in fact it only has 10, a park, a super market, a small square, a restaurant, a re-education penitentiary for minors that provides services to the entire city, schools, a specialized section of a hospital that does not provide services to the city, a small store and a theme park. The rest are underused green areas. (see Figure 66).

Figure 65 Finding the coordinates of the facilities.

Figure 66 Area covered by facilities 53% and in reality there are only 10 notable ones.

8.2.5 Analysis of an old neighborhood of commune 22

The neighborhood of Ciudad Jardín and Pance (see Figure 67), began to develop in September 1962, when it began to become a zone of atonement for the city, in those years agricultural crops still predominated.

Little by little it began to be urbanized in what would become the most expensive neighborhood in the city, the neighborhood began to grow, which was boosted by the fact that 4 universities, several schools and nearby built one of the largest and best equipped clinics in Colombia.

The neighborhood was designed to use a private car because it is a symbol of wealth, this is how this neighborhood lacks sidewalks in much of its extension and in other places 150cm sidewalks have been built.

There is a case study in the Australian literature, on social exclusion in households in the suburbs of Melbourne, where it was discovered that both upper and lower class families, who lived in places without access to public transport, generated a loss of daily activities for some family members, which means that not having sidewalks or access to public transportation is bad even if you are wealthy. (Delbocs, 2011).

Figure 67 Aerial view of the neighborhood, large empty parks, blocks of buildings separated from each other and enclosed by bars Source Google Earth

Figure 68 sidewalks of 150 cm in the area.

Figure 69 sidewalks with obstacles and empty streets.

Figure 70 streets without sidewalks surrounded by gated communities.

Figure 71 streets without sidewalks.

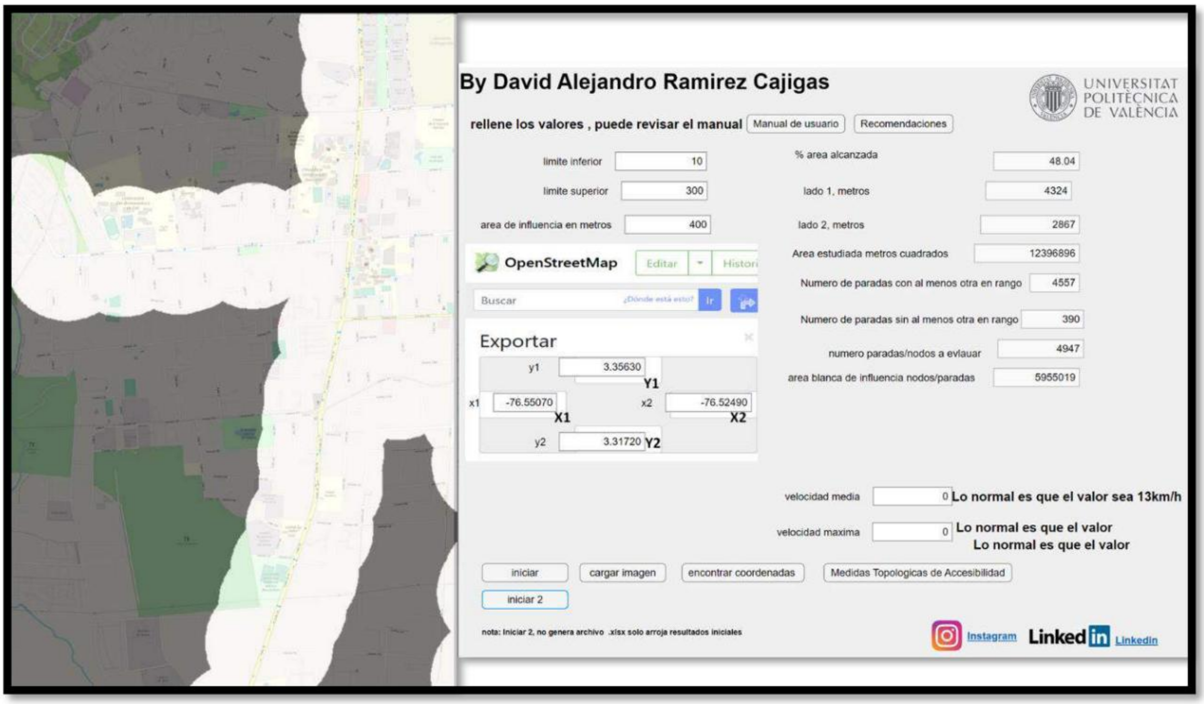


Figure 72 Dgis used to evaluate the area of influence.

This neighborhood needs sidewalks so that people can walk without the risk of dying, it needs attractive places that make it interesting apart from the parks, lately there have been restaurants with Spanish-style terraces have been implemented and have proven to be a success, however, to reach them you need to have a car or risk your life by walking on streets without sidewalks. (see Figure 68 to Figure 71).

In terms of accessibility, low is detected, since it is 48.04% for areas of influence of 300 meters, see Figure 72.

8.2.6 Recommendations to urbanize the Pance sector

Because of the base infrastructure available in the Pance area, particularly because of the conditions that its inhabitants can be expected to have, in terms of educational and therefore cultural training, and together with this, because of the certainty of being in the area whose inhabitants have the highest economic income, the mayor of Cali with its experts in urban planning, could consider reorganizing the area, both to have it as a model to do the same in other areas of the city, and to promote the sociability of the people and the economy , for which it is suggested to incorporate these general recommendations, which are inspired by the theoretical framework, it should be noted that the first two recommendations are evaluated in this work, following its general objective and the last two require a particular rigorous study that goes beyond the scope of this work and the general objective of this work, which is to generate the software.

Design transport routes for the commune that cover a percentage as close as possible to 100%, Dgis can be used, this point is discussed in chapter 7.3.

To design routes with good accessibility, Dgis can be used, in the "accessibility topological measures" button and follow the methodology used presented in the study "Design of the spatial distribution of the routes of the MIO system according to the perceived quality of service document 18" , http:// vitela.javerianacali.edu.co/handle/11522/10005?locale-attribute=pt_BR

in the commune accessible in

To measure the percentage of occupied area, you can use Dgis on your "start" button.

Generate places that attract community life, restaurants, bars, pedestrian streets, even parks, as long as they have multiple courts (skateboard, soccer, basketball, handball, petanque, etc.), libraries, theaters, activities for people to learn new habilities. In short, make the area less boring, that life is not sleeping and working.

Implement wide sidewalks, Implement bicycle lanes along with places to park them, Remove pedestrian barriers from platforms

These global recommendations can be read in the texts of the authors referenced in the theoretical framework (Gehl, 2014) (Arup Group, 2016) (Jacobs, 1961) (Davies, 2000)

The new residential buildings should not be sets closed by bars and with houses or buildings separated from each other, if not follow the recommendations of Gelh and Jacobs, make a neighborhood with a striking floor plan that invites you to tour the city. A good example of streets is Barcelona, where you can even continue to have swimming pools inside without damaging the street with bars, see Figure 73, Figure 74, Figure 75 and Figure 76.

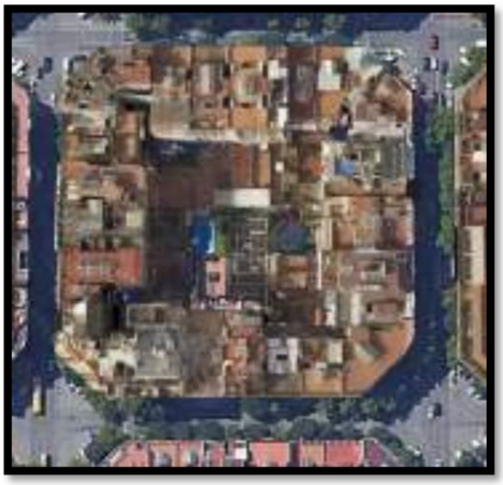


Figure 73 Barcelona block coordinate longitude 41°23'32.49"N latitude 2°9'9.98"E Source Google Earth

Figure 74 Barcelona, Street with businesses, invites you to walk source Google Earth

Figure 75 Barcelona, Wide sidewalks invite you to walk Source Google Maps

Figure 76 Barcelona shows courts, swimming pools inside the residential blocks, that is, the same as in the blocks of commune 22, only without ruining the experience of walking and enjoying the city
Google Earth Font

8.2.7 A possible public transportation route in the Pance Northwest Subarea

Applying recommendations indicated in the Pance sector, the design of a transport route is proposed in the north-west area of the commune, a sub-area where there is a total absence of collective public transport system. To evaluate and design the route, Dgis Software and AutoCAD Civil 3d 2020 will be used.

The following graphs (see Figure 77 to Figure 80) show the subarea where the new route is proposed, the results without the new route and the results with the new route obtained in Dgis.

Figure 77 In red the route generated in AutoCad Civil.

Figure 78 Area with current Dgis routes 43.13% occupancy.

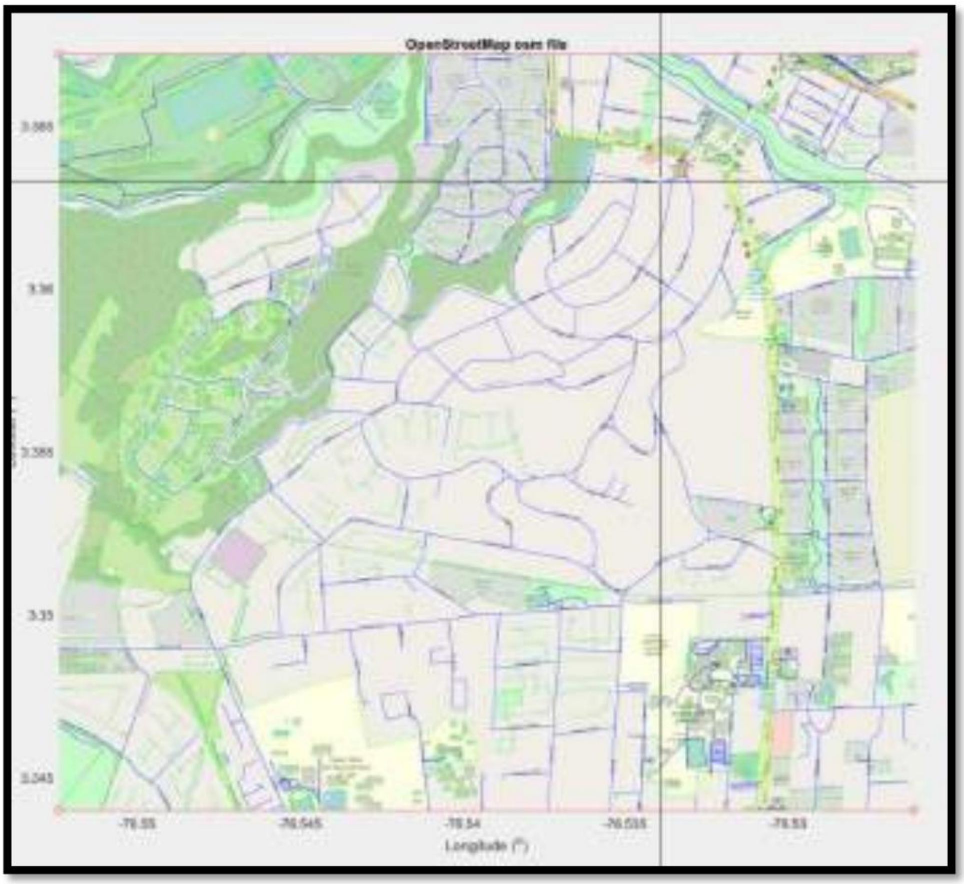


Figure 79 The coordinate points of the bus stops are searched using the Dgis software.

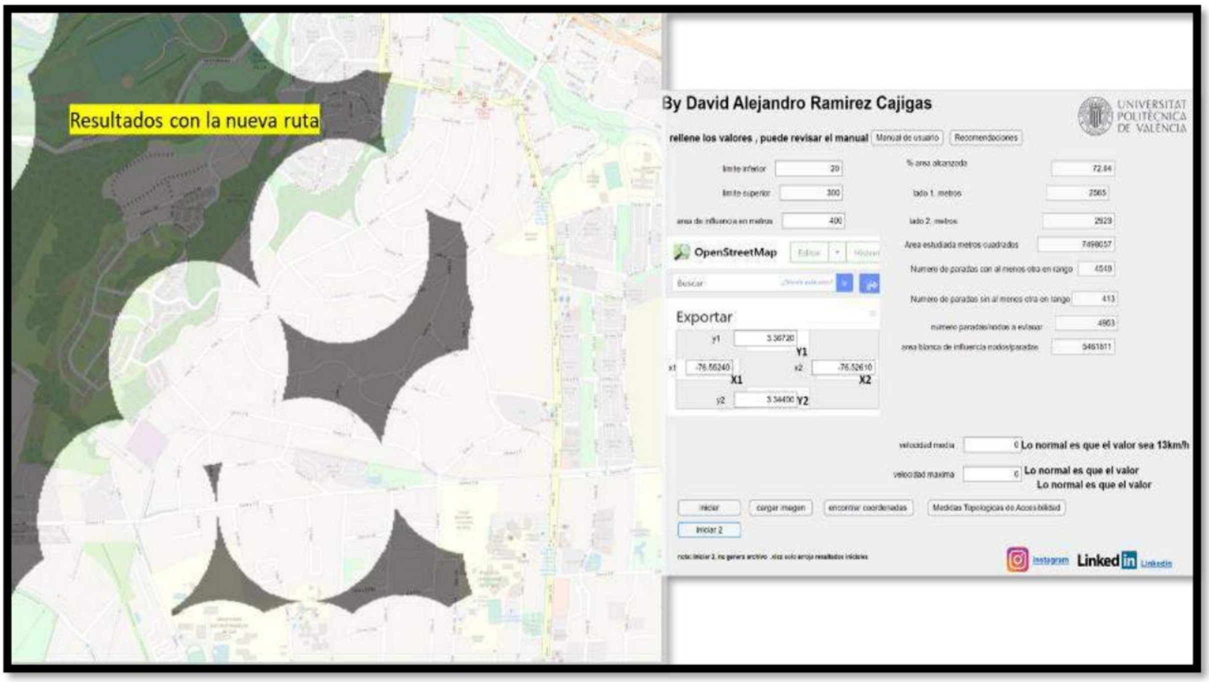


Figure 80 Zone with the route evaluated 72.84%.

With the software you can check the topology of the proposed route. Proceed once the coordinates obtained with the find coordinates button are available, and likewise once a matrix of route distances in meters has been entered, obtained in turn after measuring the travel distance between each stop. When this information has been entered into the Dgis program, the topological measurements button is clicked and the topology of the proposed route can be verified, as detailed in the tables in Table 7 to Table 16.

The final result is an increase in spatial accessibility in the area from 43.13% to 72.54%. which represents an increase of 29.41%.

The other result is a new route, although circular, and this brings with it bad results in the topological accessibility of the area, as can be seen in Table 13.

Table 7 Geographical and Cartesian coordinates resulting from Dgis Software.

Var1	lon	The t	x meters and meters	
Stop 1	-76.5339	3.3633	-1566.3887	1532.4763
Stop 2	-76.5392	3.3590	-1095.4910	944.8350
Stop 3	-76.5449	3.3547	-618.0532	316.0424
Stop 4	-76.5477	3.3491	0.0000	0.0000
Stop 5	-76.5406	3.3499	-85.0232	795.0441
Stop 6	-76.5339	3.3516	-269.7851	1532.4763

Table 8 Shows the distance from each row to each column, in total travel.

Distance on Route Km	stop 1	stop 2	stop 3	stop 4	Stop	stop 5 6
stop 1	0.000 0.839 1,677 2,442 3,259 5,314 0.000 0.837					4,063
stop 2	1,603 2,419 4,477 5,316 0.000 0.765 1,582 3,712					2,419
Stop 3	4,551 5,388 0.000 0.817 2,895 3,734 4,571 5,571					2,386
Stop 4	5,337					1,621
stop 5						0.804
stop 6						0.000

Table 9 This matrix is calculated by the program from the coordinates, it is the distance in a straight line that exists between each Dgis Software result node.

Distance line straight km	stop to 1	stop to 2	Stop 3	Stop 4	stop 5	Stop 6
Stop 1	0.000 0.753		1.542 2.191		1,655 1,297	
Stop 2	0.753 0.000		0.790 1.447		1,022 1,013	
Stop 3	1.542 0.790		0.000 0.694		0.717 1.265	
Stop 4	2,191 1,447		0.694 0.000		0.800 1.556	
Stop 5	1,655 1,022		0.717 0.800		0.000 0.760	
Stop 6	1,297 1,013		1,265 1,556		0.760 0.000	

Table 10 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another in a straight line.

time line straight Minute	stop to 1	stop to 2	Stop 3	Stop 4	stop 5	Stop 6
stop 1	0.00 3.48		7.12 10.11		7.64	5.98
stop 2	3.48 0.00 7.12		3.64	6.68	4.71	4.68
stop 3	3.64		0.00	3.20	3.31	5.84
Stop 4	10.11 6.68		3.20	0.00	3.69	7.18
Stop 5	7.64 4.71 5.98 4.68		3.31	3.69	0.00	3.51
Stop 6			5.84	7.18	3.51	0.00

Table 11 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another following the actual route of the route.

time en route Minute	stop to 1	stop to 2	Stop 3	Stop 4	stop 5	Stop 6
stop 1	0.00 3.87		7.74 11.27		15.04 18.75	
Stop 2	24.53 0.00		3.86 7.400.00		11.17 11.17	
Stop 3	20.66 24.54		3.53 24.80.00		7.30 11.01	
Stop 4	17.13 21.00				3.77 7.48	
Stop 5	13.36 17.23		21.10 24.63		0.00	3.71
Stop 6	9.65 13.52		17.39 20.92		24.69	0.00

Table 12 This matrix gives the route factor, which is nothing more than the division between the distance en route and the distance in a straight line, generating a quick way to see the similarity between the theoretical perfect straight line route and the real.

Factor Route	Stop 1	stop to 2	Stop 3	Stop 4	stop 5	Stop 6
stop 1	0.000 1.114		1,087 1,114		1,969 3,133	
stop 2	7.057 0.000		1,061 1,108		2,368 2,387	
stop 3	2,903 6,733 0,000 1,103				2,208 1,886	
Stop 4	1,694 3,146		7,762 0,000		1,021 1,042	
Stop 5	1,749 3,655 1,612 2,891		6,379 6,674		0.000 1.058	
stop 6			2,977 2,913		7,037 0,000	

Table 13 Percentage difference that exists between the current route and the straight theoretical ideal in percentages.

% Come in route and straight	Stop 1	stop to 2	Stop 3	Stop 4	stop 5	Stop 6
stop 1	0.00	10.27	8.00	10.26	49.22	68.09
stop 2	85.83	0.00	5.71	9.73	57.78	58.11
stop 3	65.55	85.15	0.00	9.30	54.70	46.97
Stop 4	40.96	68.21	87.12	0.00	2.10	4.00
Stop 5	42.84	72.64	84.32	85.02	0.00	5.46
Stop 6	37.98	65.41	66.41	65.67	85.79	0.00

Table 14 summary table of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018.

Name_stop	Addition_are distant cia_re cta	Sum_d distance _route	sum_ti time_r ect	Addition_weather _route	Sum_Ind ice_trace doTv
Stop 1	7,438	12,279	34,330	56,672	8,418
Stop 2	5,024	12,593	23,189	58,121	13,981
Stop 3	5,008	14,527	23,114	67,046	14,832
Stop 4	6,688	16,088	30,867	74,252	14,664
Stop 5	4,953	17,341	22,859	80,037	19,516
Stop 6	5,892	18,670	27,192	86,170	17,430

Table 15 summary table of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018.

Name_stop	Addition_shimb the	Sum_F actor_r uta	uno_divi dido_n_ less_1	Ri	one_divid gone_n
Stop 1	15	8.4184	0.0714	0.6013	0.0667
Stop 2	11	13.9810	0.1000	1.3981	0.0909
Stop 3	9	14.8319	0.1250	1.8540	0.1111
Stop 4	9	14.6645	0.1250	1.8331	0.1111
Stop 5	11	19.5162	0.1000	1.9516	0.0909
Stop 6	15	17.4304	0.0714	1.2450	0.0667

Table 16, summary of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018.

Name_stop	addition_time os_rut a_tie mpos_	traced_veloci dad_no do	absolute o_Time po_Glob to the	Weather_trip_until_node_min	Factor_ruta_total
Stop 1	1.651	0.110	56.672	18.751	1.651
Stop 2	2.506	0.228	58.121	11.166	2.506
Stop 3	2.901	0.322	67.046	11.013	2.901
Stop 4	2.406	0.267	74.252	7.481	2,406
Stop 5	3.501	0.318	80.037	3.711	3,501
Stop 6	3.169	0.211	86.170	0.000	3,169

8.2.8 A possible public transportation route in the southeast sub-area of Pance

Following the mechanism used to find a route in the northeast sector, routes will now be given in the southeast sector, following the methodology used in the 2018 study (Ramirez Cajigas, 2018), obviously the purpose of this work is to demonstrate the operation of the software Dgis, linear and non-circular routes will now be tried, one of the conclusions found in 2018, was that linear routes are more efficient than circular ones.

In this area (Figure 81 Existing routes in the southeast area), there is an absence of transport routes, just as in the northwest area, a route will be generated using Dgis. Everything is observed in the Figures below (see Figures Figure 81 to Figure 85).

Figure 81 Existing routes in the southeast zone.

A new bus route is generated, which supplies the need in the southeast area, there is now an area of 75.81% instead of 61.08% before, a route has been generated where it could be due to the existing infrastructure. (Figure 82 and Figure 85)

Figure 82 Southeast zone missing without new route.

Figure 83 Obtaining coordinates in the southeast zone with Dgis.

Figure 84 Proposed linear route, southeast zone.

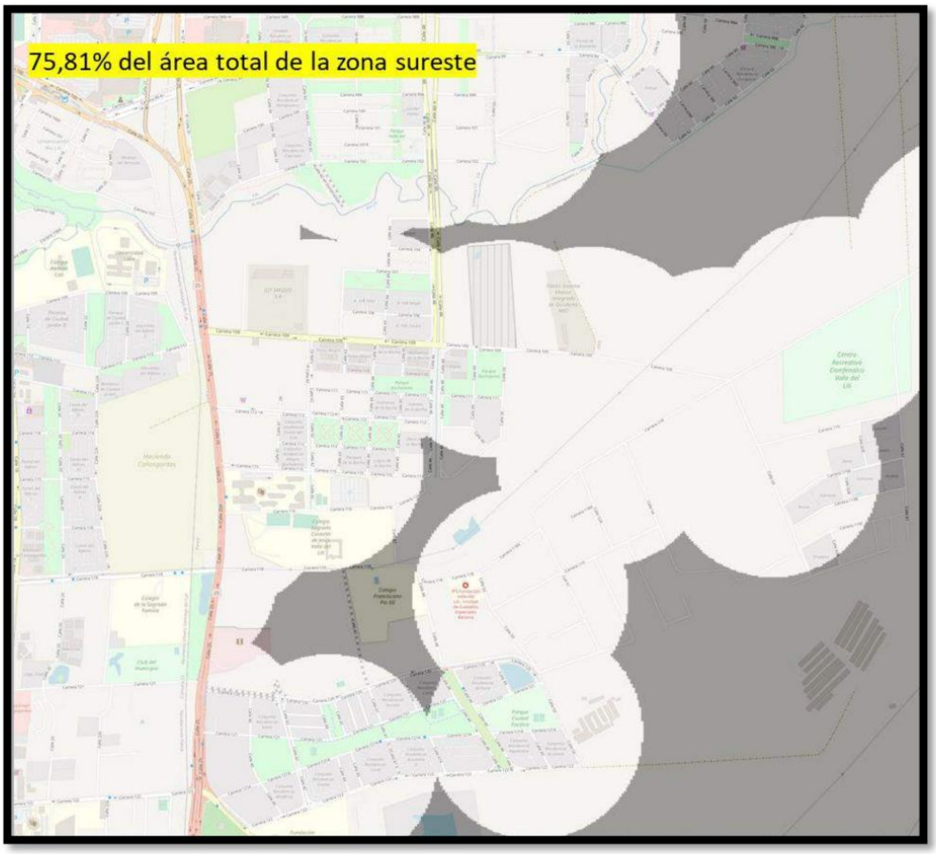


Figure 85 Southeast area with new route.

Table 17 Geographic and Cartesian coordinates result Dgis Software

var1	lon	The t	x meters	y meters
1	-76.5286	3.3666	-2438.9308	1.493E-13
2	-76.5233	3.3535	-985.3506	590.6447
3	-76.5199	3.3446	0.0000	974.9424
4	-76.5130	3.3456	-112.8264	1737.8585
5	-76.5135	3.3502	-614.9039	1684.8520
6	-76.5107	3.3548	-1126.3836	1995.3191
7	-76.5051	3.3544	-1085.0140	2618.1463

Table 18 Shows the distance from each row to each column, in total travel

Distance on Route Km	Stop 1	Stop two	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7
stop 1	0.000	1.711	3.329	4.127	4.816	5.545	6.464
stop 2	1,711	0,000	1,619	2,416	3,105	3,834	4,753
stop 3	3.329	1.619	0.000	0.798	1.486	2.215	3.134
Stop 4	4.127	2.416	0.798	0.000	0.689	1.418	2.337
stop 5	4.816	3.105	1.486	0.689	0.000	0.729	1.648
stop 6	5.545	3.834	2.215	1.418	0.729	0.000	0.919
stop 7	6.464	4.753	3.134	2.337	1.648	0.919	0.000

Table 19 This matrix is calculated by the program from the coordinates, it is the distance in a straight line that exists between each result node Dgis Software

Distance line straight km	Stop 1	Stop two	Stop 3	Stop 4	stop to 5	Stop 6	Stop 7
Stop 1	0,000	1,569	2,627	2,904	2,483	2,388	2,948
Stop 2	1,569	0,000	1,058	1,441	1,155	1,412	2,030
Stop 3	2.627	1.058	0.000	0.771	0.939	1.520	1.969
Stop 4	2.904	1.441	0.771	0.000	0.505	1.046	1.312
Stop 5	2.483	1.155	0.939	0.505	0.000	0.598	1.045
Stop 6	2.388	1.412	1.520	1.046	0.598	0.000	0.624
Stop 7	2.948	2.030	1.969	1.312	1.045	0.624	0.000

Table 20 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another in a straight line

time line straight Minute	Stop 1	Stop two	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7
Stop 1	0,000	7,242	12,123	13,401	11,460	11,023	13,604
Stop 2	7,242	0,000	4,881	6,652	5,332	6,516	9,369
Stop 3	12,123	4,881	0,000	3,559	4,335	7,015	9,088
Stop 4	13,401	6,652	3,559	0,000	2,330	4,827	6,053
Stop 5	11,460	5,332	4,335	2,330	0,000	2,762	4,823
Stop 6	11,023	6,516	7,015	4,827	2,762	0,000	2,881
Stop 7	13,604	9,369	9,088	6,053	4,823	2,881	0,000

Table 21 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another following the actual route of the route

time in route Minute	Stop 1	Stop two	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7
stop 1	0.000	7.895	15.366	19.047	22.226	25.590	29.833
Stop 2	7,895	0,000	7,471	11,152	14,332	17,695	21,938
Stop 3	15,366	7,471	0,000	3,681	6,860	10,224	14,467
Stop 4	19,047	11,152	3,681	0,000	3,179	6,543	10,786
Stop 5	22,226	14,332	6,860	3,179	0,000	3,364	7,607
Stop 6	25,590	17,695	10,224	6,543	3,364	0,000	4,243
Stop 7	29,833	21,938	14,467	10,786	7,607	4,243	0,000

Table 22 This matrix gives the route factor, which is nothing more than the division between the distance en route and the distance in a straight line, generating a quick way to see the similarity between the theoretical perfect straight line route and the real

Factor Route	Stop 1	Stop two	Stop 3	Stop 4	Stop 5	Stop 6	stop 7
Stop 1	0,000	1,090	1,268	1,421	1,939	2,322	2,193
Stop 2	1,090	0,000	1,531	1,676	2,688	2,716	2,342
Stop 3	1,268	1,531	0,000	1,034	1,583	1,458	1,592
Stop 4	1,421	1,676	1,034	0,000	1,364	1,356	1,782
Stop 5	1,939	2,688	1,583	1,364	0,000	1,218	1,577
Stop 6	2,322	2,716	1,458	1,356	1,218	0,000	1,473
Stop 7	2,193	2,342	1,592	1,782	1,577	1,473	0.000

Table 23 Percentage difference between the current route and the theoretical ideal straight line in percentages

% Come in route and straight	Stop 1	Stop two	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7
Stop 1	0,000	8,274	21,108	29,641	48,437	56,925	54,400
Stop 2	8,274	0,000	34,665	40,351	62,797	63,179	57,294
Stop 3	21,108	34,665	0,000	3,302	36,814	31,391	37,179
Stop 4	29,641	40,351	3,302	0,000	26,707	26,235	43,879
Stop 5	48,437	62,797	36,814	26,707	0,000	17,905	36,593
Stop 6	56,925	63,179	31,391	26,235	17,905	0,000	32,098
Stop 7	54,400	57,294	37,179	43,879	36,593	32,098	0,000

Table 24 summary table of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018

Name_ stop	sum_dist ancia_rect a	sum_dis tancia_ru ta	sum_tie mpo_rect a	sum_tie mpo_route	Sum_Indi ce_Trazad oTv
stop 1	14,918	25,991	68,853	119,957	10,233
stop 2	8,665	17,438	39,992	80,484	12,043
stop 3	8,884	12,582	41,001	58,070	8,464
stop 4	7,978	11,784	36,823	54,389	8,634
stop 5	6,726	12,473	31,042	57,568	10,370
stop 6	7,588	14,660	35,022	67,659	10,541
stop 7	9,927	19,256	45,818	88,873	10,958

Table 25 summary of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018

Name_ stop	Sum_Shi mbel	Sum_Fac tor_route	uno_dividi do_n_me us_1	Ri	uno_dividi Don
stop 1	twenty-one	10,233	0.050	0.512	0.048
stop 2	16	12,043	0.067	0.803	0.063
stop 3	13	8,464	0.083	0.705	0.077
stop 4	12	8,634	0.091	0.785	0.083
stop 5	13	10,370	0.083	0.864	0.077
stop 6	16	10,541	0.067	0.703	0.063
stop 7	twenty-one	10,958	0.050	0.548	0.048

Table 26 summary of the calculations made, shows accessibility indicators seen in the framework theoretical and used in the work you do in 2018

Name_ stop	sum_tie mpos_rut on time s_straight	trace_v speed_ node	Absolute_ Time_G global	Time_saw aje_until _node_my n	Factor_rut a_total
stop 1	1,742	0.083	119.957	29,833	1,742
stop 2	2,013	0.126	80.484 0.109	21,938	2,013
stop 3	1,416	58.070	0.123 54.389	14,467	1,416
stop 4	1,477	0.143	57.568 0.121	10,786	1,477
stop 5	1,855	67.659	0.098 88.873	7,607	1,855
stop 6	1,932			4,243	1,932
stop 7	1,940			0,000	1,940

8.2.9 Improving existing routes

In 2018, a topological study of public transport routes was carried out in a commune in the city of Santiago de Cali Colombia, at that time there was no DGIS, now in 2021 a comparison is made of one of those routes, against its alternatives. But this time using Dgis, which is more precise.

The existing route can be seen in Figure 86 and Figure 87 (which are equivalent to the previous topology tables, only this time the generated matrix is larger due to the number of stops evaluated.), the main characteristic of this route is that is circular, its topology is studied with Dgis.

The results obtained by Dgis, the tables from 27 to Table 34 are shown, it is important to highlight the travel time becomes greater between distant stops and the percentage of similarity that exists between the straight line distance and the real route distance , it is understood that the closer to 100% the more difference there is between the two, this percentage is quite close to 100% in many of the stops as they have a circular route.

Figure 86 Aerial view of the circular route studied.

Figure 87 Circular route studied.

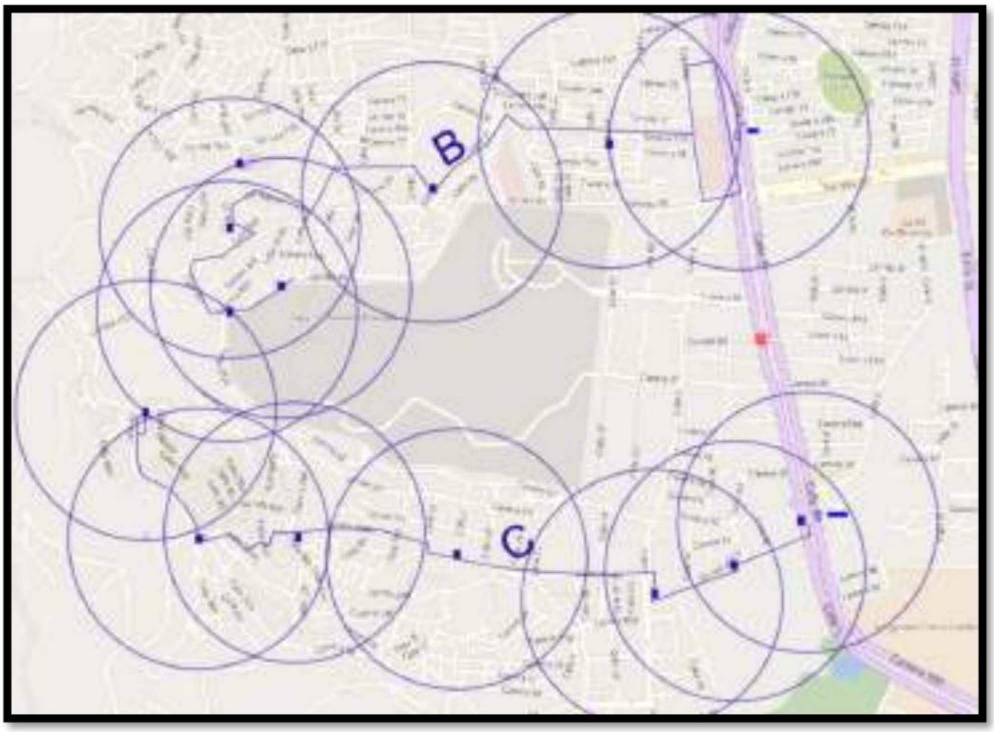


Figure 88 Two non-circular routes replace the circular one.

It is interesting how it is shown that Dgis is capable of operating routes with a certainly large number of stops (22 in this case), taking and mathematically operating each coordinate separately see. Table 27.

27 Geographic and Cartesian coordinates result Dgis Software

Address	lon	The t	x meters	y meters
MELENDEZ STATION	-76,543	3,378	-287,070 3,386	1787,571
Kr 80 between Cl 5 and 6A	-76,541	-1261,637		1955,037
Kr 80 between Cl 13 and 10A	-76,539	3,387	-1327,908	2157,143
Kr 80 between Cl 10A and 9	-76,542	3,387	-1281,354 3,387	1862,651
Cl 4 between Kr 80 and 78	-76,546	-1282,886		1445,917
Kr 78 between Cl 3D and 3A	-76,548	3,387	-1,363,125	1259,719
Kr 78 between Cl 3 and 2C	-76,549	3,387	-1375,553 3,386	1044,897
Cl 2B between Kr 78 and 80	-76,550	-1234,852		970,596
Cl 2A Bis between Kr 80 and 81	-76,553	3,385	-1120,627	691,616
Kr 83 on the Y	-76,554	3,384	-972,889 3,384	526,267
Kr 83 between Cl 1A1 and 1	-76,556	-979,011		314,873
Kr89 with Cl1BOe	-76,558	3,384	-949,987	145,887
Kr 83 with Cl 2C Oe	-76,559	3,383	-870,903 3,380	0.000
Cl 2C Oe with Kr 96	-76,558	-602,903		42,987
Cl 2B West between Kr 93Bis and 93A -76,557		3,378	-382,392	239,320
Kr 93A between Cl 2B and 1B West -76,555		3,378	-317,084 3,378	402,108
Kr 93 with Cl 1 -76.554		-310,836		580,847
Cl 2 between Kr 93 and 94	-76,552	3,377	-217,509	722,643
Kr 94 between Cls 2 and 2A	-76,552	3,376	-95,743	770,296
Cl 2C between Kr 94A and 95	-76,550	3,376	-62,666	941,365
Kr 94A between Cl 3A and 3B	-76,548	3,375	-61,085	1171,588
Kr 94 between Cl 4 and 4A	-76,547	3,375	0.000	1371,026

Dgis orders the data entered in a logical and coherent way, to later return ordered results that are easily interpreted by the professional, for example, in Table 28, you can search for the travel distance for a specific pair of stations just by looking at the reference point. intersection between the two.

Table 28 Shows the distance from each row to each column, in total travel

Distance en route Km	IS TION SCRUM NDEZ	kr80 Come in Cl 5 and 6A	kr80 Come in Cl 13 and 10A	kr80 Come in Cl 10A and 9	Cl4 Come in kr80 and 78	kr 78 Come in Cl 3D and 3A	kr 78 Come in Cl3 and 2 C	Cl2B Come in kr 78 and 80	Cl2A Bis Come in kr80 and 81	kr 83 in the Y	kr 83 Come in Cl 1A1 and 1	kr89 with Cl1B hey	kr 83 with Cl2C hey	Cl2C hey with kr96	Cl2B West Come in kr	kr 93A Come in Cl2B and 1B	kr 93 with Cl1	Cl2 Come in kr 93 and 94	kr94 Come in class 2 and 2A	Cl2C Come in kr 94A and 95	kr 94A Come in Cl 3A and 3B	kr94 Come in Cl4 and 4A
MELENDEZ STATION	0.000	7.048	5.687	5.329	5.030	4.554	4.313	4.098	3.459	3.210	2.998	2.823	2.645	2.336	2.024	1.805	1.617	1.387	1.210	1.036	0.5325	
Kr 80 between Cl 5 and 6A	1,361	0,000	6,689	6,391	5,915	5,674	5,459	5,198	4,819	4,571	4,359	4,184	4,006	3,697	3,385	3,166	2,977	2,748	2,571	2,396	1,8926	
Kr 80 between Cl 13 and 10A	1,719	0,359	0,000	6,680	6,204	5,963	5,748	5,487	5,109	4,860	4,648	4,473	4,295	3,986	3,674	3,455	3,267	3,037	2,860	2,686	2,455	
Kr 80 between Cl 10A and 9	2,018	0,657	0,299	0,000	6,274	6,033	5,817	5,556	5,178	4,929	4,717	4,543	4,365	4,055	3,744	3,525	3,336	3,107	2,930	2,755	2,514	
Cl 4 between Kr 80 and 78	2.494	1.133	0.774	0.476	0.000	0.216	0.261	0.378	0.249	0.212	0.175	0.178	0.309	0.312	0.219	0.189	0.229	0.177	0.175	0.231	0.503	
Kr 78 between Cl 3D and 3A	2,735	1,374	1,015	0,717	0,241	0,000	6,592	6,331	5,952	5,704	5,492	5,317	5,139	4,830	4,518	4,299	4,110	3,881	3,704	3,529	3,0259	
Kr 78 between Cl 3 and 2C	2,950	1,589	1,231	0,932	0,456	0,216	0,000	6,571	6,193	5,945	5,733	5,558	5,380	5,071	4,759	4,540	4,351	4,122	3,945	3,770	3,566	
Cl 2B between Kr 78 and 80	3,211	1,851	1,492	1,193	0,718	0,477	0,261	0,000	6,409	6,160	5,948	5,773	5,595	5,286	4,974	4,755	4,567	4,337	4,160	3,986	3,825	
Cl 2A Bis between Kr 80 and 81	3.589	2.229	1.870	1.571	1.096	0.855	0.639	0.378	0.000	6.421	6.209	6.034	5.856	5.547	5.235	5.016	4.828	4.598	4.421	4.247	3.7416	
Kr 83 on the Y	3.838	2.478	2.119	1.820	1.344	1.104	0.888	0.627	0.249	0.000	6.587	6.412	6.235	5.925	5.613	5.395	5.206	4.977	4.799	4.625	4.314	
Kr 83 between Cl 1A1 and 1	4,050	2,689	2,331	2,032	1,556	1,316	1,100	0,839	0,461	0,212	0,000	6,661	6,483	6,174	5,862	5,643	5,455	5,225	5,048	4,874	4,643	
Kr89 with Cl1BOe	4.225	2.864	2.506	2.207	1.731	1.490	1.275	1.014	0.636	0.387	0.175	0.000	6.695	6.386	6.074	5.855	5.667	5.437	5.260	5.086	4.855	
Kr 83 with Cl 2C Oe	4.403	3.042	2.683	2.385	1.909	1.668	1.453	1.192	0.814	0.565	0.353	0.178	0.000	6.561	6.249	6.030	5.842	5.612	5.435	4.261	5.7530	
Cl 2C Oe with Kr 96	4.712	3.351	2.993	2.694	2.218	1.977	1.762	1.501	1.123	0.874	0.662	0.487	0.309	0.000	0.310	6.208	6.019	5.790	5.438	5.4313		
CL 2B West between KR 93bis and 93a	5,024	3,663	3,305	3,006	2,530	2,289	2,074	1,813	1,435	1,186	0.974	0.799	0.621	0.312	0.000	6,517	6,329	6.099	5,922	5,748	5,517	5,517 5,517 5,517 5,517 5,517 5,517 5,517 5,517 5,517 5,517 5,517
KR 93A between CL 2B and 1B West	5,243	3,882	3,523	3,225	2,749	2,508	2,293	2,032	1,654	1,405	1,193	1,018	0.840	0.531	0.219	0.000	6,641	6,411	6,234	6,060	5,829	5,829 5,556
Kr 93 with Cl 1	5.431	4.071	3.712	3.413	2.938	2.697	2.481	2.220	1.842	1.593	1.381	1.206	1.029	0.719	0.407	0.189	0.000	6.630	6.7453	6.7453		
Cl 2 between Kr 93 and 94	5.661	4.300	3.941	3.643	3.167	2.926	2.711	2.450	2.072	1.823	1.611	1.436	1.258	0.949	0.637	0.418	0.229	0.000	6.642	6.467	5.9637	
Kr 94 between Cls 2 and 2A	5,838	4,477	4,119	3,820	3,344	3,103	2,888	2,627	2,249	2,000	1,788	1,613	1,435	1,126	0,814	0,595	0,406	0,177	0,000	6,696	6,1936	
Cl 2C between Kr 94A and 95	6.012	4.652	4.293	3.994	3.519	3.278	3.062	2.801	2.423	2.174	1.962	1.788	1.610	1.300	0.989	0.770	0.581	0.352	0.175	0.000	6.643	
Kr 94A between Cl 3A and 3B	6.243	4.882	4.524	4.225	3.749	3.508	3.293	3.032	2.654	2.405	2.193	2.018	1.840	1.531	1.219	1.000	0.812	0.582	0.405	0.231	6.0400	
Kr 94 between Cl 4 and 4A	6.516	5.156	4.797	4.498	4.023	3.782	3.566	3.305	2.927	2.678	2.466	2.291	2.114	1.804	1.492	1.274	1.085	0.855	0.678	0.504	0.0073	

Dgis calcula las distancias que existen entre dos puntos coordenados en el plano, en este caso son las paradas del sistema de transporte y luego las ordena y muestra una matriz para el uso del investigador, ahorrando extensos tiempos de cálculo manuales de distancia ver Tabla 29

Tabla 29 Esta matriz la calcula el programa a partir de las coordenadas, es la distancia en línea recta que existe entre cada nodo resultado Dgis Software

Distancia línea recta Km	ESTACION MELENDEZ	Kr 80 entre Cl 5 y 6A	Kr 80 entre Cl 13 y 10A	Kr 80 entre Cl 10A y 9	Cl 4 entre Kr 80 y 78	Kr 78 entre Cl 3D y 3A	Kr 78 entre Cl 3 y 2C	Cl 2B entre Kr 78 y 80	Cl 2A Bis entre Kr 80 y 81	Kr 83 en la Y	Kr 83 entre Cl 1A1 y 1	Kr 89 con Cl 1B Oe	Kr 83 con Cl 2C Oe	Cl 2C Oe con Kr 96	Cl 2B Oeste entre Kr 93Bis y 93A	Kr 93A entre Cl 2B y 1B Oeste	Kr 93 con Cl 1	Cl 2 entre Kr 93 y 94	Kr 94 entre Cls 2 y 2A	Cl 2C entre Kr 94A y 95	Kr 94A entre Cl 3A y 3B	Kr 94 entre Cl 4 y 4A
ESTACION MELENDEZ	0,000	0,989	1,105	0,997	1,053	1,199	1,318	1,251	1,377	1,436	1,627	1,770	1,880	1,773	1,551	1,386	1,207	1,067	1,035	0,875	0,656	0,506
Kr 80 entre Cl 5 y 6A	0,989	0,000	0,213	0,094	0,510	0,703	0,917	0,985	1,271	1,458	1,664	1,836	1,994	2,022	1,928	1,818	1,671	1,615	1,662	1,570	1,434	1,390
Kr 80 entre Cl 13 y 10A	1,105	0,213	0,000	0,298	0,713	0,898	1,113	1,190	1,480	1,669	1,875	2,046	2,205	2,235	2,138	2,025	1,876	1,814	1,855	1,755	1,605	1,543
Kr 80 entre Cl 10A y 9	0,997	0,094	0,298	0,000	0,417	0,608	0,823	0,893	1,182	1,372	1,577	1,748	1,907	1,942	1,856	1,750	1,608	1,559	1,612	1,528	1,402	1,372
Cl 4 entre Kr 80 y 78	1,053	0,510	0,713	0,417	0,000	0,203	0,412	0,478	0,772	0,970	1,171	1,342	1,503	1,559	1,506	1,422	1,301	1,288	1,366	1,320	1,252	1,285
Kr 78 entre Cl 3D y 3A	1,199	0,703	0,898	0,608	0,203	0,000	0,215	0,316	0,618	0,831	1,020	1,188	1,352	1,435	1,415	1,353	1,252	1,265	1,359	1,339	1,305	1,368
Kr 78 entre Cl 3 y 2C	1,318	0,917	1,113	0,823	0,412	0,215	0,000	0,159	0,436	0,657	0,831	0,995	1,160	1,265	1,279	1,238	1,161	1,202	1,309	1,317	1,321	1,414
Cl 2B entre Kr 78 y 80	1,251	0,985	1,190	0,893	0,478	0,316	0,159	0,000	0,301	0,516	0,704	0,873	1,037	1,122	1,123	1,080	1,003	1,047	1,157	1,173	1,191	1,298
Cl 2A Bis entre Kr 80 y 8	1,377	1,271	1,480	1,182	0,772	0,618	0,436	0,301	0,000	0,222	0,402	0,572	0,735	0,830	0,866	0,854	0,817	0,904	1,028	1,087	1,163	1,310
Kr 83 en la Y	1,436	1,458	1,669	1,372	0,970	0,831	0,657	0,516	0,222	0,000	0,211	0,381	0,536	0,609	0,657	0,667	0,664	0,780	0,910	1,000	1,117	1,288
Kr 83 entre Cl 1A1 y 1	1,627	1,664	1,875	1,577	1,171	1,020	0,831	0,704	0,402	0,211	0,000	0,171	0,333	0,464	0,601	0,668	0,719	0,864	0,994	1,110	1,256	1,440
Kr 89 con Cl 1B Oe	1,770	1,836	2,046	1,748	1,342	1,188	0,995	0,873	0,572	0,381	0,171	0,000	0,166	0,362	0,575	0,683	0,773	0,932	1,058	1,192	1,357	1,550
Kr 83 con Cl 2C Oe	1,880	1,994	2,205	1,907	1,503	1,352	1,160	1,037	0,735	0,536	0,333	0,166	0,000	0,271	0,544	0,684	0,807	0,974	1,093	1,241	1,424	1,624
Cl 2C Oe con Kr 96	1,773	2,022	2,235	1,942	1,559	1,435	1,265	1,122	0,830	0,609	0,464	0,362	0,271	0,000	0,295	0,459	0,612	0,781	0,887	1,048	1,252	1,458
Cl 2B Oeste entre Kr 93B	1,551	1,928	2,138	1,856	1,506	1,415	1,279	1,123	0,866	0,657	0,601	0,575	0,544	0,295	0,000	0,175	0,349	0,511	0,603	0,771	0,986	1,195
Kr 93A entre Cl 2B y 1B (	1,386	1,818	2,025	1,750	1,422	1,353	1,238	1,080	0,854	0,667	0,668	0,683	0,684	0,459	0,175	0,000	0,179	0,336	0,430	0,596	0,811	1,019
Kr 93 con Cl 1	1,207	1,671	1,876	1,608	1,301	1,252	1,161	1,003	0,817	0,664	0,719	0,773	0,807	0,612	0,349	0,179	0,000	0,170	0,287	0,438	0,641	0,849
Cl 2 entre Kr 93 y 94	1,067	1,615	1,814	1,559	1,288	1,265	1,202	1,047	0,904	0,780	0,864	0,932	0,974	0,781	0,511	0,336	0,170	0,000	0,131	0,268	0,475	0,684
Kr 94 entre Cls 2 y 2A	1,035	1,662	1,855	1,612	1,366	1,359	1,309	1,157	1,028	0,910	0,994	1,058	1,093	0,887	0,603	0,430	0,287	0,131	0,000	0,174	0,403	0,608
Cl 2C entre Kr 94A y 95	0,875	1,570	1,755	1,528	1,320	1,339	1,317	1,173	1,087	1,000	1,110	1,192	1,241	1,048	0,771	0,596	0,438	0,268	0,174	0,000	0,230	0,434
Kr 94A entre Cl 3A y 3B	0,656	1,434	1,605	1,402	1,252	1,305	1,321	1,191	1,163	1,117	1,256	1,357	1,424	1,252	0,986	0,811	0,641	0,475	0,403	0,230	0,000	0,209
Kr 94 entre Cl 4 y 4A	0,506	1,390	1,543	1,372	1,285	1,368	1,414	1,298	1,310	1,288	1,440	1,550	1,624	1,458	1,195	1,019	0,849	0,684	0,608	0,434	0,209	0,000

Tabla 30 En esta matriz se tiene el tiempo de recorrido teórico que tardaría un vehículo en ir de un nodo a otro en línea recta

Tiempo línea recta Minuto	ESTACION MELENDEZ	Kr 80 entre Cl 5 y 6A	Kr 80 entre Cl 13 y 10A	Kr 80 entre Cl 10A y 9	Cl 4 entre Kr 80 y 78	Kr 78 entre Cl 3D y 3A	Kr 78 entre Cl 3 y 2C	Cl 2B entre Kr 78 y 80	Cl 2A Bis entre Kr 80 y 81	Kr 83 en la Y	Kr 83 entre Cl 1A1 y 1	Kr 89 con Cl 1B Oe	Kr 83 con Cl 2C Oe	Cl 2C Oe con Kr 96	Cl 2B Oeste entre Kr	Kr 93A entre Cl 2B y 1B	Kr 93 con Cl 1	Cl 2 entre Kr 93 y 94	Kr 94 entre Cls 2 y 2A	Cl 2C entre Kr 94A y 95	Kr 94A entre Cl 3A y 3B	Kr 94 entre Cl 4 y 4A
ESTACION MELENDEZ	0,000	4,564	5,098	4,602	4,859	5,532	6,082	5,775	6,355	6,626	7,510	8,171	8,679	8,183	7,159	6,396	5,571	4,926	4,777	4,041	3,028	2,335
Kr 80 entre Cl 5 y 6A	4,564	0,000	0,982	0,436	2,352	3,243	4,233	4,545	5,867	6,728	7,682	8,473	9,202	9,334	8,898	8,389	7,713	7,455	7,672	7,246	6,616	6,417
Kr 80 entre Cl 13 y 10A	5,098	0,982	0,000	1,376	3,289	4,145	5,138	5,493	6,831	7,703	8,654	9,445	10,177	10,315	9,869	9,348	8,658	8,373	8,562	8,099	7,408	7,122
Kr 80 entre Cl 10A y 9	4,602	0,436	1,376	0,000	1,923	2,808	3,799	4,123	5,455	6,330	7,279	8,070	8,803	8,963	8,564	8,078	7,420	7,197	7,441	7,051	6,472	6,334
Cl 4 entre Kr 80 y 78	4,859	2,352	3,289	1,923	0,000	0,936	1,900	2,205	3,561	4,479	5,405	6,194	6,939	7,196	6,949	6,563	6,006	5,943	6,304	6,094	5,779	5,931
Kr 78 entre Cl 3D y 3A	5,532	3,243	4,145	2,808	0,936	0,000	0,993	1,460	2,851	3,834	4,707	5,483	6,242	6,622	6,532	6,243	5,780	5,840	6,270	6,179	6,023	6,312
Kr 78 entre Cl 3 y 2C	6,082	4,233	5,138	3,799	1,900	0,993	0,000	0,734	2,011	3,030	3,834	4,591	5,356	5,840	5,902	5,716	5,361	5,548	6,041	6,078	6,095	6,525
Cl 2B entre Kr 78 y 80	5,775	4,545	5,493	4,123	2,205	1,460	0,734	0,000	1,391	2,381	3,249	4,027	4,784	5,180	5,184	4,983	4,629	4,833	5,338	5,412	5,496	5,991
Cl 2A Bis entre Kr 80 y 81	6,355	5,867	6,831	5,455	3,561	2,851	2,011	1,391	0,000	1,023	1,858	2,639	3,394	3,830	3,996	3,942	3,772	4,171	4,744	5,017	5,369	6,048
Kr 83 en la Y	6,626	6,728	7,703	6,330	4,479	3,834	3,030	2,381	1,023	0,000	0,976	1,759	2,474	2,809	3,030	3,081	3,066	3,602	4,202	4,617	5,156	5,947
Kr 83 entre Cl 1A1 y 1	7,510	7,682	8,654	7,279	5,405	4,707	3,834	3,249	1,858	0,976	0,000	0,791	1,537	2,142	2,776	3,081	3,319	3,987	4,587	5,123	5,795	6,647
Kr 89 con Cl 1B Oe	8,171	8,473	9,445	8,070	6,194	5,483	4,591	4,027	2,639	1,759	0,791	0,000	0,766	1,671	2,655	3,151	3,568	4,303	4,884	5,500	6,264	7,155
Kr 83 con Cl 2C Oe	8,679	9,202	10,177	8,803	6,939	6,242	5,356	4,784	3,394	2,474	1,537	0,766	0,000	1,253	2,511	3,159	3,724	4,496	5,044	5,726	6,573	7,497
Cl 2C Oe con Kr 96	8,183	9,334	10,315	8,963	7,196	6,622	5,840	5,180	3,830	2,809	2,142	1,671	1,253	0,000	1,363	2,118	2,825	3,606	4,092	4,838	5,778	6,731
Cl 2B Oeste entre Kr 93Bi	7,159	8,898	9,869	8,564	6,949	6,532	5,902	5,184	3,996	3,030	2,776	2,655	2,511	1,363	0,000	0,810	1,611	2,357	2,785	3,560	4,551	5,513
Kr 93A entre Cl 2B y 1B O	6,396	8,389	9,348	8,078	6,563	6,243	5,716	4,983	3,942	3,081	3,081	3,151	3,159	2,118	0,810	0,000	0,825	1,549	1,983	2,752	3,743	4,705
Kr 93 con Cl 1	5,571	7,713	8,658	7,420	6,006	5,780	5,361	4,629	3,772	3,066	3,319	3,568	3,724	2,825	1,611	0,825	0,000	0,783	1,323	2,020	2,960	3,919
Cl 2 entre Kr 93 y 94	4,926	7,455	8,373	7,197	5,943	5,840	5,548	4,833	4,171	3,602	3,987	4,303	4,496	3,606	2,357	1,549	0,783	0,000	0,603	1,237	2,194	3,156
Kr 94 entre Cls 2 y 2A	4,777	7,672	8,562	7,441	6,304	6,270	6,041	5,338	4,744	4,202	4,587	4,884	5,044	4,092	2,785	1,983	1,323	0,603	0,000	0,804	1,859	2,808
Cl 2C entre Kr 94A y 95	4,041	7,246	8,099	7,051	6,094	6,179	6,078	5,412	5,017	4,617	5,123	5,500	5,726	4,838	3,560	2,752	2,020	1,237	0,804	0,000	1,063	2,004
Kr 94A entre Cl 3A y 3B	3,028	6,616	7,408	6,472	5,779	6,023	6,095	5,496	5,369	5,156	5,795	6,264	6,573	5,778	4,551	3,743	2,960	2,194	1,859	1,063	0,000	0,963
Kr 94 entre Cl 4 y 4A	2,335	6,417	7,122	6,334	5,931	6,312	6,525	5,991	6,048	5,947	6,647	7,155	7,497	6,731	5,513	4,705	3,919	3,156	2,808	2,004	0,963	0,000

Como en Dgis, se puede introducir la velocidad media de circulación del sistema de transporte en la ciudad, se determina fácilmente los tiempos en minutos que tarda el sistema en cubrir the distance, both theoretically straight, see Table 30, and the time it takes to cover it in actual travel, see Table 31.

It is important to emphasize that the software returns results according to the data entered, for example, it is evident that for the stop located Cl 4 between kr 80 and 78, there is an error in the city database, therefore the software gives erroneous data in its individual calculation, although this does not affect the rest, since Dgis was designed thinking that this could happen with old databases and each calculation operates independently. See Table 31.

Table 31 In this matrix there is the theoretical travel time that a vehicle would take to go from one node to another following the actual route of the route, in red the longest time and in green the shortest travel time, there is an error in the coordinate provided by the city transport entity in item Cl 4 between kr 80 and 78, this error is not suppressed because the

supplied coordinates and it has not been wanted to find the real coordinate using the Dgis software, which is done with the routes new

Time en route Minute	THIS C ION SCRUM NDEZ	kr80 Come in Cl 5 and 6A	kr80 Come in Cl 13 and 10A	kr80 Come in Cl 10A and 9	Cl4 Come in kr80 and 78	kr 78 Come in Cl 3D and 3A	kr 78 Come in Cl3 and 2 C	Cl2B Come in kr 78 and 80	Cl2A Bis Come in kr80 and 81	kr 83 in the Y	kr 83 Come in Cl 1A1 and 1	kr89 with Cl 1B Oe	Kr 83 with Cl 2C Oe	Cl2C hey with kr96	Cl2B West Come in kr 93Bis	kr 93A Come in Cl2B and 1B	Kr 93 with Cl 1	Cl2 Come in kr 93 and 94	kr94 Come in class 2 and 2A	Cl2C Come in kr 94A and 95	kr 94A Come in Cl3A and 3B	kr94 Come in Cl4 and 4A		
MELENDEZ STATION	0.000	32,530	26,249	24,594	23,215	21,020	19,908	18,913	15,963	14,815	13,837	13,030	12,209	10,782	9,342	8,332	7,461	6,403	5,585	4,780	3,716	2,454		
Kr 80 between Cl 5 and 6A	6,280	0.000	30,874	29,496	27,300	26,188	25,193	23,989	22,244	21,095	20,117	19,310	18,489	17,062	15,622	14,612	13,742	12,683	11,865	11,060	9,996	8,734		
KR 80 Between CL 13 and 10A	7,936	1,655	0.000	30,831	28,635	27,523	26,529	25,324	23,579	22,430	21,452	20,645	19,824	18,397	16,957	15,947	15,077	14,018	13,201	12,395	11,331	10.069		
KR 80 BETS CL 10A AND 9	9,314	3,034	1,379	0.000	28.956	27,844	26,849	25,644	23,899	22,750	21,772	20,965	20,144	18,718	17,278	16,267	15,397	14,338	13,521	12,715	11,651	10,390	10,390	10,390
Cl 4 between Kr 80 and 78	11.510	5.229	3.574	2.195	0.000	0.995	1.205	1.745	1.149	0.978	0.807	0.821	1.427	1.440	1.010	0.870	1.059	0.106467	12628					
KR 78 Between CL 3D and 3a	12,621	6,341	4,686	3,307	1,112	0.000	30,423	29,218	27,473	26,324	25,346	24,539	23,718	22,291	20,852	19,841	18,971	17,912	17,095	16,289	15,225	13,964		
KR 78 Between CL 3 and 2C	13,616	7,336	5,681	4,302	2,107	0.995	0.000	30,330	28,585	27,436	26,458	25,651	24,830	23,403	21,964	20,953	20,083	19,024	18,207	17,401	16,337	15,075		
CL 2B BETWE KR 78 AND 80	14,821	8,541	6,886	5,507	3,312	2,200	1,205	0.000	29,580	28,431	27,453	26,646	25,825	24,398	22,958	21,948	21,078	20,019	19,202	18,396	17,332	16,070		
CL 2A BIS BET -BR 80 AND 81	16.566	10,286	8,631	7,252	5,057	3,945	2,950	1,745	0.000	29,636	28,658	27,851	27,030	25,603	24,163	23,153	22,283	21,224	20,406	19,601	18,537	17,275		
KR 83 at the Y	17,715	11,435	9,779	8,401	6,205	5,093	4,099	2,894	1,149	0.000	30,403	29,596	28,775	27,348	25,908	24,898	24,028	22,969	22,151	21,346	20,282			
KR 83 Between CL 1A1 and 1	18,693	12,413	10,758	9,379	7,184	6,072	5,077	3,872	2,127	0.978	0,000	30,745	29,924	28,497	27,057	26,047	25,176	24,117	23,300	22,495	21,431	20,169		
KR 89 with CL 1B OE	19,500	13,220	11,564	10,186	7,990	6,878	5,883	4,679	2,934	1,785	0.807	0.000	30,902	29,475	28,035	27,025	26,155	25,096	24,278	23,473	22,409	21,147		
Kr 83 with Cl 2C Oe	20,321	14,041	12,385	11,007	8,811	7,699	6,704	5,500	3,755	2,606	1,628	0,821	0,000	30,282	28,842	27,832	26,961	25,902	25,295	25,295	23,085	25,085		
CL 2C OE with KR 96	21,748	15,467	13,812	12,433	10,238	9,126	8,131	6,927	5,182	4,033	3,055	2,248	1,427	0.000	1,431	28,653	27,782	26,723	25,906	25,100	24,037	22,775		
CL 2B West between KR 93bis and 93a	23,187	16,907	15,252	13,873	11,678	10,566	9,571	8,366	6,621	5,473	4,494	3,688	2,867	1,440	0.000	30,080	29,209	28,150	27,333	26,527	25.463	25,463	24.202	
KR 93A BETS CL 2B AND 1B OEST	24,198	17,918	16,262	14,884	12,688	11,576	10,581	9,377	7,632	6,483	5,505	4,698	3,877	2,450	1,010	0.000	30,649	29,590	28,773	27,967	26,967	26,967	26,967	
KR 93 with CL 1	25,068	18,788	17,133	15,754	13,559	12,447	11,452	10,247	8.502	7,353	6,375	5,568	4,747	3,320	1,881	0.870	0.000	30,600	29,783	28,977	27,913	26,652		
CL 2 BETWE KR 93 AND 94	26,127	19,847	18,192	16,813	14,618	13,506	12,511	11,306	9,561	8,412	7,434	6,627	5,806	4,379	2,940	1,929	1,059	0.000	30,653	29,848	28,784	27,52222222222222		
KR 94 Between CLS 2 and 2a	26,944	20,664	19,009	17,630	15,435	14,323	13,328	12,123	10,378	9,229	8,251	7,445	6,623	5,197	3,757	2,747	1,876	0.817	0.000	30,907	29,843	28,581	28,581	
CL 2C BETWE KR 94A AND 95	27,750	21,470	19,814	18,436	16,240	15,129	14.134	12,929	11,184	10,035	9,057	8,250	7,429	6,002	4,562	3,552	2,682	1,623	0.806	0.000	30,660	29,398		
KR 94a Between CL 3A and 3B	28,814	22,534	20,878	19,500	17,304	16,192	15,198	13,993	12,248	11,099	10,121	9,314	8,493	7,066	5,626	4,616	3,746	2,687	1,870	1,064	0.000	30,204		
KR 94 Between CL 4 and 4A	30,076	23,795	22,140	20,761	18,56	17,454	16,459	15,254	13,509	12,361	11,382	10,576	9,755	8,328	6,888	5,878	5,007	3,948	3,131	2,326	1,262	0.000	0.000	

Table 32 This matrix gives the route factor, which is nothing more than the division between the distance en route and the distance in a straight line, generating a quick way to see the similarity between the theoretical perfect straight line route and the

Route Factor	THIS C ION SCRUM NDEZ	kr80 Come in Cl 5 and 6A	kr80 Come in Cl 13 and 10A	kr80 Come in Cl 10A and 9	Cl4 Come in kr80 and 78	kr 78 Come in Cl 3D and 3A	kr 78 Come in Cl3 and 2 C	Cl2B Come in kr 78 and 80	Cl2A Bis Come in kr80 and 81	kr 83 Cl in the Y	kr 83 Come in 1A1 and 1	kr89 with Cl 1B Oe	kr 83 with Cl 2C Oe	Cl2C Oe with kr96	Cl2B West Come in kr 93Bis	kr 93A Come in Cl 2B and 1B	kr 93 with Cl 1	Cl2 Come in kr 93 and 94	kr94 Come in class 2 and 2A	Cl2C Come in kr 94A and 95	kr 94A Come in Cl3A and 3B	kr94 Come in Cl4 and 4A	
MELENDEZ STATION	0.000	7.128	5.149	5.344	4.778	3.800	3.273	3.275	2.512	2.236	1.842	1.595	1.407	1.318	1.305	1.303	1.339	1.300	1.169	1.183	1.0517		
KR 80 BETS CL 5 AND 6A	1,376	0.000	31,451	67,650	11,608	8,075	5,951	5,278	3,791	3,136	2,619	2,279	2,009	1,828	1,756	1,742	1,782	1,701	1,547	1,526	1,511	1,361	1,361
KR 80 Between CL 13 and 10A	1,557	1,686	0.000	22,405	8,706	6,640	5,163	4,610	3,452	2,912	2,479	2,186	1,948	1,783	1,718	1,706	1,741	1,674	1,542	1,531	1,530	1,414	1,414
Kr 80 between Cl 10A and 9	2.024	6.959	1.002	0.000	15.054	9.915	7.067	6.220	4.381	3.594	2.991	2.598	2.288	2.088	2.017	2.014	2.075	1.8092	1.8092	1.8092			
Cl 4 between Kr 80 and 78	2.369	2.224	1.087	1.141	0.000	1.063	0.634	0.791	0.323	0.218	0.149	0.133	0.206	0.200	0.145	0.133	0.176	0.137	0.1858				
KR 78 Between CL 3D and 3a	2,282	1,955	1,130	1,178	1,188	0.000	30,633	20,014	9,637	6,865	5,384	4,476	3,800	3,366	3,192	3,178	3,282	3,067	2,726	2,636	2,636	2,528	2,212 2,212
Kr 78 between Cl 3 and 2C	2.239	1.733	1.106	1.132	1.109	1.002	0.000	41.300	14.216	9.054	6.900	5.588	4.636	4.008	3.721	3.666	3.746	2.360	2.80124	3.8129			
CL 2B between KR 78 and 80	2,56,879	1,253	1,336	1,502	1,50,641	0.000	21,260	11,943	8,451	6,617	5,398	4,710	4,429	4,405	4,554	4,142	3,597	3,399	3,153	2,153	2,6822222222222	2,682	
CL 2A BIS BET -BR 80 AND 81	2,607	1,753	1,263	1,329	1,420	1,384	1,46,254	0.000	28,958	15,427	10,554	7,965	6,684	6,047	5,873	5,907	5,089	4,301	3,907	3,907	3,453	2,453	2,453
Kr 83 on the Y	2,673	1,700	1,269	1,327	1,385	1,328	1,352	1,216	1,122	0,000	31,148	16,828	11,630	9,735	8,550	8,082	7,837	6,376	34,933	34,937	34,9371		
KR 83 Between CL 1A1 and 1	2,489	1,616	1,243	1,289	1,329	1,290	1,324	1,192	1,145	1,002	0.000	38,851	19,475	13,304	9,748	8,453	7,585	6,049	5,080	4,391	3,698	3.034	
Kr 89 with Cl 1B Oe	2,386	1,560	1,224	1,262	1,290	1,254	1,282	1,162	1,112	1,015	1,019	0,000	40,347	17,641	10,560	8,576	7,330	4,597	3,5732	4,5732	4,5732		
Kr 83 with Cl 2C Oe	2,341	1,526	1,217	1,250	1,270	1,233	1,252	1,150	1,106	1,053	1,059	1,072	0,000	24,172	11,488	8,811	7,240	5,761	4,974	4,240	3,5292		
Cl 2C Oe with Kr 96	2,658	1,657	1,339	1,387	1,423	1,378	1,392	1,337	1,353	1,436	1,426	1,345	1,139	0,000	1,050	13,526	9,835	7,411	6,330	5,188	4,3830		
CL 2B West between KR 93bis and 93a	3,239	1,900	1,545	1,620	1,681	1,618	1,622	1,614	1,657	1,806	1,619	1,389	1,142	1,057	0.000	37,156	18,137	11,943	9,814	7,451	5,595	4.390	
KR 93A between CL 2B and 1B west	3,783	2,136	1,740	1,843	1,933	1,854	1,851	1,882	1,936	2,104	1,786	1,491	1,227	1,157	1,248	0.000	37.130	19,101	14,511	10,163	7,188	5,449	
Kr 93 with Cl 1	4,500	2,436	1,979	2,123	2,258	2,154	2,136	2,214	2,254	2,398	1,921	1,561	1,275	1,175	1,168	1,055	0,000	39,057	22,830	69,513			
CL 2 BETWE KR 93 AND 94	5,304	2,662	2,173	2,336	2,460	2,313	2,255	2,339	2,292	2,335	1,865	1,540	1,291	1,214	1,247	1,245	1,352	0.000	50.793	24,132	13,118	8,719	
KR 94 Between CLS 2 and 2nd	5,640	2,694	2,220	2,369	2,448	2,284	2,206	2,271	2,188	2,196	1,799	1,524	1,313	1,270	1,349	1,385	1,418	1,354	0.000	38.433	16,053	10,180	
CL 2C between KR 94A and 95	6,868	2,963	2,447	2,615	2,665	2,448	2,325	2,389	2,229	2,173	1,768	1,500	1,297	1,241	1,281	1,291	1,328	1,312	1,002	0.000	28,854	14,670	
KR 94a between CL 3A and 3B	9,515	3,406	2,818	3,013	2,994	2,688	2,493	2,546	2,281	2,153	1,746	1,487	1,292	1,223	1,236	1,233	1,265	1,224	1,006	1,001	0.000	31,375	
Kr 94 between Cl 4 and 4A	12.881	3.708	3.109	3.278	3.130	2.765	2.523	2.546	2.234	2.079	1.713	1.478	1.301	1.237	1.249	1.249	1.278	1.01051	1.01051				

It is interesting to be able to see the theoretical difference that exists between the ideal route in a straight line and the route that really exists or may come to exist due to the conditions that mark reality, which is why Dgis throws up a matrix that relates these two parameters and gives their similarity in percentage see Table 33

The idea of these matrices is to serve the researcher as a guiding pattern when making their routes, Dgis gives a summary table that sums the rows of each matrix, where you can see such interesting data as the total travel time that a user can undergo when using the evaluated route see Table 34

Table 33 Percentage difference that exists between the current route and the straight theoretical ideal in percentages. The closer to 100%, the more both distances differ.

% between route and straight	STATION ON MELENDEZ	kr80 Come in Cl 5 and 6A	kr80 Come in Cl 13 and 10A	kr80 Come in Cl10A and 9	Cl4 Come in kr 80 and 78	kr 78 Come in Cl 3D and 3A	kr 78 Come in Cl3 and 2 C	Cl2B Come in kr 78 and 80	Cl2A encore between kr 80 and 81	kr 83 at the Y	kr 83 Come in Cl 1A1 and 1	Kr 89 with Cl 1B Oe	Kr 83 with Cl 2C Oe	Cl2C Oe with Kr 96	Cl2B West Come in kr 93Bis and 93A	Kr 93A between Cl 2B and 1 B West	kr 93 with Cl 1	Cl2 Come in kr 93 and 94	kr94 Come in class 2 and 2A	Cl2C Come in Kr94A Cl3Ayy9	Kr94A Come in 3B	kr94 Come in Cl4 and 4A		
MELENDEZ STATION	0,000	85,970	80,580	81,288	79.070	73,683	69,451	69,465	60,190	55,272	45,724	37,287	28,910	24,106	23,366	23,236	25,342	23,069	14,465	15,464	18,502	4,57	4,857	4,857
KR 80 BETS CL 5 AND 6A	27,328	0.000	96.820	98,522	91,385	87,616	83,196	81,052	73,622	68,108	61,815	56,122	50,231	45,295	43,043	42,588	43,874	41,219	35,344	34.344				
KR 80 BETS CL 13 AND 10A	35,761	40,700	0.000	95,537	88.514	84,940	80,632	78,308	71,028	65,656	59,659	54,250	48,663	43,929	41,803	41,384	42,573	40,272	35,138	34,662	34,623			
KR 80 BETS CL 10A AND 9	50,591	85,629	0.183	0.000	93,357	89,914	85,850	83,923	77,173	72,176	66,569	61,509	56,300	52.113	50,431	50,345	51,806	49,807	44,970	44,546	44.449	39,032		
Cl 4 between Kr 80 and 78	57.782	55.026	7.969	12.387	0.000	5.943	49.601																	
KR 78 BETWEEN																								
KR 78 Between CL 3 and 2C	55,335	42,294	9,551	11,690	9,833	0.177	0.000	97,579	92,966	88,955	85,508	82,104	78,431	75.048	73,128	72,723	73,308	70,837	66,819	65,069	62,693	56,693	56,69.	
CL 2B BETWEEN																								
CL 2A BIS BET -BR 80 AND 81	61,638	42,957	20,848	24,773	29,577	27,729	31,836	20,267	0.000	96,547	93,518	90,525	87,444	85.039	83,463	82,974	83,071	80,349	76,752	74,404	71,98			
KR 83 at the Y	62,595	41,164	21,227	24,648	27,817	24,717	26,060	17,731	10,909	0.000	96,790	94,057	91,402	89,728	88,304	87,627	87,240	84,317	81,030	78,369	74,580	68,735		
KR 83 Between CL 1A1 and 1	59,825	38,116	19,555	22,394	24,754	22,469	24,473	16,099	12,664	0.222	0.000	97,426	94,865	92,484	89,742	88,169	86,816	83,469	80,315	77,224	72.959	67,059	67,959 6	
KR 89 with CL 1B OE	58,095	35,906	18,323	20,772	22,483	20,285	21,972	13,926	10,041	1,461	1,891	0.000	97,522	94,331	90.530	88,339	86,357	82,854	79,885	76,568	72,045 6			
KR 83 with CL 2C OE	57,289	34,464	17,829	20,020	21,248	18,926	20,119	13,008	9,611	5,059	5,600	6,722	0.000	95,863	91,295	88,650	86,187	82,641	79,893	76,414	71,685	65,853		
CL 2C OE with KR 96	62,374	39,655	25,316	27,911	29,718	27,443	28,185	25,210	26,076	30,343	29,877	25,673	12,205	0.000	4,759	92,607	89.832	86.506	84.203	80,724	75,961	70,443		
CL 2B West between KR 93bis and 93a	69,124	47,372	35,295	38,267	40,496	38,178	38,334	38,041	39,651	44,631	38,242	28,007	12,418	5,355	0.000	97,309	94,486	91,627	89,811	827,21,21,21,21,8.				
KR 93A BETWEEN																								
KR 93 with CL 1	77,778	58,949	49,464	52,898	55,705	53,564	53,191	54,830	55,631	58,305	47,934	35,921	21,555	14,928	14,366	5,169	0.000	97,440	95,558	93,029,295	85,29			
CL 2 BETWEEN																								
KR 94 Between CLS 2 and 2a	82,269	62,874	54,956	57,796	59,155	56,221	54,672	55,968	54,287	54,470	44,413	34,400	23,851	21,250	25,869	27,810	29,488	26,147	0.000	97,398	93,771,10,77			
CL 2C BETWEEN																								
KR 94a between CL 3A and 3B	89,490	70,637	64,519	66,807	66,601	62,803	59,895	60,721	56,167	53,548	42,740	32,743	22,603	18,229	19,110	18,918	20,972	18.331	0.564	0.124	0.1.			
KR 94 Between CL 4 and 4A	92,237	73,035	67,831	69,490	68,054	63,835	60,358	60,723	55,228	51,890	41,606	32,344	23,150	19,170	19,958	19,949	21,736	20,059	10,338	13,829,01,701				

Table 34, summary of the calculations carried out, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018, here the row that gives an error has been deleted because it would carry an error in the others, all because of a wrong coordinate supplied.

stop_name	Addition_distance_rect a	Addition_distance_route	sum_time_recta	Sum_time_route	Sum_In says_TrazadoTv	Sum_Shimbel	Addition_Factor_route	uno_divido_n_Minus 1	Ri	one_divivid_n	addition_weathers_route_time os_rec	trace o_velocity_node	absolute o_Time po_Glob	time o_trip_until_node_min	Factor_route_total
MELENDEZ STATION	26.058	63.947	120.269	295.138	53.533	231.000	53.533	0.004348	0.233	0.004	2.454	0.011	295.138	2.454	2.454
Kr 80 between Cl 5 and 6A	27.743	83.623	128.046	385.951	159.976	211,000	159.976	0.004762	0.762	0.005	3.014	0.014	385.951	8.734	3.014
Kr 80 between Cl 13 and 10A	31.652	83.147	146.085	383.755	78.382	193.000	78.382	0.005208	0.408	0.005	2.627	0.014	383.755	10.069	2.627
Kr 80 between Cl 10A and 9	26.547	78.612	122.525	362.825	81.341	177.000	81.341	0.005682	0.462	0.006	2.961	0.017	362.825	10.390	2.961
Cl 4 between Kr 80 and 78	21.842	11.208	100.808	51.730	13.634	163.000	13.634	0.006173	0.084	0.006	0.513	0.003	51.730	11.768	0.513
Kr 78 between Cl 3D and 3A	21.241	81.802	98.037	377.550	114.730	151.000	114.730	0.006667	0.765	0.007	3.851	0.026	377.550	13.964	3.851
Kr 78 between Cl 3 and 2C	20.541	80.118	94.806	369.775	119.453	141.000	119.453	0.007143	0.853	0.007	3.900	0.028	369.775	15.075	3.900
Cl 2B between Kr 78 and 80	18.896	78.392	87.213	361.807	100.423	133.000	100.423	0.007576	0.761	0.008	4.149	0.031	361.807	16.070	4.149
Cl 2A Bis between Kr 80 and 81	18.227	78.401	84.126	361.850	119.499	127.000	119.499	0.007937	0.948	0.008	4.301	0.034	361.850	17.275	4.301
Kr 83 on the Y	17,952	78,757	82,854	363,493	130,588	123,000	130,588	0.008197	1.070	0.008	4,387	0.036	363,493	19,020	4,387
Kr 83 between Cl 1A1 and 1	19,703	77,027	90,938	355,508	133,587	121,000	133,587	0,008333	1,113	0,008	3,909	0,032	355,508	20,169	3,909
Kr89 with Cl1BOe	21.571	74.407	99.560	343.419	120.624	121.000	120.624	0.008333	1.005	0.008	3.449	0.029	343.419	21.147	3.449
Kr 83 with Cl 2C Oe	23.473	71.420	108.335	329.629	88.675	123.000	88.675	0.008197	0.727	0.008	3.043	0.025	329.629	21.954	3.043
Cl 2C Oe with Kr 96	22.683	64.184	104.690	296.234	70.153	127.000	70.153	0.007937	0.557	0.008	2.830	0.022	296.234	22.775	2.830
Cl 2B West between Kr 93Bis and 93A	20.924	70.405	96.574	324.948	117.994	133.000	117.994	0.007576	0.894	0.008	3.365	0.025	324.948	24.202	3.365
Kr 93A between Cl 2B and 1B West	19.633	69.043	90.614	318.661	121.514	141.000	121.514	0.007143	0.868	0.007	3.517	0.025	318.661	25.641	3.517
Kr 93 with Cl 1	18.385	66.515	84.852	306.990	124.751	151.000	124.751	0.006667	0.832	0.007	3.618	0.024	306.990	26.652	3.618
Cl 2 between Kr 93 and 94	18.668	64.539	86.159	297.874	132.987	163.000	132.987	0.006173	0.821	0.006	3.457	0.021	297.874	27.522	3.457
Kr 94 between Cls 2 and 2A	19.960	61.773	92.123	285.107	102.596	177.000	102.596	0.005682	0.583	0.006	3.095	0.017	285.107	28.581	3.095
Cl 2C between Kr 94A and 95	20.467	58.747	94.463	271.142	84.665	193.000	84.665	0.005208	0.441	0.005	2.870	0.015	271.142	29.398	2.870
Kr 94A between Cl 3A and 3B	21.490	56.889	99.187	262.565	77.997	211.000	77.997	0.004762	0.371	0.005	2.647	0.013	262.565	30.204	2.647
Kr 94 between Cl 4 and 4A	23.847	56.086	110.061	258.858	52.594	231.000	52.594	0.004348	0.229	0.004	2.352	0.010	258.858	0.000	2.352

The data calculated using Dgis have been presented, based on the coordinates and addresses provided by the city's transport entity, now two routes capable of completely replacing the pre-existing circular route are evaluated. Figure 88 Two non-circular routes replace the circular one.

1. Route B

The proposed route B has been designed to replace the northern section of the circular route this can be seen in Figure 88. It is seen in Figure 89 when the coordinates are being extracted using Dgis.

Figure 89 Finding stop coordinates using Dgis

Figure 90 Path B in AutoCAD

Table 35 Geographic and Cartesian coordinates result Dgis Software

lon address		lat	x meters and meters	
Capri	-76,545	3,387	-508,121	1534,608
Stop 1	-76,548	3,388	-543,843	1184,533
Stop 2	-76,553	3,386	-375,441	632,631
Stop 3	-76,558	3,385	-280,670	54,309
Stop 4	-76.559	3.383	0.000	0.000
Stop 5	-76,557	3,384	-105,707	231,916

Table 36 Shows the distance from each row to each column, in total travel

Distance on Route Km	Capri	stop to 1	stop to 2	stop to 3	stop to 4	stop to 5
Capri	0.000	0.842	1.482	2.249	2.750	2.963
Stop 1	0.842	0.000	0.639	1.406	1.907	2.120
Stop 2	1.482	0.639	0.000	0.767	1.268	1.481
Stop 3	2.249	1.406	0.767	0.000	0.501	0.714
Stop 4	2.750	1.907	1.268	0.501	0.000	0.312
Stop 5	2.963	2.120	1.481	0.714	0.312	0.000

Table 37 This matrix is calculated by the program from the coordinates, it is the distance in a straight line that exists between each result node Dgis Software

line distance straight km	Capri	stop to 1	stop to 2	stop to 3	stop to 4	stop to 5
Capri	0.000	0.352	0.912	1.498	1.617	1.363
Stop 1	0.352	0.000	0.577	1.160	1.303	1.049
Stop 2	0.912	0.577	0.000	0.586	0.736	0.483
Stop 3	1.498	1.160	0.586	0.000	0.286	0.249
Stop 4	1.617	1.303	0.736	0.286	0.000	0.255
Stop 5	1.363	1.049	0.483	0.249	0.255	0.000

Table 38 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another in a straight line

time line straight Minute	Capri	stop to 1	stop to 2	stop to 3	stop to 4	stop to 5
Capri	0.000	1.624	4.208	6.912	7.461	6.293
Stop 1	1,624	0,000	2,663	5,356	6,016	4,839
Stop 2	4,208	2,663	0,000	2,705	3,395	2,229
Stop 3	6,912	5,356	2,705	0,000	1,319	1,151
Stop 4	7,461	6,016	3,395	1,319	0,000	1,176
Stop 5	6,293	4,839	2,229	1,151	1,176	0,000

Table 39 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another following the actual route of the route

time en route Minute	Capri	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5
Capri	0,000	3,887	6,839	10,379	12,691	13,674
Stop 1	3,887	0.000	2,951	6,491	8,804	9,787
Stop 2	6,839	2.951	0,000	3,540	5,852	6,835
Stop 3	10,379	6.491	3,540	0,000	2,312	3,295
Stop 4	12,691	8.804	5,852	2,312	0,000	1,440
Stop 5	13,674	9.787	6,835	3,295	1,440	0.000

Table 40 This matrix gives the route factor, which is nothing more than the division between the distance en route and the distance in a straight line, generating a quick way to see the similarity between the theoretical perfect straight line route and the real

Factor Route	Capri	stop to 1	stop to 2	stop to 3	stop to 4	stop to 5
Capri	0.000	2.393	1.625	1.501	1.701	2.173
Stop 1	2,393	0,000	1,108	1,212	1,463	2,022
Stop 2	1,625	1,108	0,000	1,309	1,724	3,066
Stop 3	1,501	1,212	1,309	0,000	1,753	2,864
Stop 4	1,701	1,463	1,724	1,753	0,000	1,224
Stop 5	2,173	2,022	3,066	2,864	1,224	0,000

Table 41 Percentage difference between the current route and the theoretical ideal straight line in percentages

% Come in route and straight	Capri	Stop 1	Stop two	Stop 3	Stop 4	Stop 5
Capri	0.000	58.220	38.472	33.399	41.211	53.981
Stop 1	58,220	0,000	9,768	17,493	31,669	50,552
Stop 2	38,472	9,768	0,000	23,594	41,984	67,384
Stop 3	33,399	17,493	23,594	0,000	42,939	65,082
Stop 4	41,211	31,669	41,984	42,939	0,000	18,311
Stop 5	53.981	50.552	67.384	65.082	18.311	0.000

Table 42 summary of the calculations made, shows accessibility indicators seen in the framework theoretical and used in the work you do in 2018

name e_for gives	Addition_distance ia_rect a	Addition_distance ia_route	Addition_weather _straight	Addition_weather _route	Addition_Index_trace oTv
Capri	5,741	10,285	26,498	47,470	9,394
Stop 1	4,441	6,916	20,498	31,921	8,200
Stop 2	3,293	5,637	15,200	26,018	8,832
Stop 3	3,779	5,637	17,443	26,018	8,639
Stop 4	4,196	6,738	19,368	31,100	7,865
Stop 5	3,399	7,590	15,689	35,032	11,349

Table 43 summary of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018

name e_for gives	Addition_shimb the	Addition_Factor _route	uno_divi dido_n_ less_1	Ri	one_di vivid _n
Capri	15.000	9.394	0.07143	0.671	0.067
Stop 1	11.000	8.200	0.10000	0.820	0.091
Stop 2	9.000	8.832	0.12500	1.104	0.111
Stop 3	9.000	8.639	0.12500	1.080	0.111
Stop 4	11,000	7.865	0.10000	0.786	0.091
Stop 5	15.000	11.349	0.07143	0.811	0.067

Table 44 summary of the calculations made, shows accessibility indicators seen in the framework theoretical and used in the work you do in 2018

name e_for gives	addition_weather s_route _time os_rec ta	trace o_velo city_ node	absolute to_Tie mpo_ Global	time o_trip _until _node _min	Factor _route_ total
Capri	1.791	0.119	47.470	13.674	1.791
Stop 1	1.557	0.142	31.921	9.787	1.557
Stop 2	1.712	0.190	26.018	6.835	1.712
Stop 3	1.492	0.166	26.018	3.295	1.492
Stop 4	1.606	0.146	31.100	1.440	1.606
Stop 5	2.233	0.149	35.032	0.000	2.233

Between Table 35 and Table 43, the topological results produced by Dgis are observed, it is important to highlight the travel time that has been significantly shortened, the simulation being run at an average of 13 kilometers per hour, giving the time greater than 13.67 minutes, which is equivalent to approximately 14 minutes.

It is satisfactory to find in Table 40, that the similarity between the ideal route and the real route has improved, being closer to 0% than to 100%. Let us remember that the closer to 0% is the result of this table, the more efficient the route will be. drawn.

2. Path C

The proposed route C has been designed to replace the southern section of the circular route this can be seen in Figure 92 and in Figure 91 it is observed when the coordinates are being extracted using Dgis

In the Tables that have the numbering between 44 and 53, the topological results thrown by Dgis are observed, it is important to highlight the travel time that has been significantly shortened, the simulation being run at 13 kilometers per hour on average, giving the longest time of 12.28 minutes, which is equivalent to approximately 13 minutes.

It is also satisfactory to find in Table 50, that the similarity between the ideal layout and the real layout has improved, being closer to 0% than to 100%. Let us remember that the more close to 0% is the result of this table, the more efficient the route will be.

It is evident then the superiority that exists in the linear routes, with respect to the circular ones, the travel time for any passenger has been improved, since in the original route the maximum travel time for a passenger was 32.5 minutes (Table 30) , while in the worst case on the new route the passenger will have to travel 13 minutes in 14 minutes, which represents a significant reduction in travel time for the user of 43.07%.

A significant improvement in the efficiency of the route is also generated, which has been measured with Dgis and can be clearly seen in the percentage result of similarity between the ideal route and the real route, in which a significant decrease in the route is always observed. linear.

The effectiveness of Dgis is then demonstrated to measure routes and make new routes based on accessibility and its topology, it is important to emphasize that the speed with which it is simulated is chosen by the user, therefore, for the same route, n simulations at different speeds.

Figure 91 Finding stop coordinates using Dgis

Dgis calculated coordinates, which will be used to put stops of the transport system Figure 91

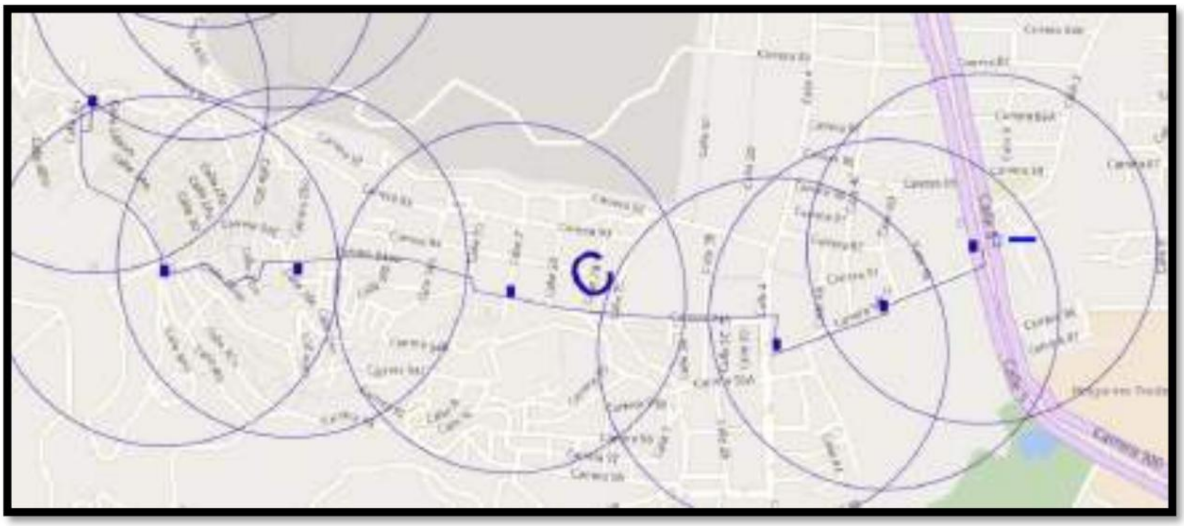


Figure 92 Route C

Table 45 Geographic and Cartesian coordinates result Dgis Software

Address	lon	lat x meters and meters		
Melendez station	-76,543	3,377	-229,785	2030,994
Stop 1	-76,544	3,376	-140,987	1903,958
stop2	-76.547	3.375	0.000	1533.047
stop 3	-76,553	3,376	-116,840	943,353
stop 4	-76,557	3,377	-189,281	460,306
stop 5	-76,560	3,376	-166,692	157,618
stop 6	-76,561	3,380	-558,495	0,000

Table 46 Shows the distance from each row to each column, in total travel

Distance en route Km	Melendez station	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6
Melendez station	0.000	0.180	0.587	1.257	1.794	2.133	2,645
stop 1	0.180	0.000	0.414	1.058	1.585	1.921	2,429
stop2	0.587	0.414	0.000	0.699	1.214	1.567	2,175
stop 3	1.257	1.058	0.699	0.000	0.516	0.869	1,477
stop 4	1.794	1.585	1.214	0.516	0.000	0.353	0.961
stop 5	2.133	1.921	1.567	0.869	0.353	0.000	0.608
stop 6	2.645	2.429	2.175	1.477	0.961	0.608	0.000

Table 47 Geographic and Cartesian coordinates result Dgis Software

Lat direction	lon	x meters and meters		
Melendez station	-76,543	3,377	-229,785	2030,994
stop 1	-76,544	3,376	-140,987	1903,958
stop2	-76.547	3.375	0.000	1533.047
stop 3	-76,553	3,376	-116,840	943,353
stop 4	-76,557	3,377	-189,281	460,306
stop 5	-76,560	3,376	-166,692	157,618
stop 6	-76,561	3,380	-558,495	0,000

Table 48 Shows the distance from each row to each column, in total travel

Distance en route Km	Melendez season	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6
Melendez station	0.000	0.180	0.587	1.257	1.794	2.133	2,645
stop 1	0.180	0.000	0.414	1.058	1.585	1.921	2,429
stop2	0.587	0.414	0.000	0.699	1.214	1.567	2,175
stop 3	1.257	1.058	0.699	0.000	0.516	0.869	1,477
stop 4	1.794	1.585	1.214	0.516	0.000	0.353	0.961
stop 5	2.133	1.921	1.567	0.869	0.353	0.000	0.608
stop 6	2.645	2.429	2.175	1.477	0.961	0.608	0.000

Table 49 This matrix is calculated by the program from the coordinates, it is the distance in a straight line that exists between each result node Dgis Software

Distance line straight km	Scrum ndez	stop to 1	stop a2	stop to 3	stop to 4	stop to 5	stop to 6
Meléndez	0.000	0.155	0.548	1.093	1.571	1.874	2.057
Stop 1	0.155	0.000	0.397	0.961	1.444	1.747	1.949
Stop2	0.548	0.397	0.000	0.601	1.089	1.385	1.632
Stop 3	1.093	0.961	0.601	0.000	0.488	0.787	1.042
Stop 4	1.571	1.444	1.089	0.488	0.000	0.304	0.590
Stop 5	1.874	1.747	1.385	0.787	0.304	0.000	0.422
Stop 6	2.057	1.949	1.632	1.042	0.590	0.422	0.000

Table 50 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another in a straight line

time line straight Minute	Scrum ndez station on	stop to 1	stop a2	stop to 3	stop to 4	stop to 5	stop to 6
Melendez station	0.000	0.715	2.531	5.047	7.252	8.651	9.496
Stop 1	0.715	0.000	1.831	4.435	6.667	8.061	8.996
Stop2	2,531	1,831	0,000	2,775	5,028	6,395	7,531
Stop 3	5,047	4,435	2,775	0,000	2,254	3,634	4,807
Stop 4	7,252	6,667	5,028	2,254	0,000	1,401	2,723
Stop 5	8,651	8,061	6,395	3,634	1,401	0,000	1,949
Stop 6	9,496	8,996	7,531	4,807	2,723	1,949	0,000

Table 51 This matrix shows the theoretical travel time that a vehicle would take to go from one node to another following the actual route of the route

Weather on Route Minute	Melenten station	stop to 1	stop a2	stop to 3	stop to 4	stop to 5	stop to 6
Melendez station	0.000	0.831	2.709	5.802	8.280	9.845	12.208
Stop 1	0.831	0.000	1.911	4.883	7.315	8.866	11.211
Stop2	2,709	1,911	0,000	3,224	5,604	7,232	10,040
Stop 3	5,802	4,883	3,224	0,000	2,381	4,008	6,816
Stop 4	8,280	7,315	5,604	2,381	0,000	1,628	4,435
Stop 5	9.845	8.866	7.232	4.008	1.628	0.000	2.807
Stop 6	12,208	11,211	10,040	6,816	4,435	2,807	0,000

Table 52 This matrix gives the route factor, which is nothing more than the division between the route distance and the straight line distance, generating a quick way to see the similarity between the perfect theoretical straight line route and the real one. .

Factor Route	Melenten stations on	stop at 1	stop a2	stop at 3	stop at 4	stop at 5	stop at 6
Melendez station	0,000	1,161	1,070	1,150	1,142	1,138	1,286
Stop 1	1,161	0,000	1,043	1,101	1,097	1,100	1,246
Stop2	1,070	1,043	0,000	1,162	1,115	1,131	1,333
Stop 3	1,150	1,101	1,162	0,000	1,056	1,103	1,418
Stop 4	1,142	1,097	1,115	1,056	0,000	1,162	1,629
Stop 5	1,138	1,100	1,131	1,103	1,162	0,000	1,440
Stop 6	1,286	1,246	1,333	1,418	1,629	1,440	0,000

Table 53 Percentage difference that exists between the current route and the straight theoretical ideal in percentages

% Come in route and straight	melendez station on	stop to 1	stop a2	stop to 3	stop to 4	stop to 5	stop to 6
Melendez station	0,000	13,892	6,574	13,008	12,419	12,122	22,215
Stop 1	13,892	0,000	4,154	9,177	8,867	9,082	19,753
Stop2	6,574	4,154	0,000	13,936	10,293	11,583	24,993
Stop 3	13,008	9,177	13,936	0,000	5,303	9,348	29,467
Stop 4	12,419	8,867	10,293	5,303	0,000	13,941	38,596
Stop 5	12,122	9,082	11,583	9,348	13,941	0,000	30,572
Stop 6	22,215	19,753	24,993	29,467	38,596	30,572	0,000

Table 54 summary table of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018

Name_	Addition_distance ia_rect a	Addition_distance time stop	Addition_time ia_route_straight	sum__route	Addition_Index_trace oTv
Meléndez	7,300	8,596	33,692	39,674	6,947
Stop 1	6,653	7,587	30,706	35,017	6,749
Stop2	5,653	6,656	26,090	30,720	6,855
Stop 3	4,973	5,875	22,952	27,113	6,989
Stop 4	5,487	6,423	25,325	29,644	7,200
Stop 5	6,520	7,450	30,091	34,387	7,074
Stop 6	7,692	10,295	35,503	47,517	8,352

Table 55 summary of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018

Name_stop us_1	Addition_shimb the	Add_One_Divide Factor _route	do_n_me	Ri	one_divided _n
Meléndez	21.000	6.947	0.050000	0.347	0.048
Stop 1	16.000	6.749	0.066667	0.450	0.063
Stop2	13.000	6.855	0.083333	0.571	0.077
Stop 3	12.000	6.989	0.090909	0.635	0.083
Stop 4	13.000	7.200	0.083333	0.600	0.077
Stop 5	16.000	7.074	0.066667	0.472	0.063
Stop 6	21.000	8.352	0.050000	0.418	0.048

Table 56 summary of the calculations made, shows accessibility indicators seen in the theoretical framework and used in the work carried out in 2018

Name_s_route stop_time	sum_plotted time ncity_ os_rec ta	o_velo	Absolute to_Tie mpo_ Global	time o_trip _to _path _node	Factor _total _min
Meléndez	1.178	0.056	39.674	12.208	1.178
stop 1	1.140	0.071	35.017	11.211	1.140
stop2	1.177	0.091	30.720	10.040	1.177
stop 3	1.181	0.098	27.113	6.816	1.181
stop 4	1.171	0.090	29.644	4.435	1.171
stop 5	1.143	0.071	34.387	2.807	1.143
stop 6	1.338	0.064	47.517	0.000	1.338

8.3 Applicability of the software to multiple cities around the world

This section uses the Dgis software in different cities around the world, to check beyond the particular case of Cali, its level of assertiveness by measuring the level of accessibility of the different areas in those cities for those who need to move around them using public and pedestrian transport. , information that a development team must necessarily have available to reorganize the accessibility of a city in favor of its residents and visitors.

To make the evaluation, the OpenStretMaps database will be used together with the Overpass Api, Qgis as api data extractor, Excel as a filter of the txt database extracted from Qgis and later the Software created in this work as an iterator.

Overpass should be used because city databases can be up to 2 gigabytes in size, which makes it impossible to use the OpenStreetMap base exporter, which only supports up to 5000 nodes, while Overpass can support between 0 and 600,000 nodes.

It is important to emphasize that the coordinates of the nodes can be extracted from multiple places from a database of the city transport office to external bases such as Google, Bing, OpenStreetMaps or using the software in its maps section where it can be searched coordinates from the loaded data just by clicking etc.

To facilitate the computational computation, a new button was programmed in the software that performs the matrix calculation without throwing it in xlxs, in this way the computation time is reduced by 70% and the resources used by 56%.

The results are shown in the software response box, there you can see the coordinates of the area that was studied, the evaluated public transport nodes, the size of the studied area in meters, the size of the studied area in square meters, the area reached by public transport, the name of the city and the country to which it belongs.

The image displayed by the software is superimposed on an image of the city in the same coordinates to facilitate viewing.

Some cities were studied in an area that covers practically their entire length and some metropolitan areas, other cities have a study in the downtown area and others with both.

8.3.1 Thirty-four cities analyzed using Dgis

34 cities of the world were evaluated, using public access data, each of the individual results can be read in the Annex included in the Annex of chapter 8.3, thirty-four cities analyzed

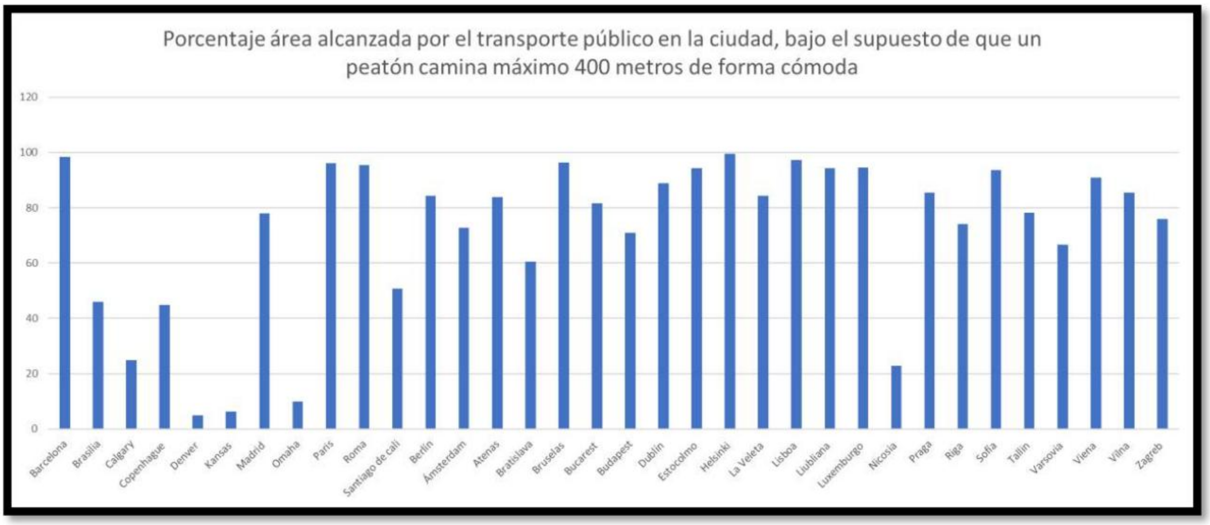


Figure 93 Summary showing the area percentage reached by public transport in the city, under the assumption that a pedestrian walks a maximum of 400 meters comfortably, graphically

After evaluating 34 cities in the world, including the 27 capitals of the 27 member states of the European Union. It can be said that the Dgis program has indeed been validated for massive and systematic data management.

The most notable result of the study is that European cities have a high level of spatial accessibility, compared to non-European cities, see Figure 93 and Table 57

Tabla 57 Resumen de los análisis realizados

Ciudad	Pais	Continente	Zona analizada	Porcentaje área alcanzada por el transporte público en la zona
Ámsterdam	países bajos	Europa	Ciudad	72.64
Atenas	Grecia	Europa	Ciudad	83.8
Barcelona	España	Europa	Ciudad	98.43
Berlín	Alemania	Europa	Ciudad	84.29
Brasilia	Brasil	Sur América	Ciudad	46.07
Bratislava	República Eslovaca	Europa	Ciudad	60.48
Bruselas	Bélgica	Europa	Ciudad	96.35
Bucarest	Rumania	Europa	Ciudad	81.67
Budapest	Hungría	Europa	Ciudad	70.97
Calgary	Canadá	Norte América	Barrio centrico	97.95
Calgary	Canadá	Norte América	Barrio periferico	54.78
Calgary	Canadá	Norte América	Ciudad	24.96
Copenhague	Dinamarca	Europa	Barrio centrico	98.81
Copenhague	Dinamarca	Europa	Ciudad	44.83
Denver	Estados unidos de América	Norte América	Barrio centrico	79.68
Denver	Estados unidos de América	Norte América	Ciudad	4.96
Dublín	Irlanda	Europa	Ciudad	88.94
Estocolmo	Suecia	Europa	Ciudad	94.3
Helsinki	Finlandia	Europa	Ciudad	99.52
Kansas	Estados unidos de América	Norte América	Ciudad	6.33
La Veleta	Malta	Europa	Ciudad	84.35
Lisboa	Portugal	Europa	Ciudad	97.19
Liubliana	Eslovenia	Europa	Ciudad	94.25
Los ángeles	Estados unidos de América	Norte América	Barrio periferico	73.98
Luxemburgo	Luxemburgo	Europa	Ciudad	94.62
Madrid	España	Europa	Berrio centrico	96.6
Madrid	España	Europa	Ciudad	77.88
Nicosia	Chipre	Europa	Ciudad	22.88
Omaha	Estados unidos de América	Norte América	Barrio centrico	30.66
Omaha	Estados unidos de América	Norte América	Ciudad	10
Paris	Francia	Europa	Barrio centrico	99.83
Paris	Francia	Europa	Ciudad	96.12
Praga	República Checa	Europa	Ciudad	85.51
Riga	letonia	Europa	Ciudad	74.11
Roma	Italia	Europa	Ciudad	95.34
Sanatiago de Chile	Chile	Sur América	Barrio centrico	99.98
Santiago de cali	Colombia	Sur América	Barrio periferico	34.27
Santiago de cali	Colombia	Sur América	Ciudad	50.84
Sofía	Bulgaria	Europa	Ciudad	93.59
Tallin	Estonia	Europa	Ciudad	78.21
Varsovia	Polonia	Europa	Ciudad	66.65
Viena	Austria	Europa	Ciudad	90.96
Vilna	Lituania	Europa	Ciudad	85.36
Zagreb	Croacia	Europa	Ciudad	76.03

8.3.2 Analysis of cities

After using the Dgis program to measure the level of accessibility of the different areas in these cities for those who need to move around them using public transport and on foot, using the public database of the cities observed, the following can be inferred:

European cities have an area reached by the transport system very close to 100%.

Many attractions are generated in European cities in the streets, which in the Figures of annex 11.2 correspond to the point of interest icons.

American cities have an area reached by the acceptable transportation system only in the downtown area, when the entire city is evaluated including its peripheral areas, these cities have a percentage of area close to only 10%

The Canadian city evaluated seems to follow the same American scheme, although its area reached was close to 24%.

It can be determined that in North American cities the pedestrian is relegated to the background, a city has been designed for cars and they lack attractiveness as it is separated from the central zone, rectifying what the authors of the theoretical framework say.

The South American cities evaluated, Santiago de Cali-Colombia, Santiago de Chile-Chile and Brasilia-Brazil, present a union between the European city and the North American city, reaching a percentage of 50% to 100% of total area, however, they lack of attractors for the daily life of the citizen, who thus does not enjoy his city, since it was not made for the people.

9 Conclusion and discussion

The study managed to achieve the general objective proposed by reaching partial goals as indicated below, raising the respective implications.

The bibliographical research led to know the different positions or approaches of urbanism throughout history, to allow the understanding of why the current cities have the organization they present, which certainly prevents in many cases, especially in the oldest cities. , access to public mass transportation systems, imposing walking almost as an exclusive method, given the narrowness of the streets and the location of some buildings on the corners.

At this point it should be noted that in many cities around the world, such as those in Colombia, They continue to build vast areas with old methods, such as the one proposed by Le Corbusier, which by having groups of houses and buildings separated from each other by enclosures, leaving long spaces, greater than 400 meters recommended as appropriate for the walker, causing this that the experience of walking turns out to be unrewarding, because the walker will see himself alone, without even someone seeing him, exposed to dangers, likewise, the built layout of these cities makes it difficult to design an accessible transportation system, because as seen in theory, some kind of built organization is required to generate adequate systems.

It throws up the recognition made of the urban models applied in the world, that the appropriate one to follow is the one that manages to arrange cities for the people, that is, cities whose residents can find the different sites accessible, combining public transport with walking, where it is therefore possible for him to socialize, buy and sell, and in general,
live more kindly, since the city is efficiently interconnected to make it closer to the human condition of its inhabitants.

It is economically unfeasible to tear down and rebuild cities, particularly those planned on obsolete and non-functional urban principles, but this is tolerable if people find that they can get from one place to another within each area or the entire city, more efficiently, thanks to the provision of routes that allow this, both by public transport and on foot.

Modern urbanism cannot reject the old one, since it cannot be denied that poorly laid out cities also have their charm for the resident and more for the tourist, the point is that all cities are better for citizen life if they facilitate mobility inside.

The implication at this point is that the concept "cities for people" should be amplified, to mean cities where it is pleasant to move, where social integration can be carried out, since both old and new cities, regardless of their territorial area, are more appetizing if they are presented organized, for which it contributes in a superlative way the fact that people can move in them efficiently.

Dgis is then a tool that facilitates the design of accessible transport, in cities for the people.

The theoretical heritage studied leaves as a central principle for planning and achieving more humane cities, that mass public transport and walking must be perfectly complementary, if urbanization is based on ensuring that people can move within 400-meter radius. around when requiring to take the transport service and when leaving it, both at the beginning of the trip and at the end of it.

Assuming this principle has a relevant implication, because if it is disseminated, perhaps with the help of an easy-to-use technological tool such as DGIS, making it known not only to the rulers and their urban planning officials, but above all to the general public. , the latter above all will make people come to understand and appropriate it and therefore come to demand it, with which it will be easier to get cities to reorganize their mobility on a valid and proven principle in the condition of the human being himself, who at start and finish a day, it will be acceptable for you to walk a range of up to 400 meters to reach the means of transport that serves you to finally reach your destination, after walking the last up to 400 meters of the day.

He studied allowed, finally, to materialize a digital program arising from the precept that for humanity has always been a problem to solve its mobility, from the past times of the nomadic primitive man, until today, in the times of life in the city, to which compels human interdependence.

Recognizing the reality of cities in their existing organization, beyond how well or poorly planned they are urbanistically, the citizens who move in it expect a direct human interconnection that is as fluid and easy as possible, before which it was necessary to generate
software such as Dgis, capable of making it easier for the urban planner to establish travel routes by public transport and on foot that make cities more accessible to people.

Indeed, it was possible to structure a first model of the program, and from this arises the superior implication of this study, encrypted in continuing to perfect the Dgis software over time, by gaining more knowledge about urban planning, by deepening ideas, and by learning to program. with greater detail and accuracy.

To fulfill this implication, it is necessary that the evaluators of this study understand that this program is a novelty, it can be taken as a version one point zero (1.0), for which it will necessarily be subject to modifications, just as it was done Bill Gates with his famous Windows program, because in the world of programming, as in almost all fronts, products are not born 100% perfected, because this is achieved over time, when those who generously review and use it, report the shortcomings and points to improve, knowing how to forgive those weaknesses when qualifying the first time.

The essential purpose was achieved, to structure a software that facilitates planning urban mobility based on the measurement of the level of accessibility of the different areas in each city.

of the world for those who need to get around them using public and pedestrian transport, with the objective that the urban planner establishes public transport stops, complying with the premise that they have the key places required by citizens within a radius of 400 meters on foot.

The urban model that will survive will be the one that has as its beginning and end to make people's lives in cities friendlier, by aiming and ensuring that people do not suffer from the city, but rather enjoy it, by being organized so that the public moves in it in a pleasant way, accessing all the places it requires, minimizing time, costs and effort. Cities, as indicated by the urban planner Jan Gehl (Gehl, 2014), must be for the people, human cities, where man is the greatest joy of man.

The physical infrastructure of a city makes sense as long as people can enjoy it as soon as it is accessible, for this they must be able to move around it easily, so the developer, and his boss, the ruler, must plan to ensure that transport mass public and the march on foot are complementary, that is, they are harmonized, in such a way that people in the forced journeys on foot manage to move within a maximum radius of 400 meters, when getting on the transport service and when getting off, this is, both in its origin and destination.

Apparently linear routes offer greater accessibility to people from their topology than circular routes, as has been seen in chapter 8.2.9, however, a single result is not enough to determine that it will always be like this, it is left open letter to future research where this situation is compared several times.

Through the simulation carried out by the software in the city of Cali, Valle del Cauca, in Colombia, an increase in spatial accessibility was achieved in the northeast area called
Pance, from 29.41%, only implementing a new transport route.

A second simulation in that city, this time in its southeastern area, showed an improvement in spatial accessibility of 14.73%

By replacing an existing circular route in commune 18 with two linear routes, the travel time was reduced, this can be seen in the tables in chapter 8.2.9, where a substantial improvement in the maximum travel times is evident. trip going from 32.53 minutes on the existing route to only 13.67 minutes for route B and 12.28 minutes for route C. This improves the quality of life of the user, since he will have more free time in his day a day.

Public access data can be used when measuring the spatial accessibility in Dgis of a city or an area of it, as evidenced in chapter 8.3, where 34 cities in the world were evaluated, using only free and public access data.

As a general rule, European cities have a higher rate of spatial accessibility than cities on other continents, as could be seen in this work, which is a reflection of the type of city that predominates on that continent (cities for people). I know

I could then say that the accessibility of the transport system reflects the type of city with which it coexists.

In chapter 8.3, the justification of the urban and transport theoretical framework as complementary aspects was validated, allowing this to conclude that cities designed for people, as Gelh would say (European cities), have greater spatial accessibility than cities designed for people. for automobiles, supporting this the importance of assuming that the design of a city must be done in conjunction with its public transport system, taking care that its stops are established fulfilling the premise of achieving

cover places commonly required by citizens within a radius of 400 meters on foot around each stop.

The Dgis software was accepted as a paper/communication at a spatial planning congress, which would indicate that it is seen as useful unless at the discretion of the judges of the event.

The Dgis software returns values for each analysis, these values must be compared by the planner with multiple iterations in order to choose the best alternative for each stop.

Dgis software certainly facilitates urban mobility planning, saves time and reduces failures during the planning process, thus fulfilling
with the general objective and the second specific objective

The software analyzes cities from the point of view of accessibility, thinking of cities for people, under the teachings of researchers, urban planners and writers seen in the theoretical framework, thus, Dgis allows the user to establish their measurement parameters, but advises locating stops within 400 meter radius of the key places for the citizen, supported
this in the theoretical framework, for which the first specific objective was achieved

Dgis has been validated in the case study of Santiago de Cali Colombia and was also validated in the analysis of the spatial accessibility of 34 cities in the world, to demonstrate the scope
of the third specific objective

The Dgis software has been used in this work as a tool to measure the
accessibility of routes and transport systems, however, it is important to emphasize that the software does not take into account other factors when designing routes, such as the economic factor, satisfaction surveys, dangerousness of some streets, topography of the streets or the legal factor in the territory. That is why a human being is always needed to operate it and analyze its results.

The final conclusion, of convergence, says that a software capable of contributing to making urbanism an integrating concept was provided, where the organization of the geographical space in each city with areas where houses, business and institutional premises interconnected by streets are or are being built. must be planned through routes that, facilitating mobility, lead to the interaction of people, thanks to the fact that public transport and on foot complement each other amicably, with the aim of getting people to socialize with each other because they live in urbanized cities for people.

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eleven Annexes

11.1 Annex to chapter 8.3, thirty-four cities analyzed

11.1.1 Barcelona – Spain – Large Urban Area

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 98.43% spatial accessibility. See Figure 94

and Figure 95

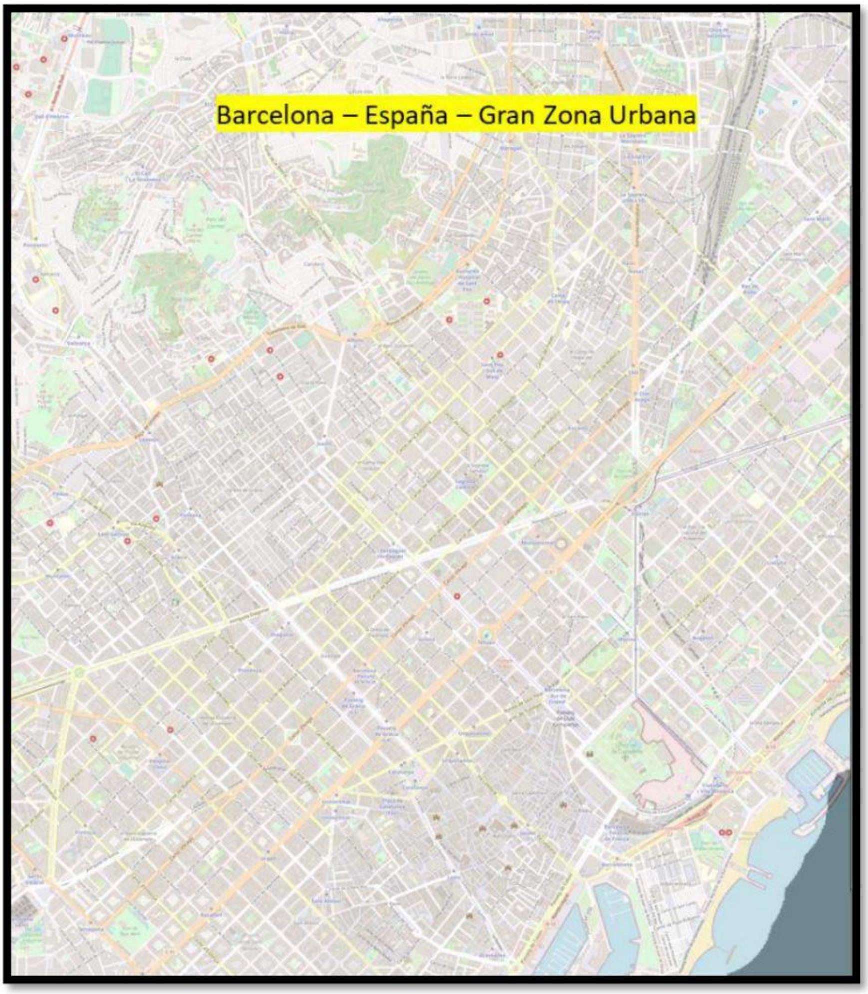

Figure 94 Barcelona – Spain – Large Urban Area

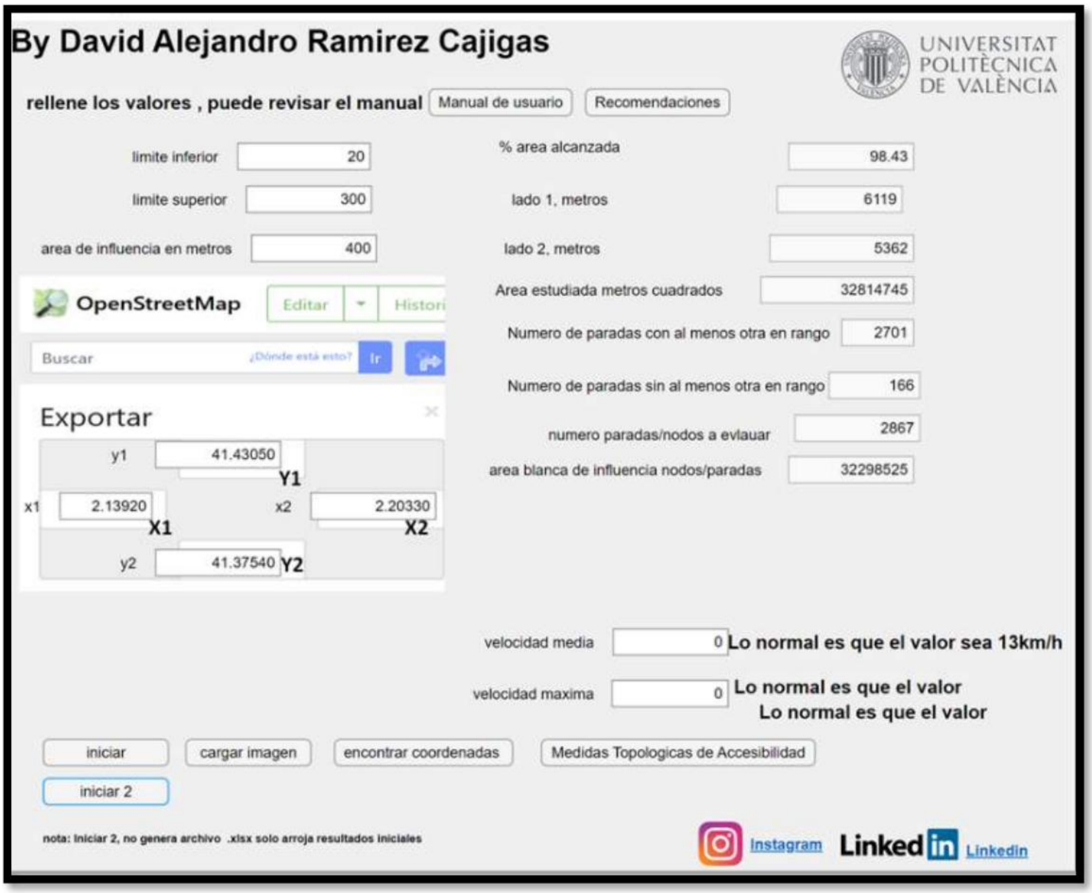

Figure 95 Results Barcelona – Spain – Large Urban Area

11.1.2 Brasilia - Brazil

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 46.07% spatial accessibility. See Figure 94
and Figure 95.

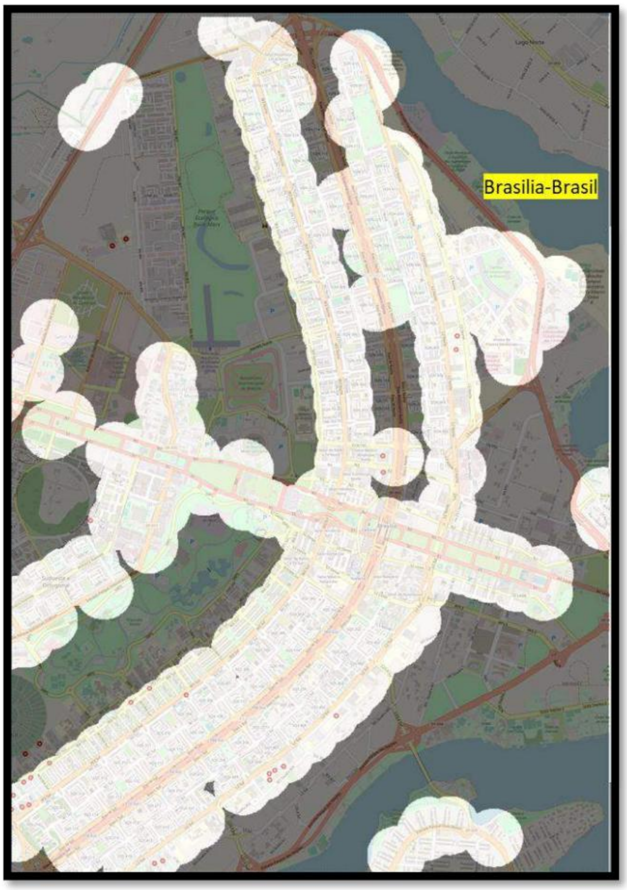

Figure 96 Brasilia-Brazil

Figure 97 Results Brasilia-Brazil

11.1.3 Calgary – Canada

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is a 97.95% spatial accessibility for its central area and 54.78% for the entire city. See Figures from 96 to Figure 103.

This city is an example of how urban planning and transportation are directly related, its central area is designed for walking, while the rest of the city is made up of large expanses of land, what Gehl would call a 60km/h city.

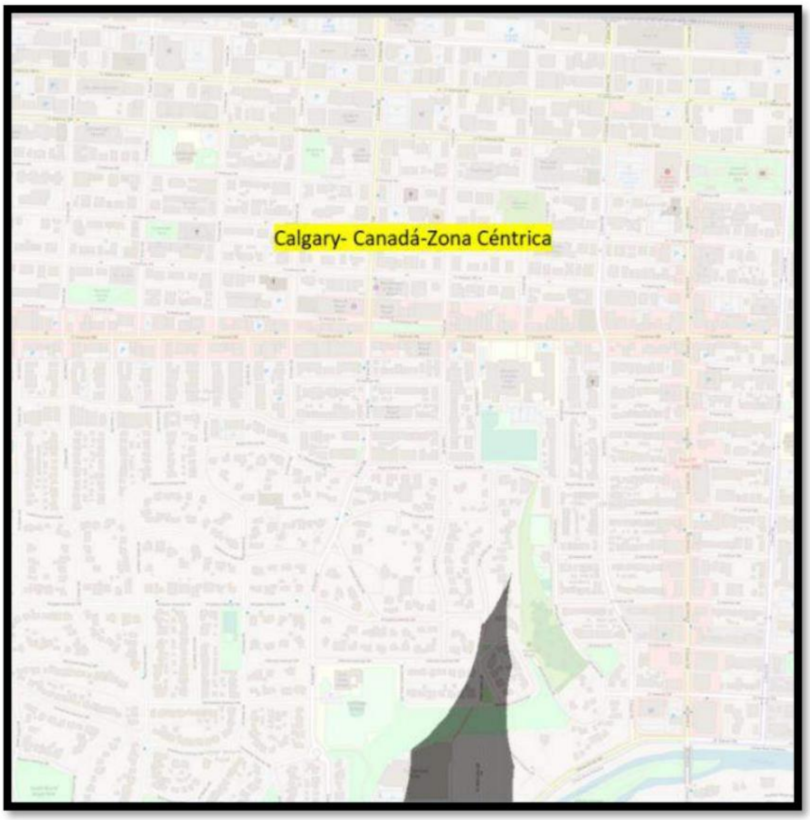

Figure 98 Calgary- Canada-Downtown Area

Figure 99 Calgary-Canada-Downtown Results

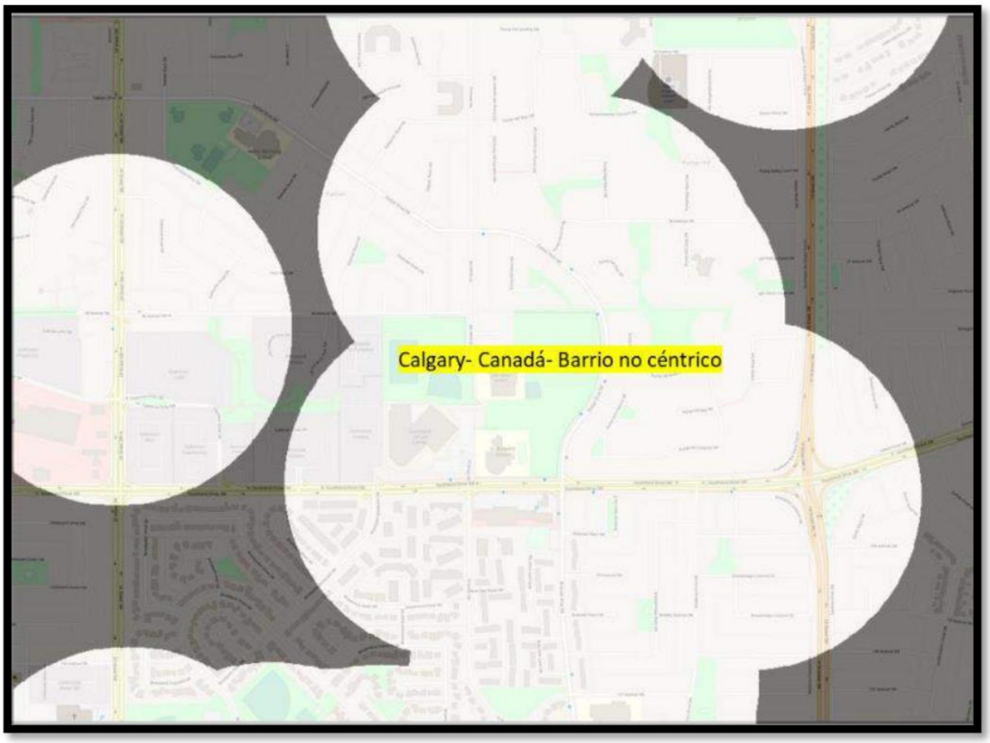

Figure 100 Calgary- Canada- Non-downtown neighborhood

Figure 101 Results Calgary- Canada- Non-downtown neighborhood

Figure 102 Calgary- Canada

Figure 103 Results Calgary- Canada

11.1.4 Copenhagen - Denmark

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is a 99.81% spatial accessibility in its central area and 44.83% in the rest, however, this is due to the physical shape of the city. Watch
Figure 104 to Figure 107 Results Copenhagen- Denmark

Figure 104 Copenhagen- Denmark -Central Area

Figure 105 Results Copenhagen- Denmark -Central Zone

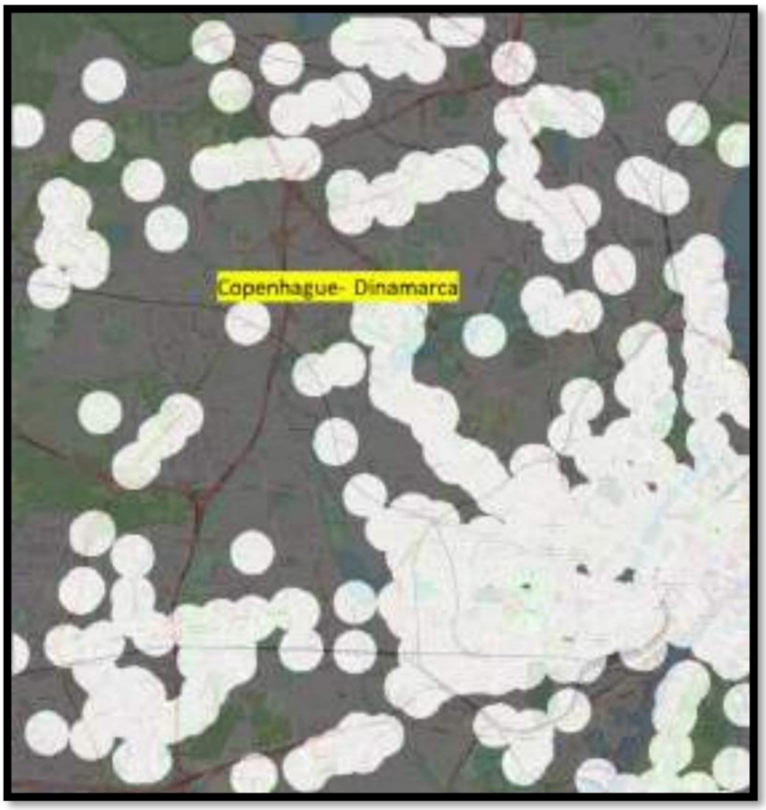

Figure 106 Copenhagen- Denmark

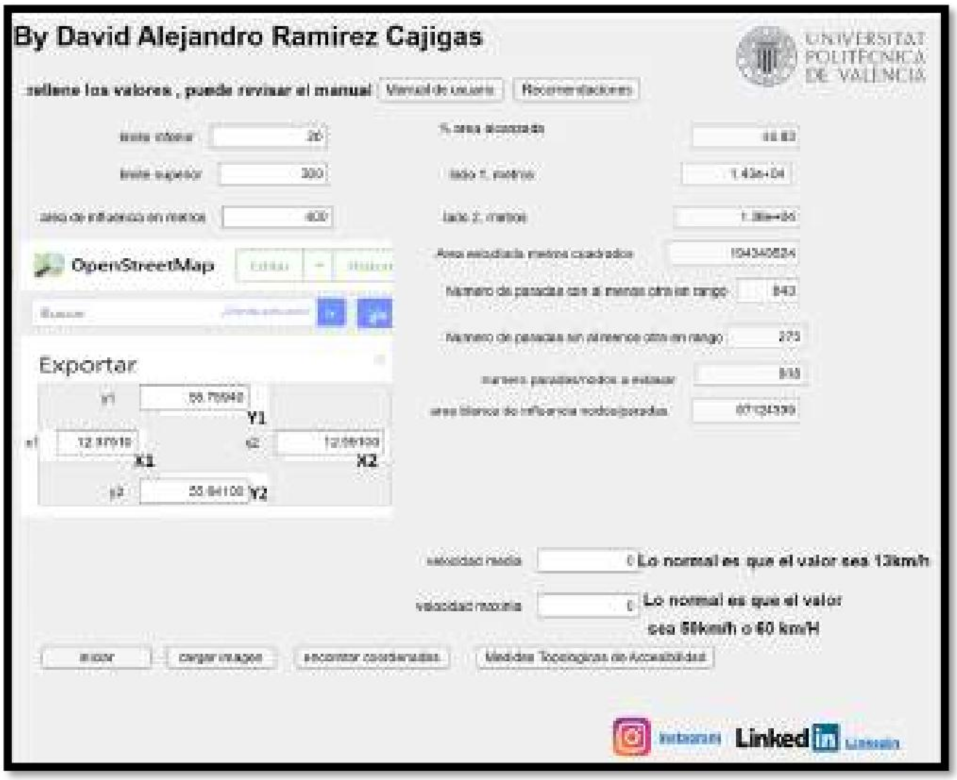

Figure 107 Results Copenhagen- Denmark

11.1.5 Denver – United States of America

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is a 79.68% spatial accessibility in its downtown area and 4.96% in the rest, this is a consequence of the North American garden city planned to use individual transport. See Figure 108 to Figure 111

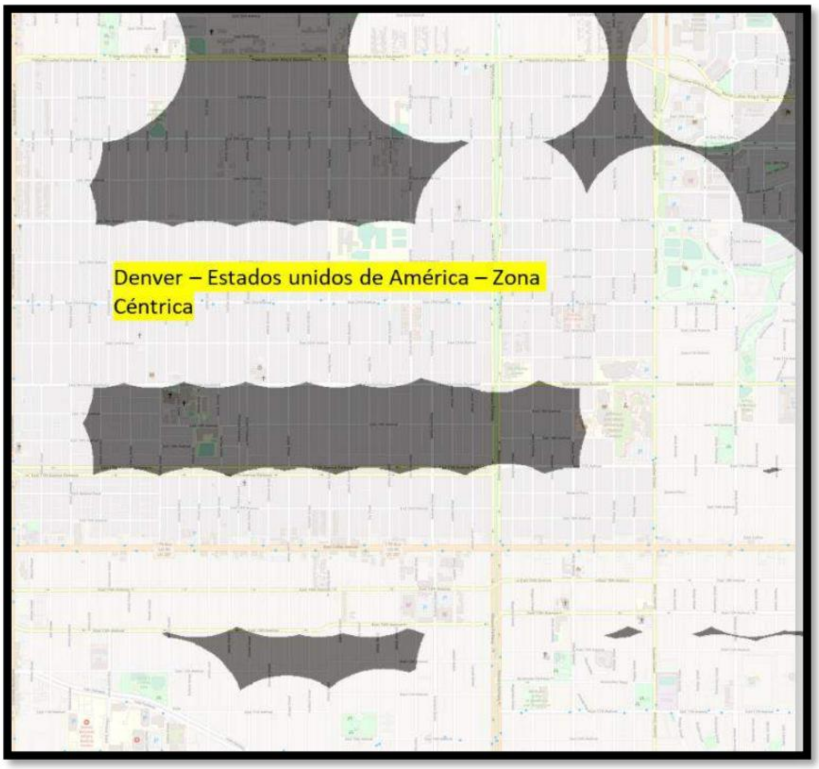

Figure 108 Denver – United States of America – Downtown

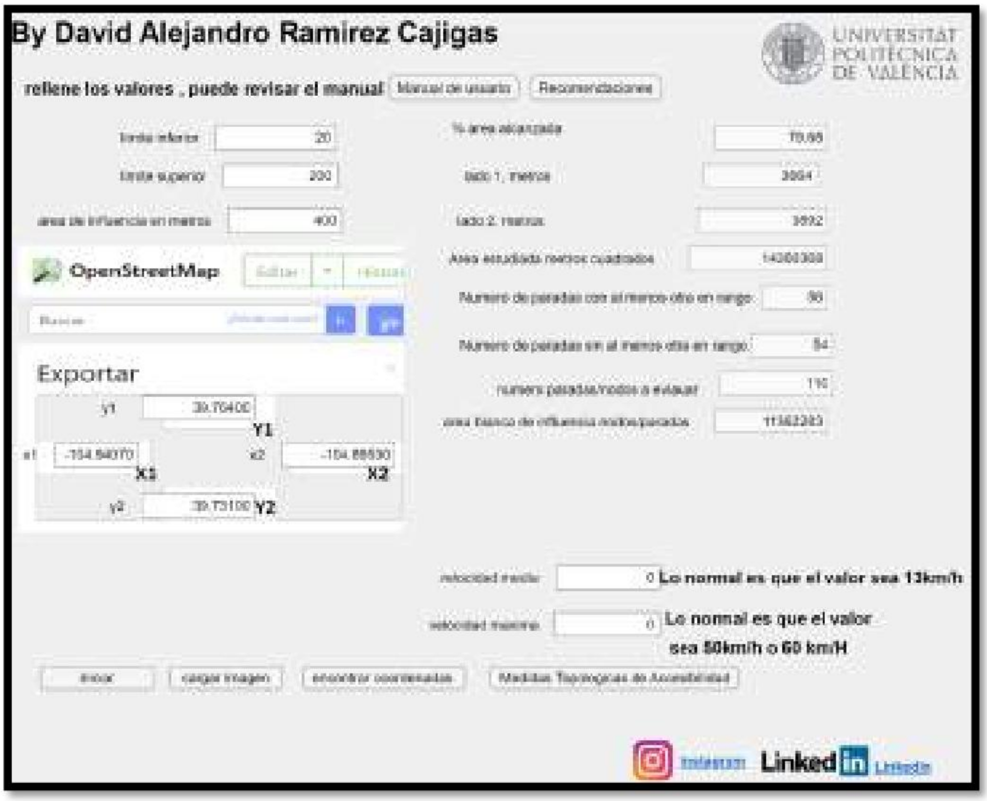

Figure 109 Results Denver – United States of America – Downtown

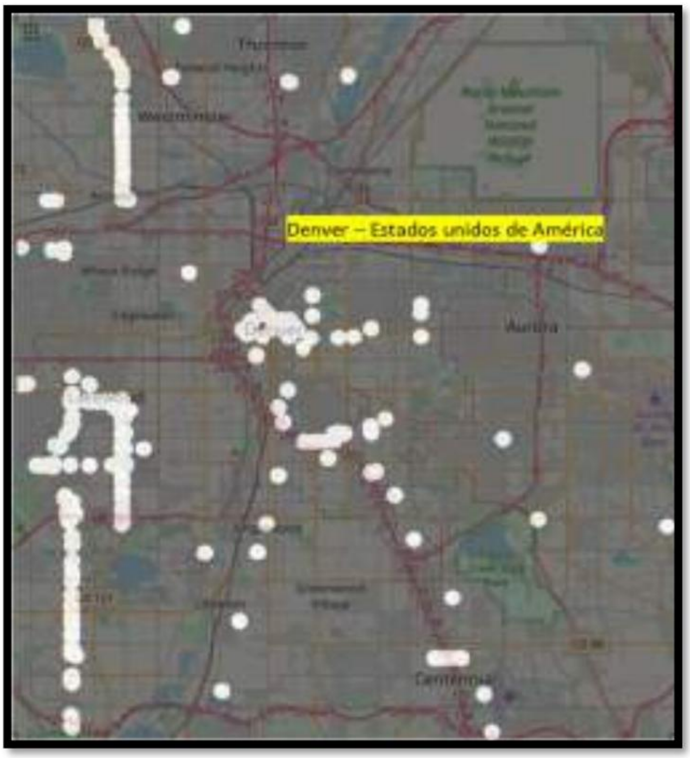

Figure 110 Denver – United States of America

Figure 111 Results Denver – United States of America

11.1.6 Kansas – United States of America

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 6.339% spatial accessibility. See Figure 113
and Figure 112

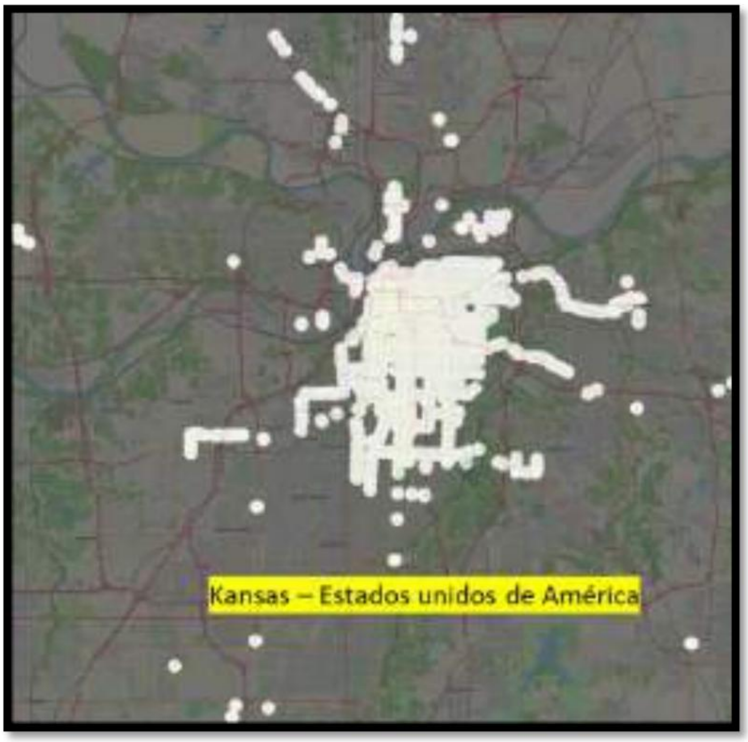

Figure 112 Kansas – United States of America

Figure 113 results Kansas – United States of America

11.1.7 Los Angeles – United States of America- Downtown

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 73.98% spatial accessibility in the downtown area. Figure 114 and Figure 115

Figure 114 Los Angeles – United States of America- Downtown

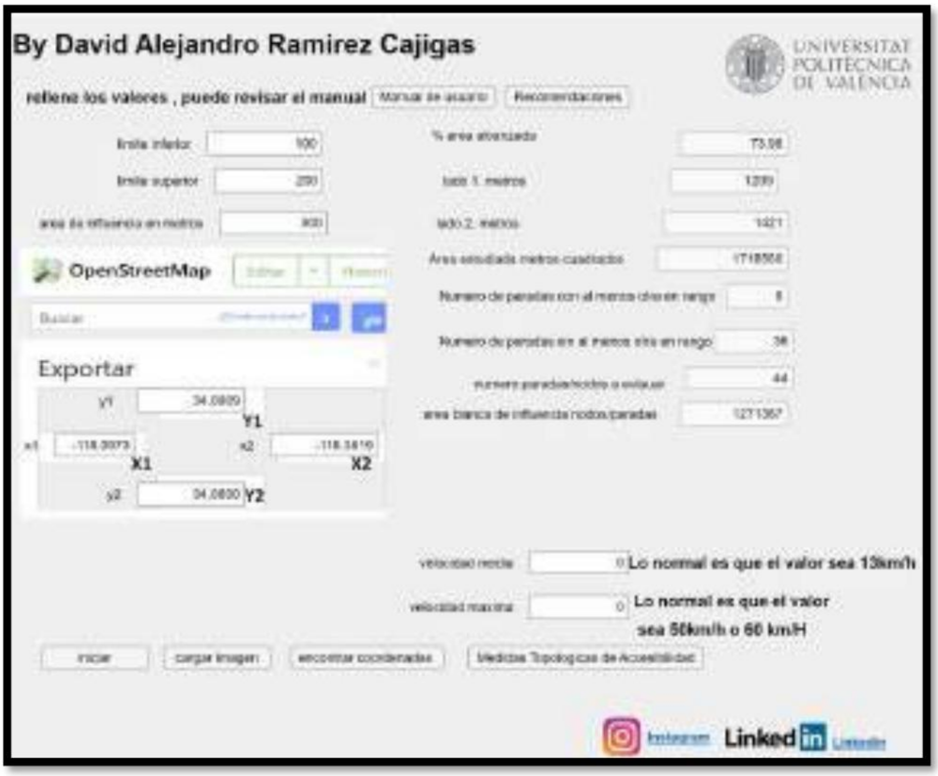

Figure 115 Results Los Angeles – United States of America- Downtown

11.1.8 Madrid – Spain

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 96.6% spatial accessibility in the downtown area and 77.88% in the rest, see Figure 116 to Figure 119

Figure 116 Madrid – Spain – Downtown area

Figure 117 Results Madrid – Spain – Downtown area

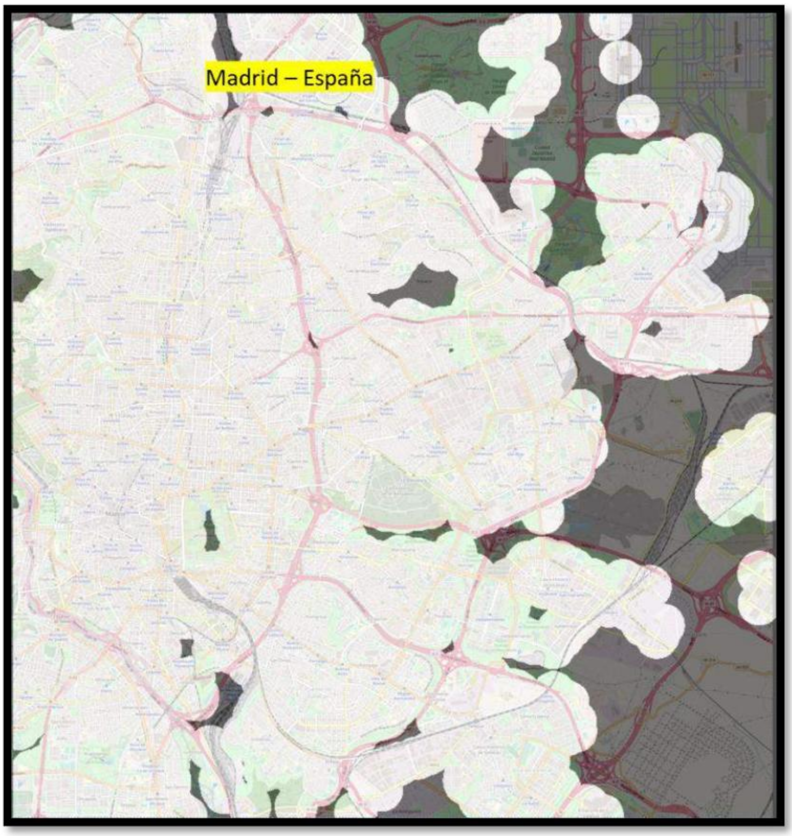

Figure 118 Madrid – Spain

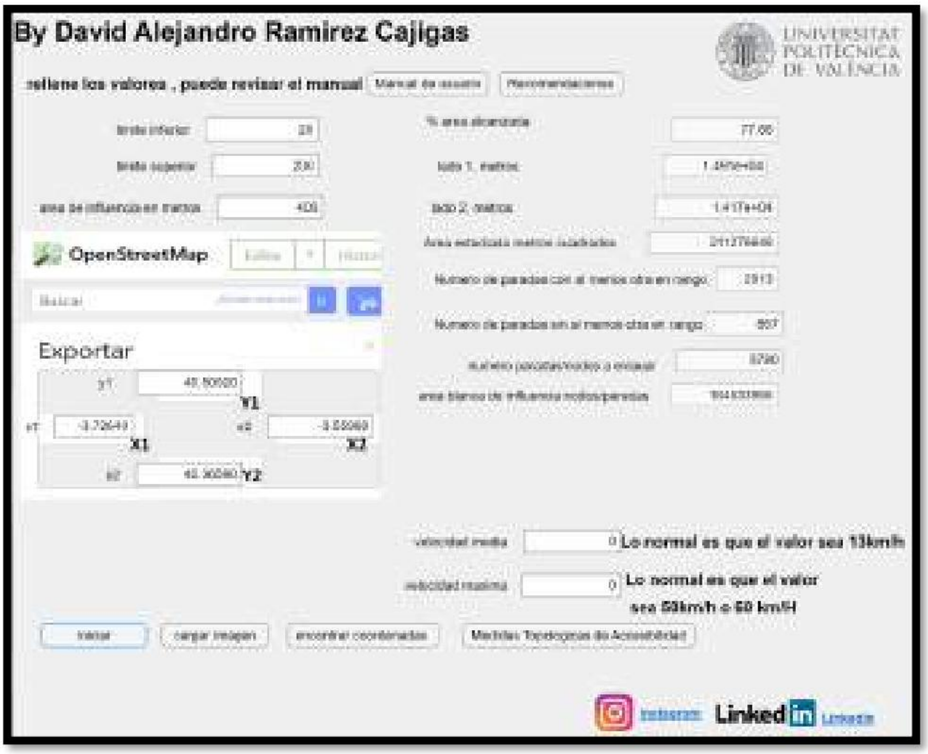

Figure 119 Results Madrid – Spain

11.1.9 Omaha–United States of America

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is a 30.66% spatial accessibility in the center of the city and only 10% for the rest, this responds to the urbanism chosen in that city. see in the Figures of this same section

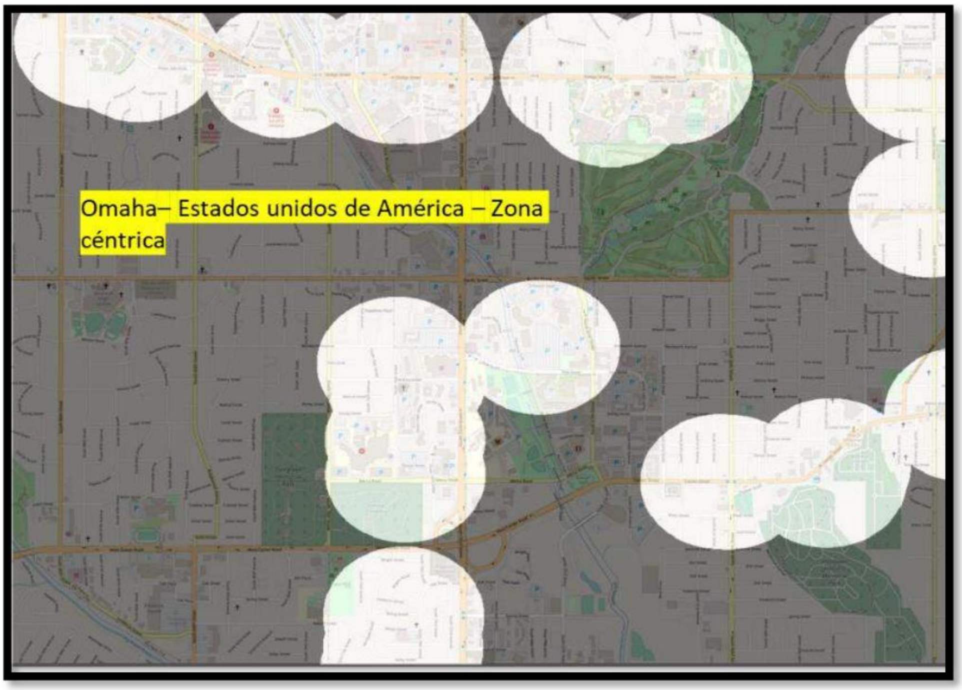

Figure 120 Omaha– United States of America – Downtown

Figure 121 Results Omaha– United States of America – Downtown

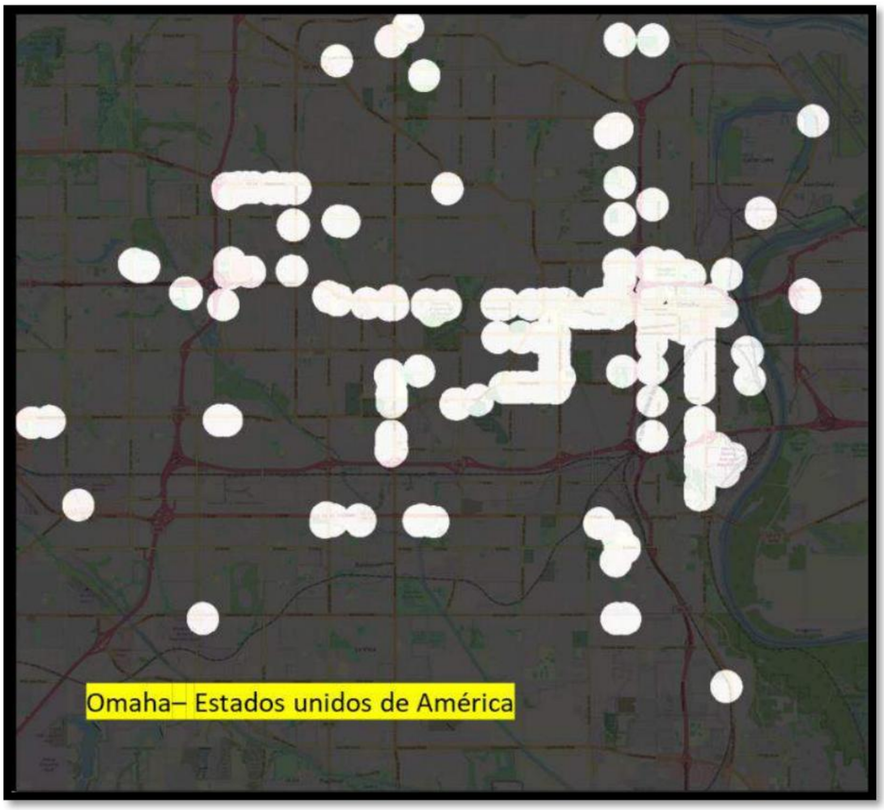

Figure 122 Omaha– United States of America

Figure 123 Results Omaha– United States of America

11.1.10 Paris France

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is 99.83% spatial accessibility in the central area and 96.12% in the rest of the city. see in the Figures of this same section

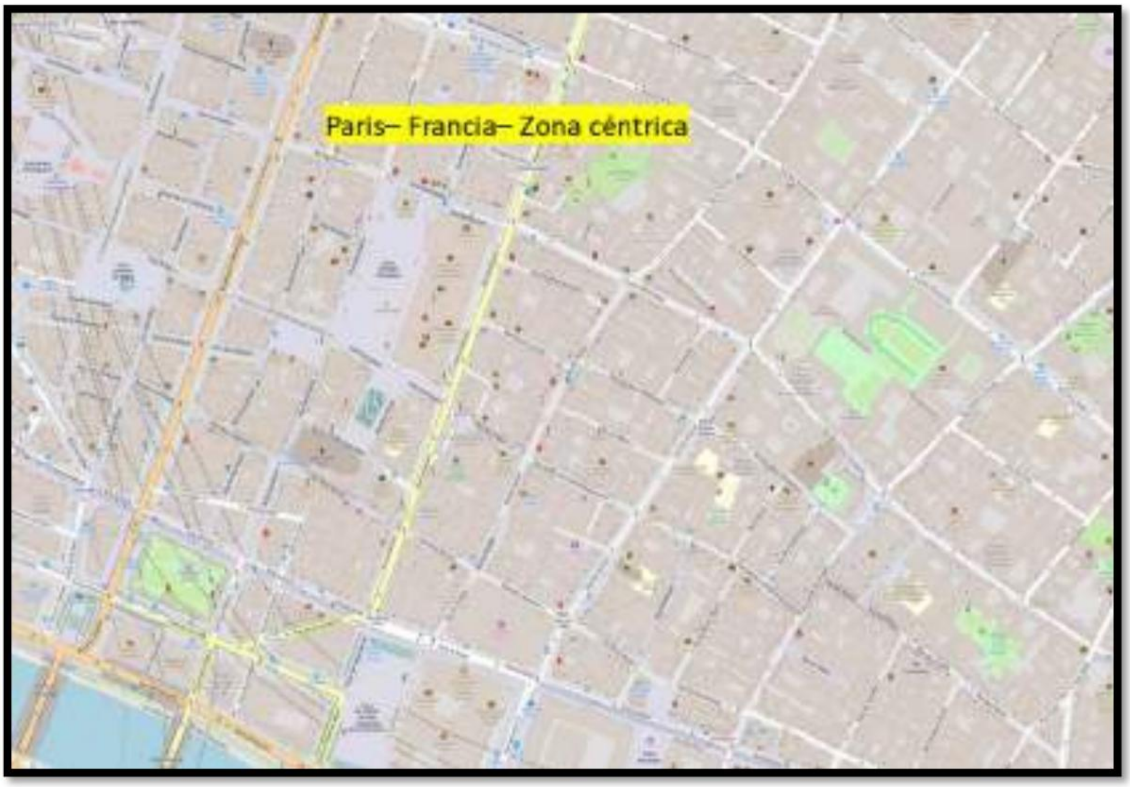

Figure 124 Paris– France– Downtown area

Figure 125 Results Paris– France– Downtown area

Figure 126 Paris– France

Figure 127 Results Paris– France

11.1.11 Rome Italy

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 95.34% spatial accessibility. see in the Figures of this same section

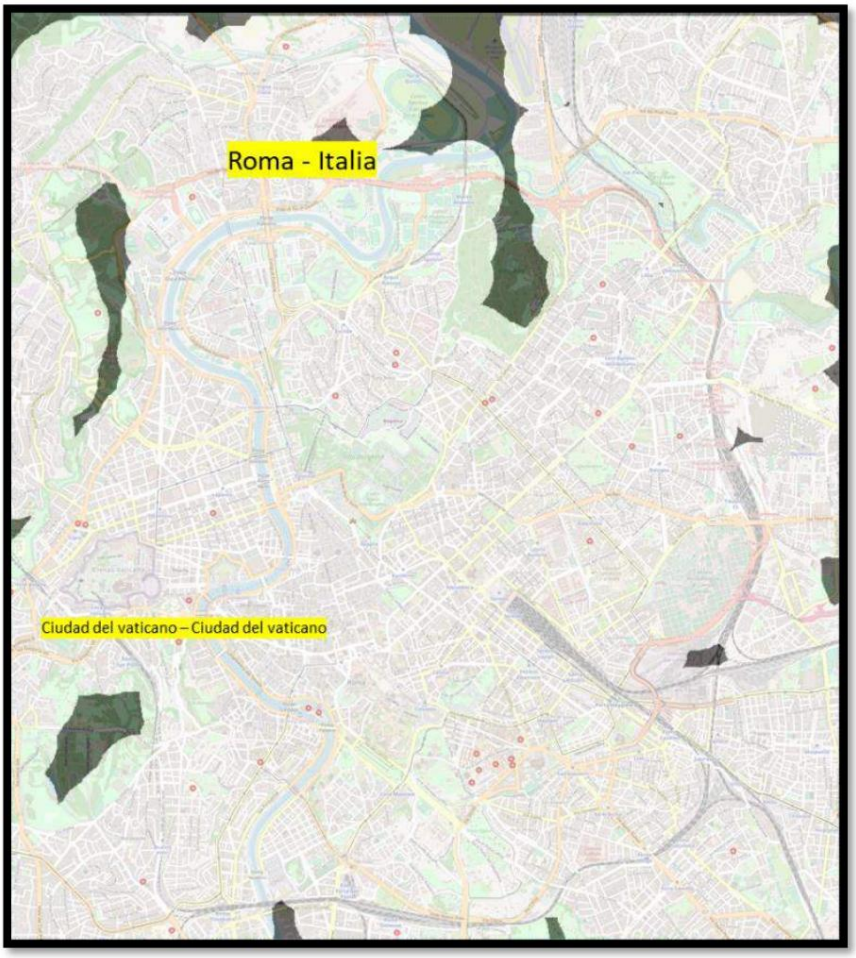

Figure 128 Rome - Italy Vatican City – Vatican City

Figure 129 Result Rome - Italy Vatican City – Vatican City

11.1.12 Santiago de Chile – Chile- Central Zone

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is 99.98% spatial accessibility in the downtown area. see in the Figures of this same section

Figure 130 Santiago de Chile – Chile- Central Zone

Figure 131 Result Santiago de Chile – Chile- Central Zone

11.1.13 Berlin Germany

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 84.29% spatial accessibility. see in the Figures of this same section

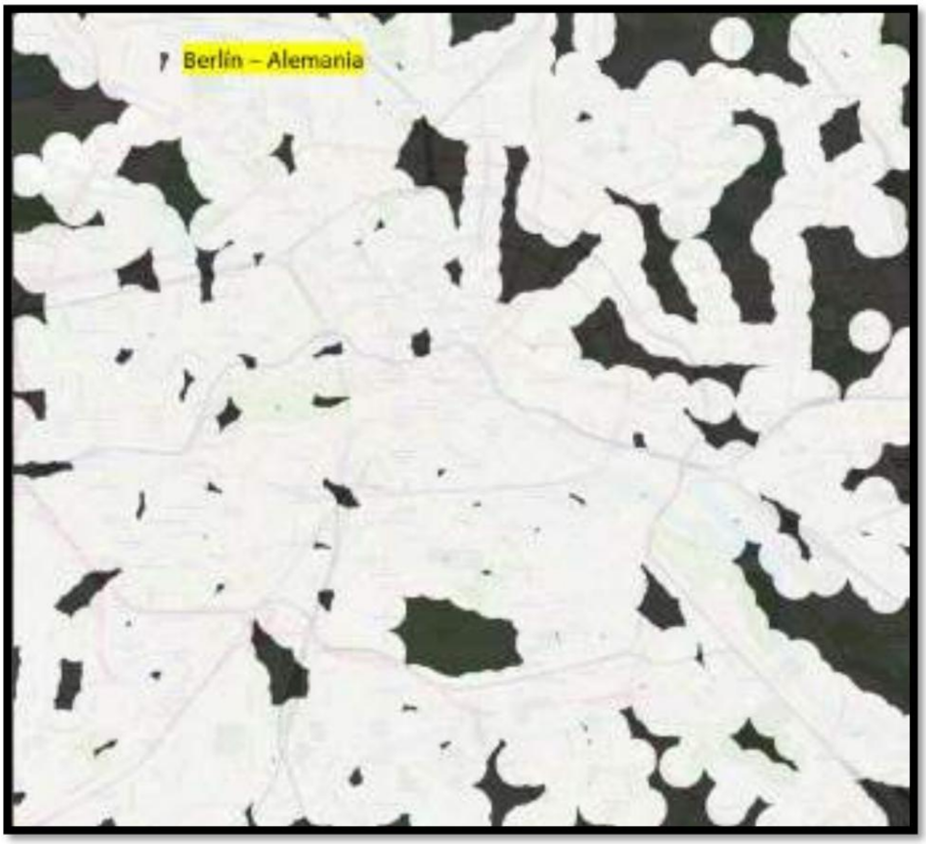

Figure 132 Berlin – Germany

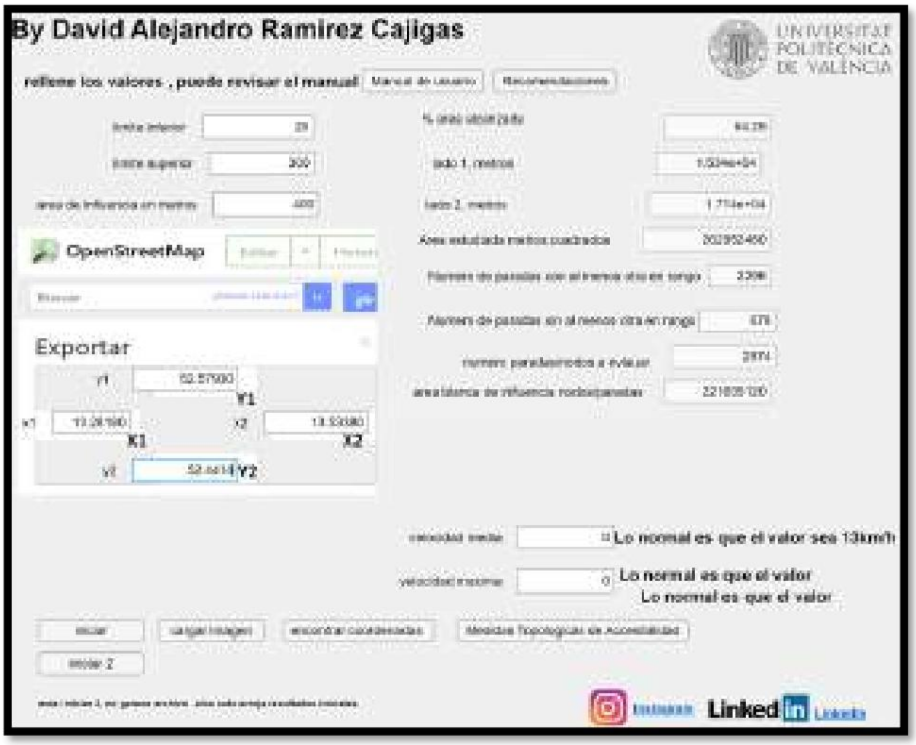

Figure 133 Result Berlin – Germany

11.1.14 Amsterdam – Netherlands

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case there is a 72.64% spatial accessibility. see in the Figures of this same section

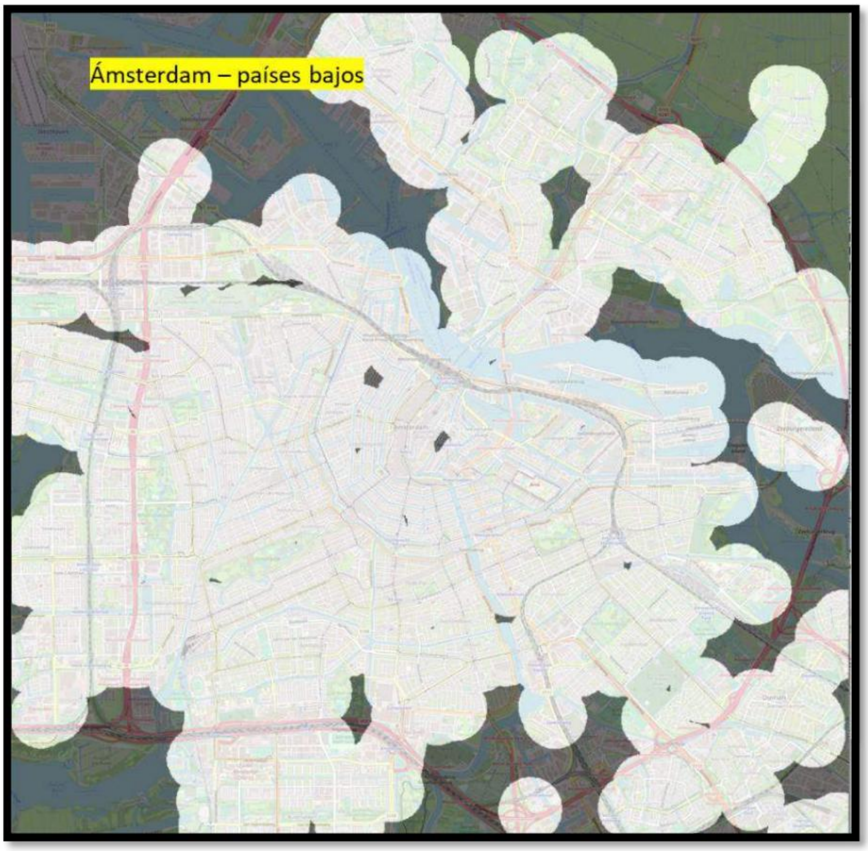

Figure 134 Amsterdam – Netherlands

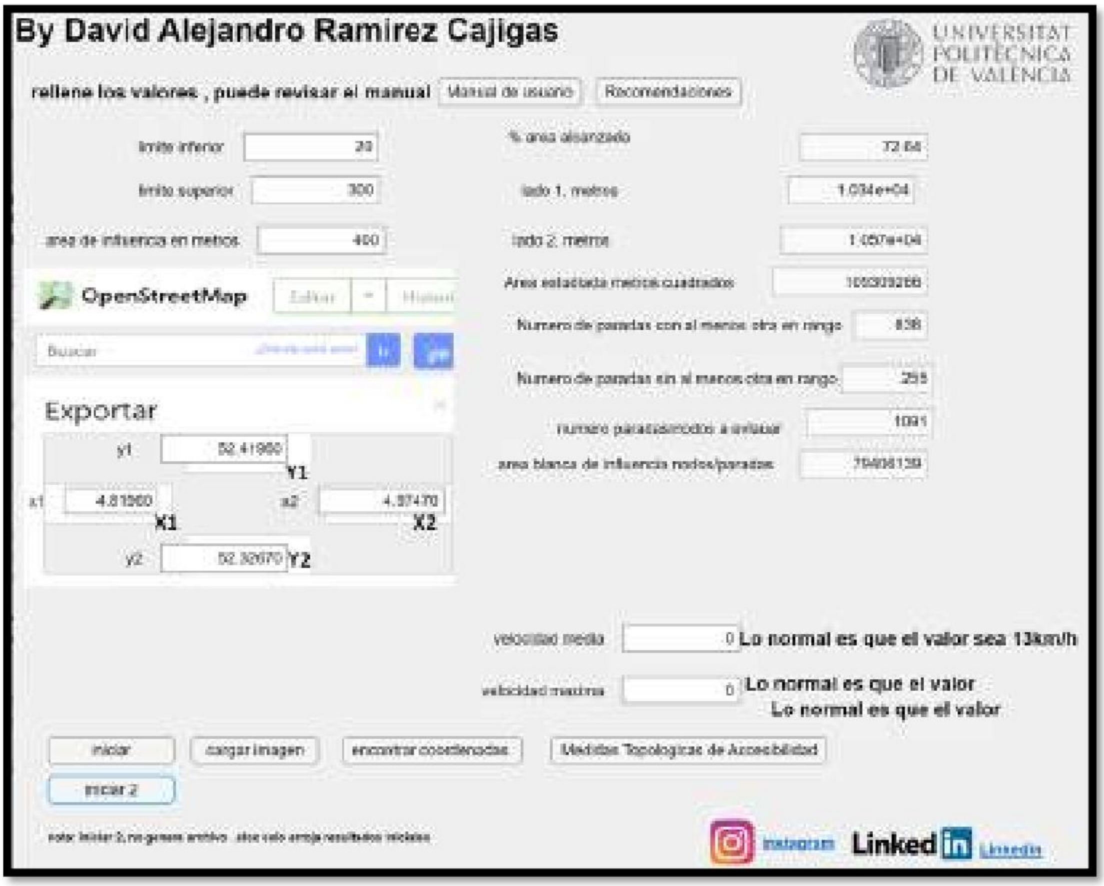

Figure 135 Result Amsterdam – Netherlands

11.1.15 Athens, Greece

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 83.8% spatial accessibility. see in the Figures of this same section

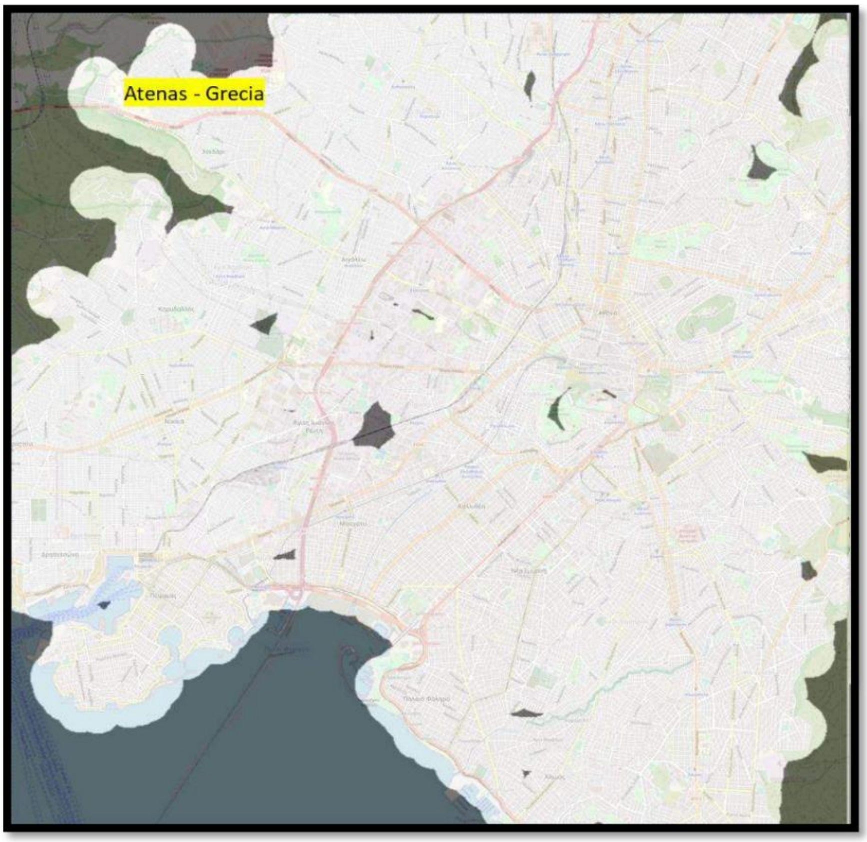

Figure 136 Athens – Greece

Figure 137 Result Athens – Greece

11.1.16 Bratislava – Slovak Republic

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 60.48% spatial accessibility. see in the Figures of this same section

Figure 138 Bratislava – Slovak Republic

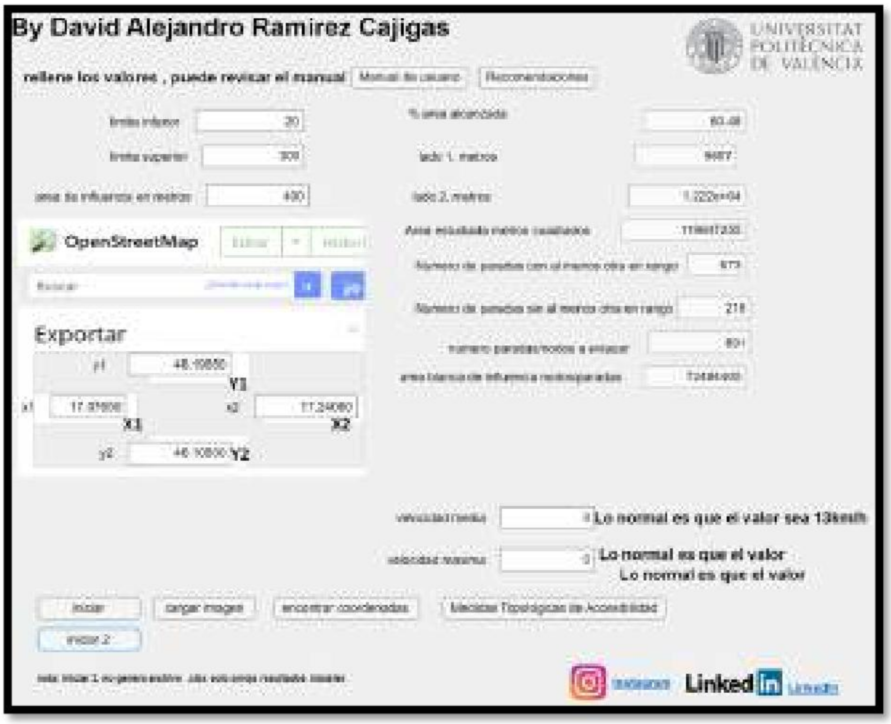

Figure 139 Result Bratislava – Slovak Republic

11.1.17 Brussels, Belgium

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 96.35% spatial accessibility. see in the Figures of this same section

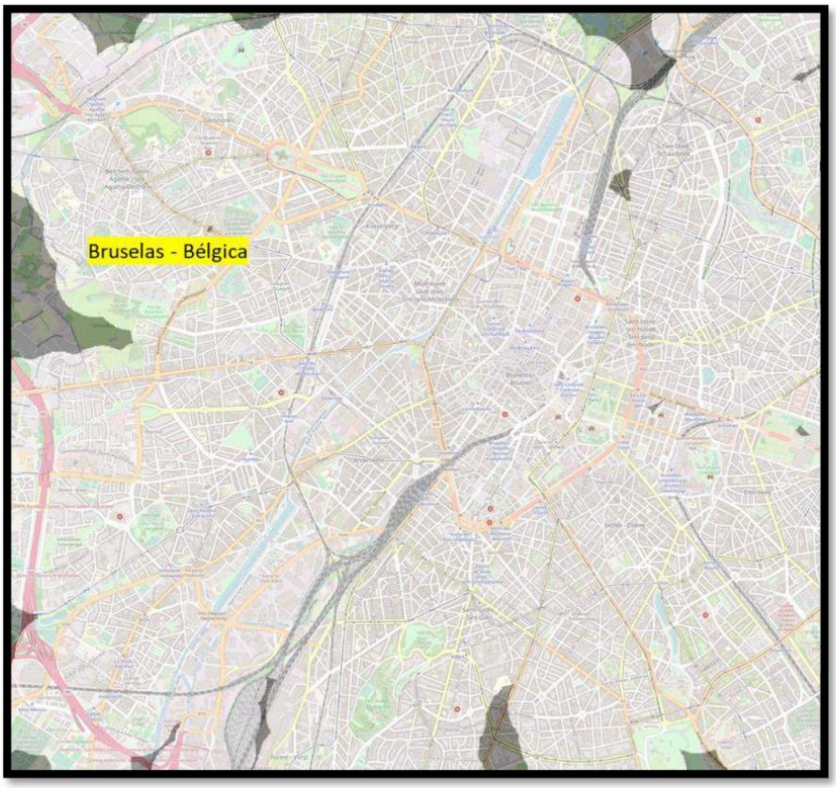

Figure 140 Brussels – Belgium

Figure 141 Result Brussels – Belgium

11.1.18 Bucharest – Romania

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 81.67% spatial accessibility. see in the Figures of this same section

Figure 142 Bucharest – Romania

Figure 143 Result Bucharest – Romania

11.1.19 Budapest, Hungary

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 70.97% spatial accessibility. see in the Figures of this same section

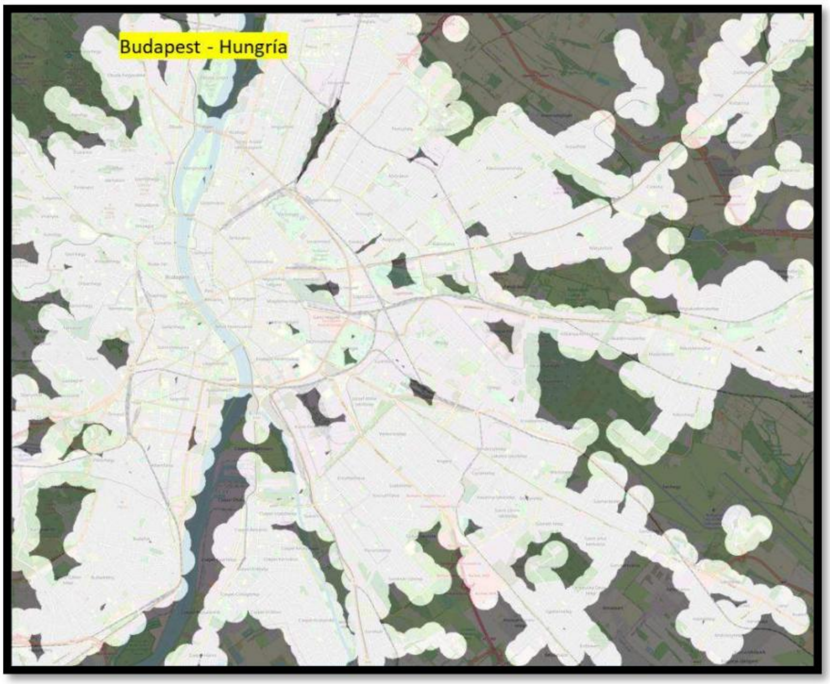

Figure 144 Budapest – Hungary

Figure 145 Result Budapest – Hungary

11.1.20 Dublin – *Ireland*

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 88.94% spatial accessibility. see in the Figures of this same section

Figure 146 Dublin – Ireland

Figure 147 Result Dublin – Ireland

11.1.21 Stockholm – Sweden

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 94.3% spatial accessibility. see in the Figures of this same section

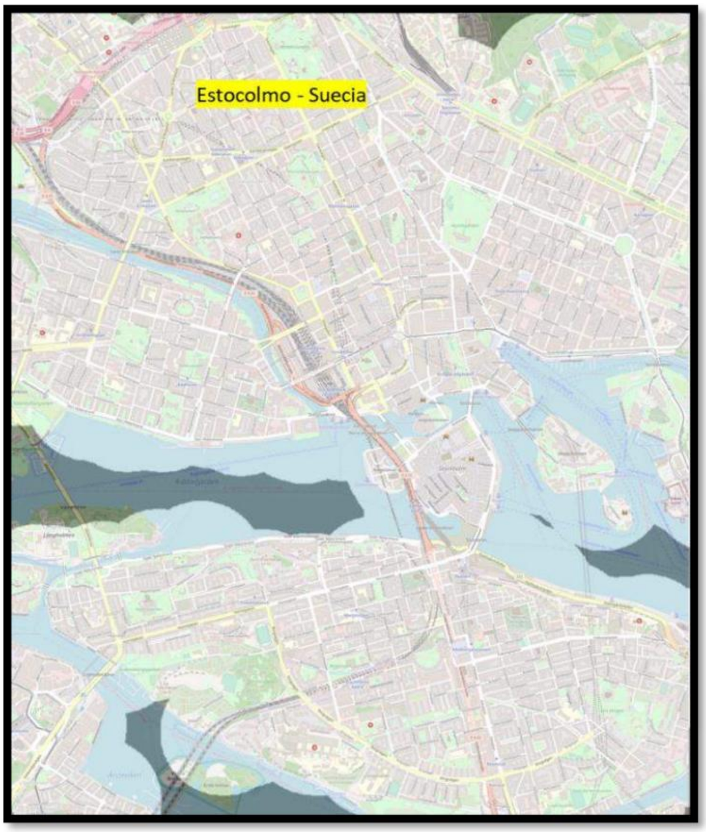

Figure 148 Stockholm – Sweden

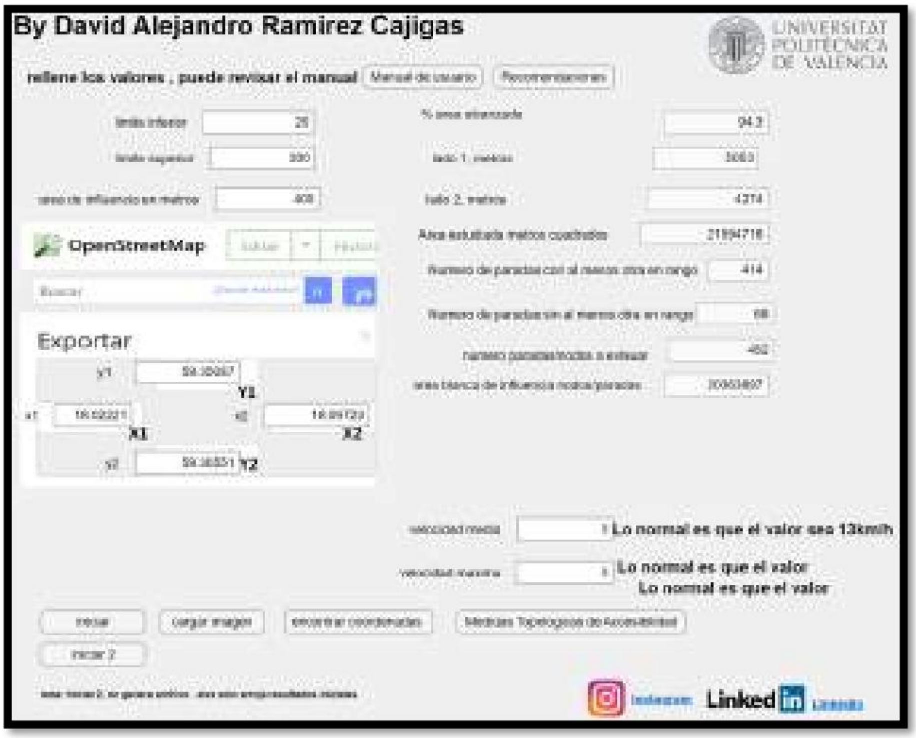

Figure 149 Result Stockholm – Sweden

11.1.22 Helsinki–Finland

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case there is a 99.52% spatial accessibility. see in the Figures of this same section

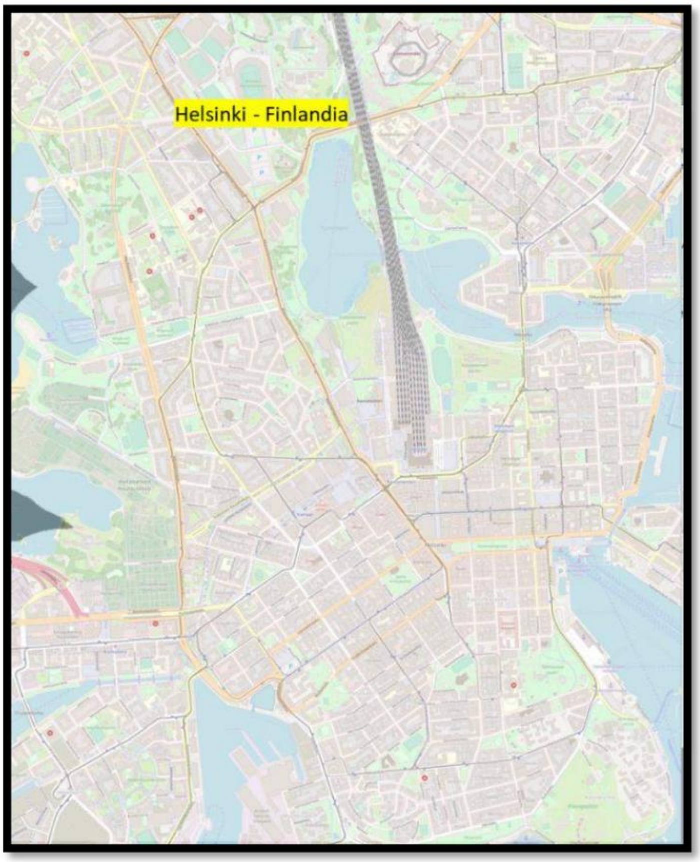

Figure 150 Helsinki – Finland

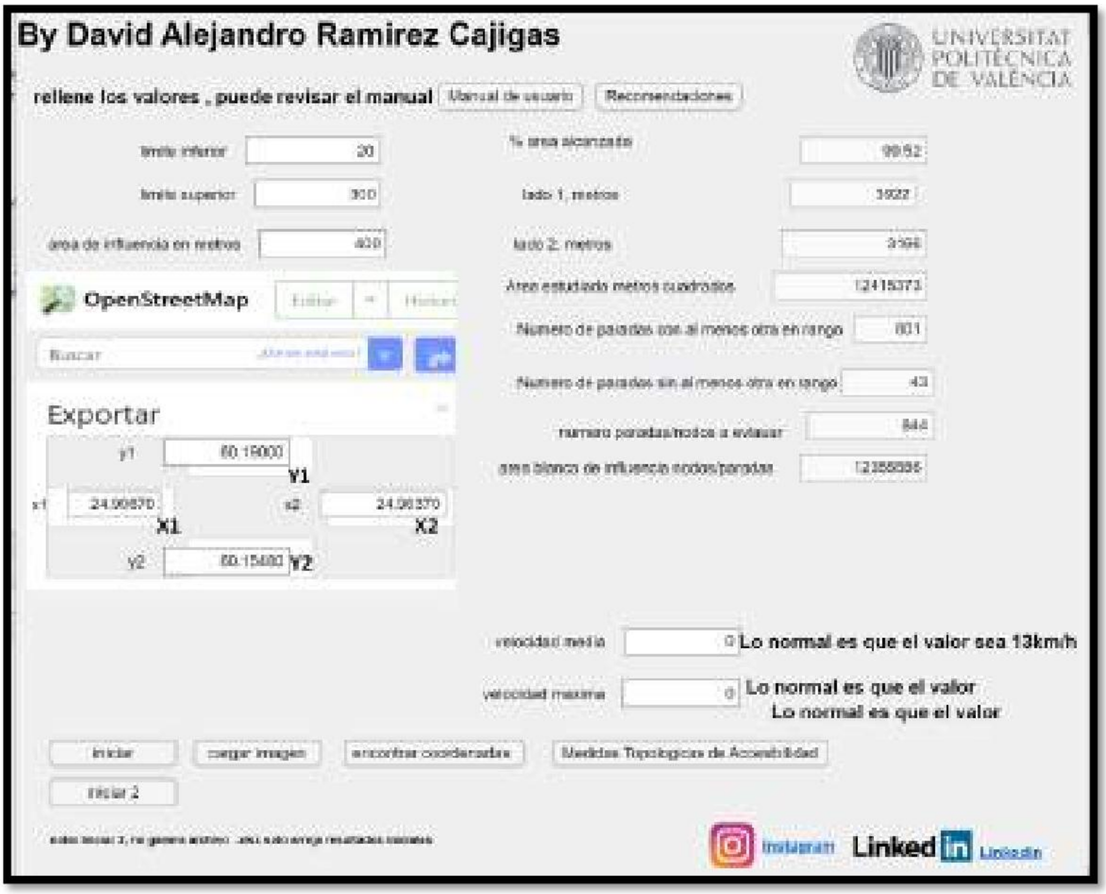

Figure 151 Result Helsinki – Finland

11.1.23 The Vane – Malta

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 84.35% spatial accessibility. see in the Figures of this same section

Figure 152 La Vane – Malta

Figure 153 Result La Veleta – Malta

11.1.24 Lisbon Portugal

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 97.19% spatial accessibility. see in the Figures of this same section

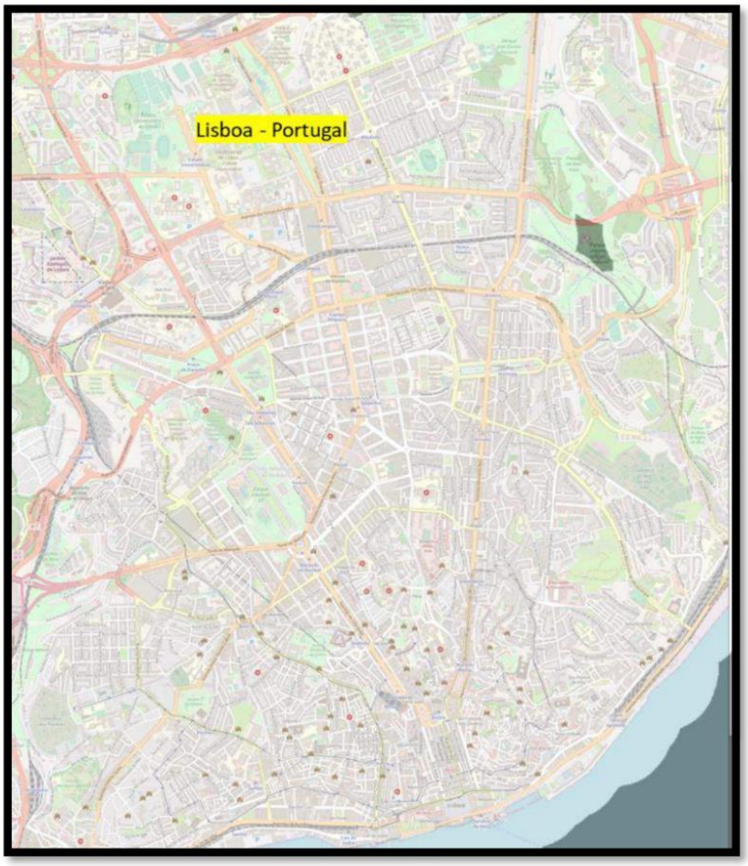

Figure 154 Lisbon – Portugal

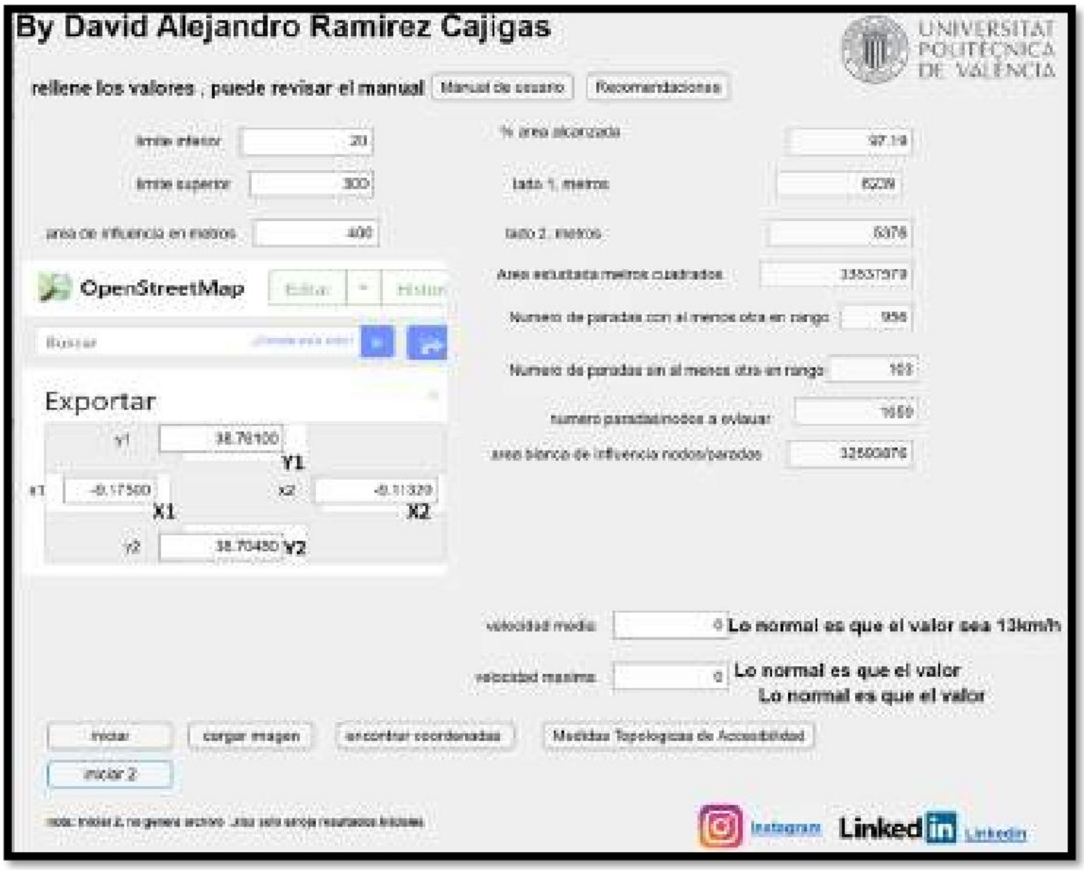

Figure 155 Result Lisbon – Portugal

11.1.25 Ljubljana – Slovenia

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 94.25% spatial accessibility. see in the Figures of this same section

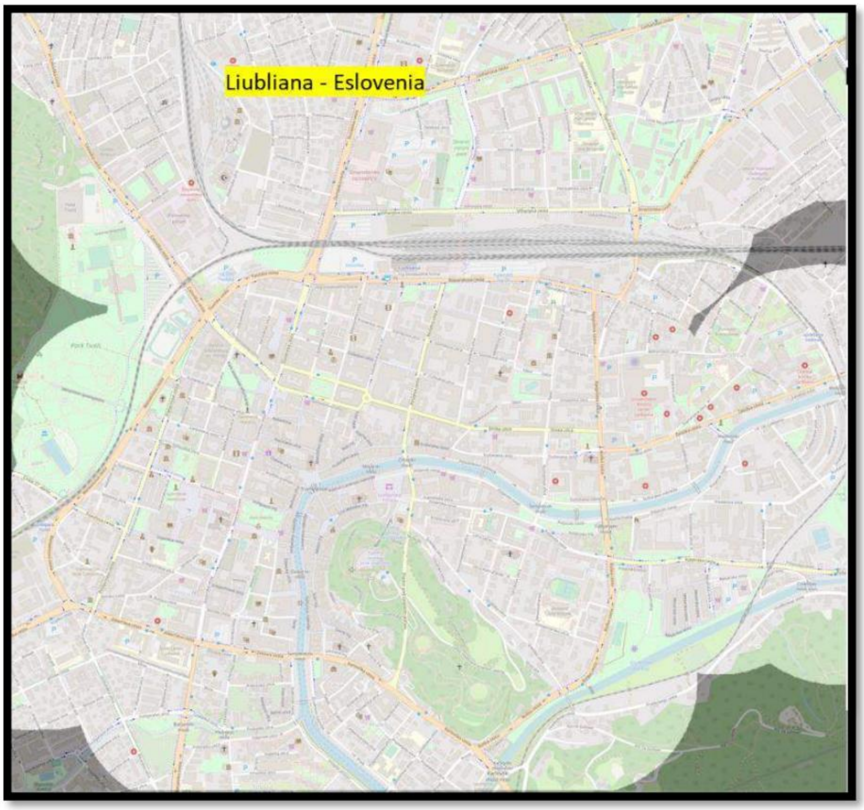

Figure 156 Ljubljana – Slovenia

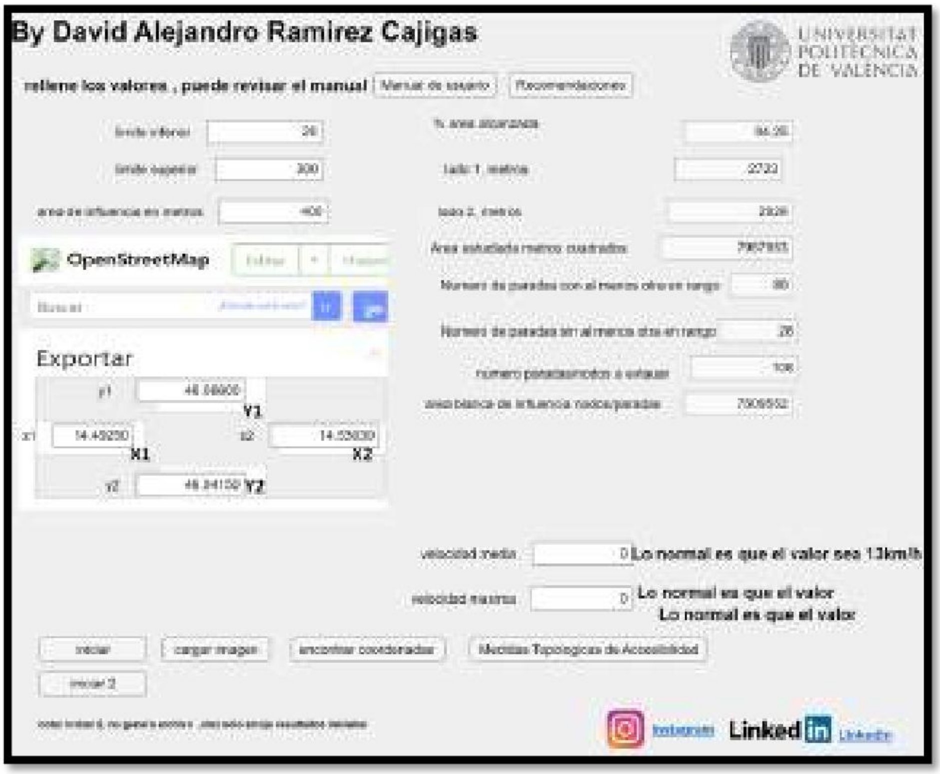

Figure 157 Result Ljubljana – Slovenia

11.1.26 Luxembourg – Luxembourg

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 94.62% spatial accessibility. see in the Figures of this same section

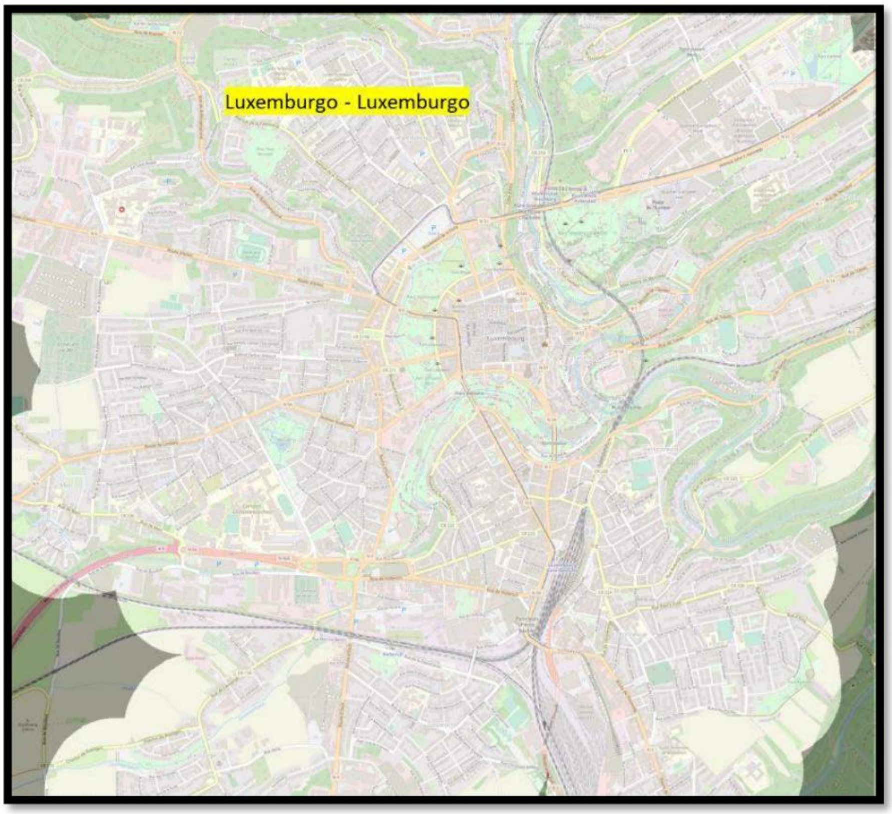

Figure 158 Luxembourg – Luxembourg

Figure 159 Result Luxembourg – Luxembourg

11.1.27 Nicosia – Cyprus

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. In this case, there is a 22.88% spatial accessibility in Cyprus, there could be an error in the database of the city that has been accessed. see in the Figures of this same section

Figure 160 Nicosia – Cyprus

Figure 161 Result Nicosia – Cyprus

11.1.28 Prague – Czech Republic

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 85.51% spatial accessibility. see in the Figures of this same section

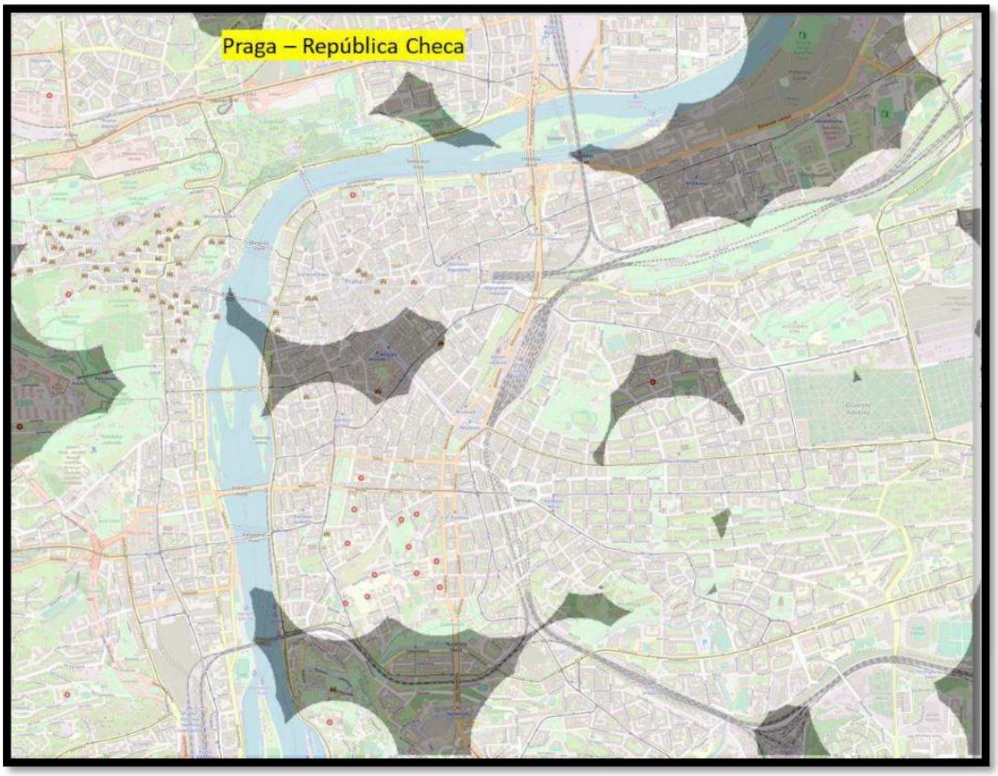

Figure 162 Prague – Czech Republic

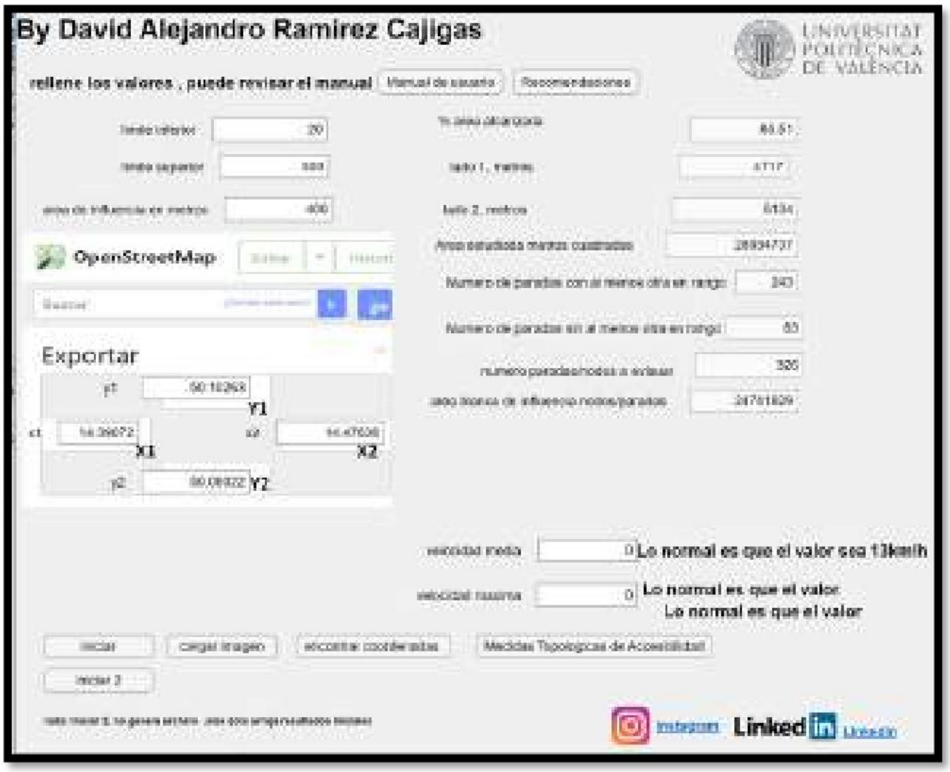

Figure 163 Result Prague – Czech Republic

11.1.29 Riga – latvia

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 74.11% spatial accessibility. see in the Figures of this same section

Figure 164 Riga – latvia

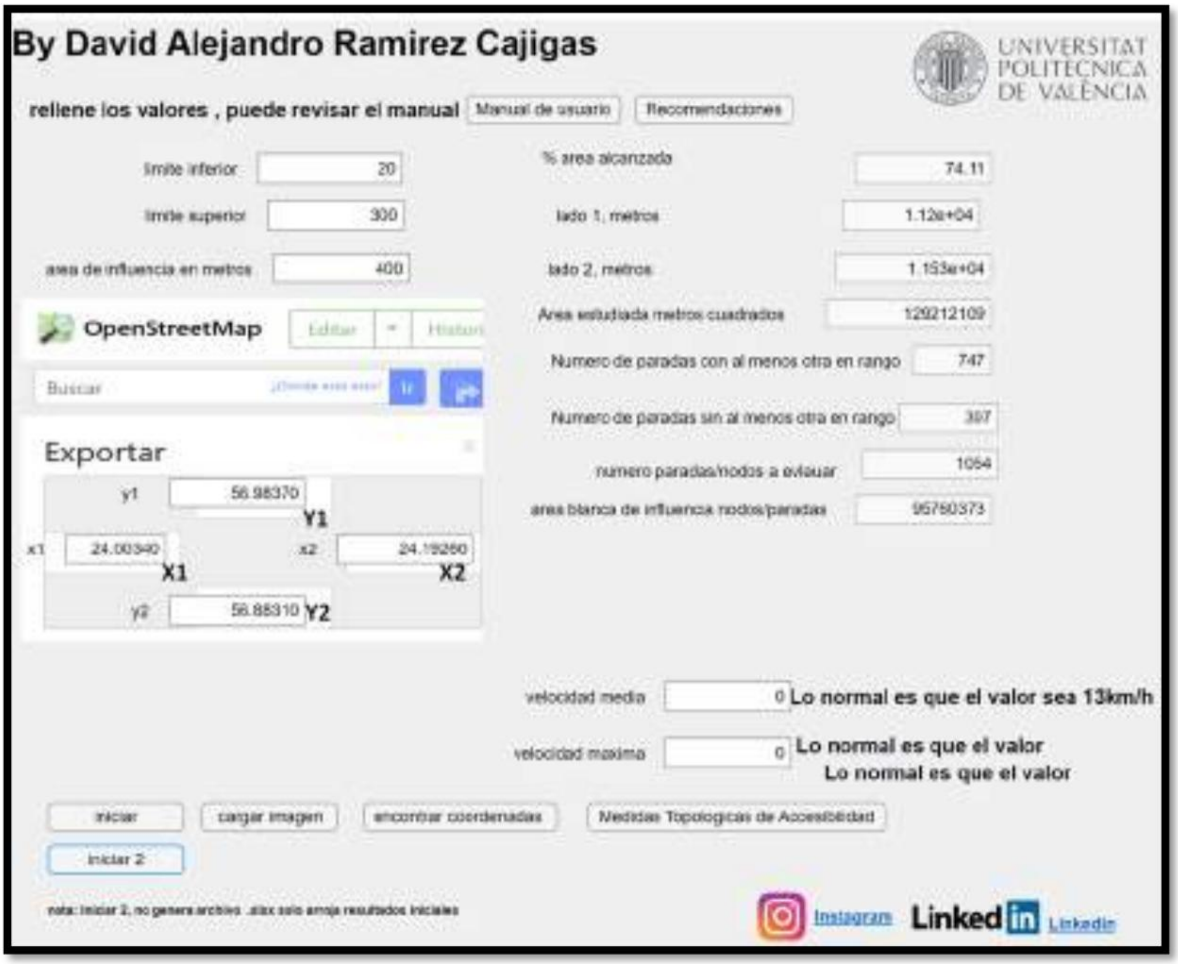

Figure 165 Result Riga – latvia

11.1.30 Sofia – Bulgaria

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 93.59% spatial accessibility. see in the Figures of this same section

Figure 166 Sofia – Bulgaria

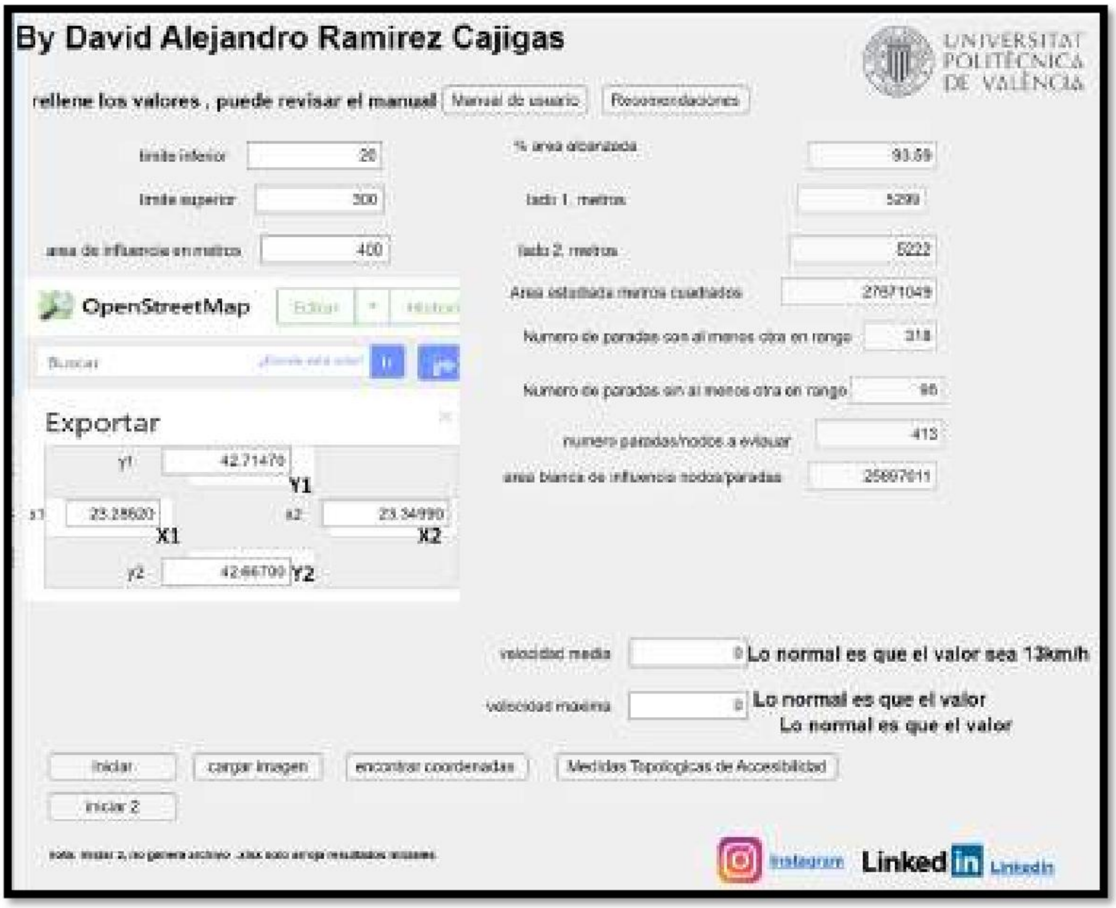

Figure 167 Result Sofia – Bulgaria

11.1.31 Tallinn – Estonia

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 78.21% spatial accessibility. see in the Figures of this same section

Figure 168 Tallinn – Estonia

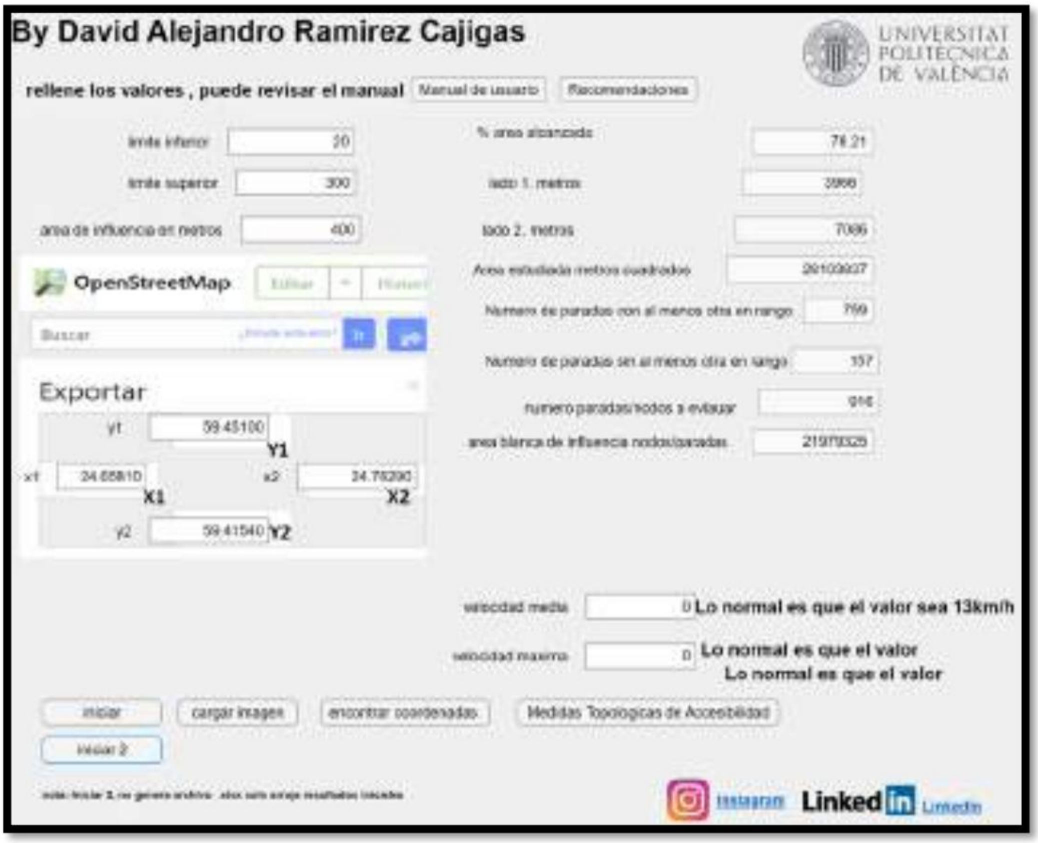

Figure 169 Result Tallinn – Estonia

11.1.32 Warsaw, Poland

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 66.65% spatial accessibility. see in the Figures of this same section

Figure 170 Warsaw – Poland

Figure 171 Result Warsaw – Poland

11.1.33 Vienna–Austria

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 90.96% spatial accessibility. see in the Figures of this same section

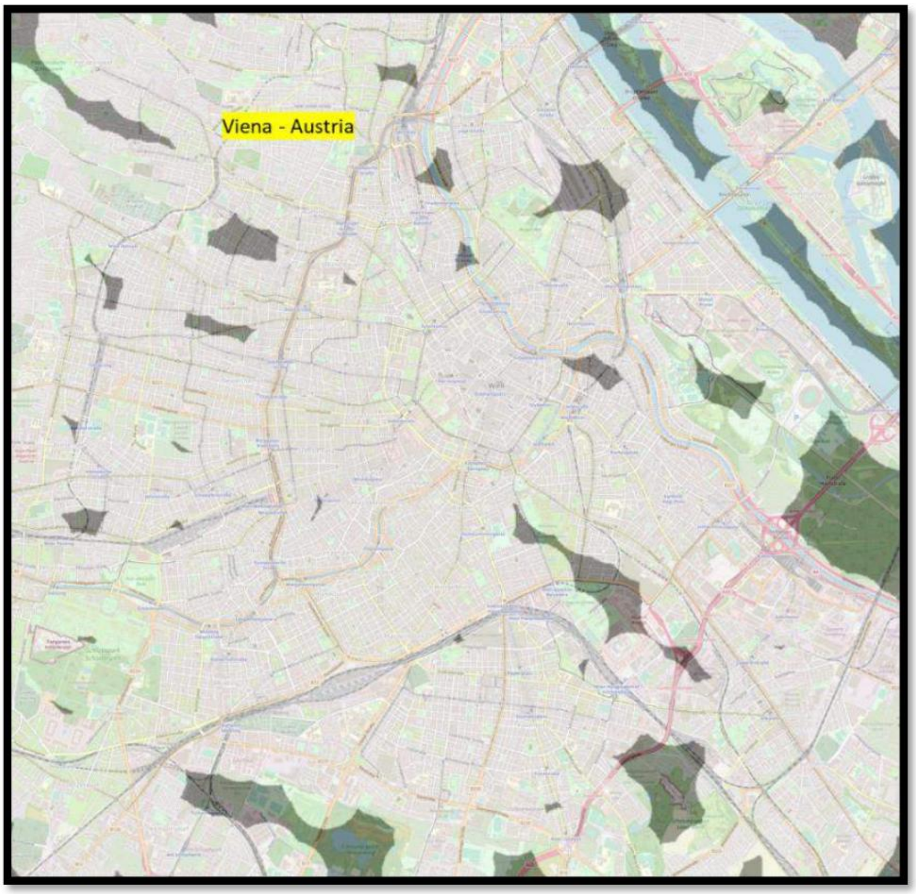

Figure 172 Vienna – Austria

Figure 173 Result Vienna – Austria

11.1.34 Vilnius Lithuania

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is 86.36% spatial accessibility. see in the Figures of this same section

Figure 174 Vilnius Lithuania

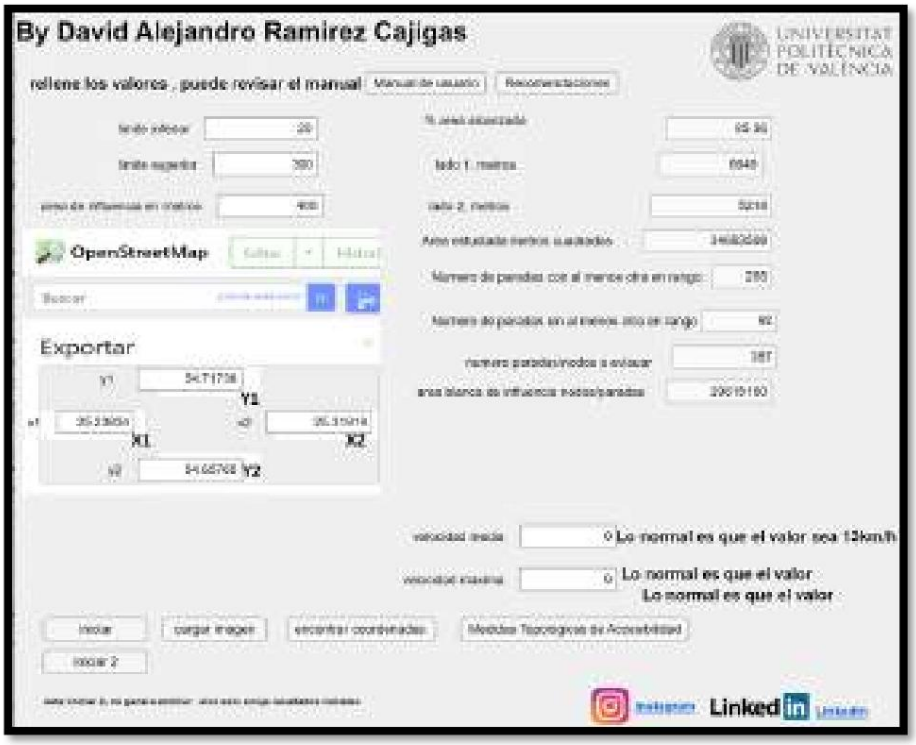

Figure 175 Result Vilnius Lithuania

11.1.35 Zagreb Croatia

The transport system is evaluated using the OpenStreetMaps public database, the result of Dgis is superimposed on a map of the city whose corners are the same coordinates, in dark color the area without accessibility to public transport and in light color the area accessible. For this case, there is a 76.03% spatial accessibility. see in the Figures of this same section

Figure 176 Zagreb Croatia

Figure 177 Result Zagreb Croatia

11.2 Dgis program code

To develop the program, use Matlab R2021a, as a development environment and compiler, one version in Windows 10 and the other in Mac Os 10.14.

The code has a total of **1170** lines including the graphics modules.

```
classdef app1 < matlab.apps.AppBase

    % Properties that correspond to app components

    properties (Access = public)

        UI Figure                               matlab.ui.Figure

        LonormalthanLabel_2 value               matlab.ui.control.Label

        start2Button                            matlab.ui.control.Button

        RecommendationsButton                   matlab.ui.control.Button

        UserManualButton                        matlab.ui.control.Button

        hyperlink2                              matlab.ui.control.Hyperlink

        Image4                                  matlab.ui.control.Image

        Image3                                  matlab.ui.control.Image

        hyper link                              matlab.ui.control.Hyperlink

        noteStart2does not generatexlsxLabel file matlab.ui.control.Label

        Normal than the Label value             matlab.ui.control.Label

        Normally, the value is 13kmh Label matlab.ui.control.Label

        VelMax                                  matlab.ui.control.NumericEditField

        maxspeedEditFieldLabel matlab.ui.control.Label

        TopologicalAccessibilityMeasuresButton matlab.ui.control.Button

        VelMedi                                 matlab.ui.control.NumericEditField

        averagespeedEditFieldLabel matlab.ui.control.Label
```

whiteareainfluencenodosstopsEditField
matlab.ui.control.NumericEditField

whiteareainfluencenodosstopsEditFieldLabel
matlab.ui.control.Label

findcoordinatesButton matlab.ui.control.Button

loadimageButton matlab.ui.control.Button

totalstops matlab.ui.control.NumericEditField

numberstopnodosaevlauarLabel matlab.ui.control.Label

stops2 matlab.ui.control.NumericEditField

NumberofstopswithoutatleastbringinrangeEditFieldLabel
matlab.ui.control.Label

stops1 matlab.ui.control.NumericEditField

NumberofstopswithatleasttrainrangeEditFieldLabel
matlab.ui.control.Label

total area matlab.ui.control.NumericEditField

AreaStudysquaremetersLabel matlab.ui.control.Label

side2 matlab.ui.control.NumericEditField

side2metersLabel matlab.ui.control.Label

side1 matlab.ui.control.NumericEditField

side1metersLabel matlab.ui.control.Label

image2 matlab.ui.control.Image

areareachedEditField matlab.ui.control.NumericEditField

areareachedEditFieldLabel matlab.ui.control.Label

b123 matlab.ui.control.NumericEditField

areaofinfluenceinmetersLabel matlab.ui.control.Label

ByDavidAlejandroRamirezCajigasLabel matlab.ui.control.Label

x111 matlab.ui.control.NumericEditField

upperboundEditFieldLabel matlab.ui.control.Label

y111 matlab.ui.control.NumericEditField

```
lowerboundEditFieldLabel matlab.ui.control.Label
startButton matlab.ui.control.Button
fill in the values you can review the manual Label matlab.ui.control.Label
y22 matlab.ui.control.NumericEditField
y2EditFieldLabel matlab.ui.control.Label
y11 matlab.ui.control.NumericEditField
y1EditFieldLabel matlab.ui.control.Label
x22 matlab.ui.control.NumericEditField
x2EditFieldLabel matlab.ui.control.Label
x11 matlab.ui.control.NumericEditField
x1EditFieldLabel matlab.ui.control.Label
picture matlab.ui.control.Image
end

% Callbacks that handle component events
methods (Access = private)

% Callback function
function findfileButtonPushed(app, event)
[name,path]=uigetfile('*.xlsx','open data file');
if name==0
return;
else
data=strcat(path,name)
T=readable(data);
end
end
```

```
% Value changed function: x11
function x11ValueChanged(app, event)
    value = app.x11.Value;

end

% Callback function
function areasquaremetersEditFieldValueChanged(app, event)
    value = app.x3.Value;

end

% Value changed function: x22
function x22ValueChanged(app, event)
    value = app.x22.Value;

end

% Value changed function: y11
function y11ValueChanged(app, event)
value = app.y11.Value;
end

% Value changed function: y22
function y22ValueChanged(app, event)
value = app.y22.Value;
```

```
end

% Button pushed function: startButton
function startButtonPushed(app, event)
%disp('enter the coordinate x1,x2,y1,y2 of the edges of the study area to know the total area in meters')
x4=app.x11.Value
x5= app.x22.Value
y4= app.y11.Value
y5=app.y22.Value
v3=app.y111.Value%input('enter the inner range of the buffer')
v4=app.x111.Value%input('enter the upper range of the buffer')
v5=app.b123.Value
lon = [x4 x5];
lat = [y4 y5];
lonlat = table(lon.',lat.');
llb = [fliplr(table2array(lonlat)) zeros(size(lonlat,1),1)]
I = lla2flat(llb,[min(llb(:,1)) min(llb(:,2))],90,0)
I1= I(:,1)
I2= I(:,2)
x1=I1(1)
x2=I1(2)
y1=I2(1)
y2=I2(2)
%v3=%input('enter the inner range of the buffer')
%v4=%input('enter the upper range of the buffer')
%v5=input('enter the buffer size in meters')
```

```
side1=sqrt((x1-x1)^2+(y2-y1)^2)

Side2=sqrt((x2-x1)^2+(y1-y1)^2)%*100000

Studio_Area=side1*side2

disp('table imported from excel')

[name,path]=uigetfile('*.xlsx','open data file');

if name==0

return;

else

data=strcat(path,name)

T=readable(data);

end

%T=readtable('mini2.xlsx')

H = table(T.lon,T.lat);

%plot(T.lon,T.lat,'ko')

U=length(T.lon);

n=U;

J = table(T.lon,T.lat);

%E = J{:,:}

%lla = [fliplr(table2array(J)) zeros(size(J,1),1)]

%position = lla2flat(lla,[min(lla(:,1)) min(lla(:,2))],90,0)

% same as before

%r = ;

lon3 = T.lon;

lat3 = T.lat;

lonlat1 = table(lon3,lat3);

% boundary

box = [x4 y4; x5 y5]; % lon/lat
```

```
% process table & box; convert to meters

lla1 = [fliplr(table2array(lonlat1)) zeros(size(lonlat1,1),1)];

position = lla2flat(lla1,[min(lla1(:,1)) min(lla1(:,2))],90,0);

boxpos = lla2flat([fliplr(box) [0, 0]],[min(lla1(:,1)) min(lla1(:,2))],90,0);

boxpos = boxpos(:,1:2);

% same as before

r = v5;

C = position(:,1:2); %locations(x,y)

p = 10; % padding

s = ceil([(max(C(:,2))-min(C(:,2))),(max(C(:,1))-min(C(:,1)))] + r*2 + p*2);

refpoint = [min(C(:,1)) min(C(:,2))];

C = round(C - refpoint + r + p);

corners = round(boxpos - refpoint + r + p);

m = false(s);

m(sub2ind(s,C(:,2),C(:,1))) = 1;

m = bwdist(m)<=r;

m(:,[1:corners(1,1) corners(2,1):end]) = 0;

m([1:corners(1,2) corners(2,2):end],:) = 0;

size(C,1)*round(pi*r^2)

totalarea = sum(m(:)) % total number of white pixels = area

imshow(m); hold on

plot(corners([1 2 2 1 1],1),corners([1 1 2 2 1],2),':')

%w1234=totalarea % white area

%totalarea2 = sum(m23(:))

p4=position(:,1);

p5=position(:,2);

p89=table(p4,p5);%new X from the code
```

```
X = p89{:,:}
for i=1:n-1
for j=i+1:n
d{i}(ji) = norm(X(i,:)-X(j,:));
end
end
(d);
size(d{2});
d1 = zeros(n, n);
for i=1:n-1
for j=i+1:n
d1(i, j) =norm(X(i,:)-X(j,:));
end
end
disp('distance array in meters')
d1 %this is the matrix
k1=find(d1>v3 & d1<v4); %array of positions where if stop exists, internal use

length(k1);
%traverse the array
%[f,c]=size(d1);
%for p=1:c
% for b=1:f
%disp(d1(b,p));
% end
%end
k2=(d1(k1));
```

```
length(d1(k1));

f3=(d1>v3 & d1<v4);% condition of excluded distances

disp('distance matrix in meters, between stops that meet the condition')

f4=d1.*f3 %%matrix of distances that meet the range

f5=sum(f4);

f6=find(f5>1);

disp('Total stops that meet the condition')

f7=length(f6) %stops that are between 200 and 450 meters away

disp('Total stops that do not meet the condition')

f14=n-f7

f8=sum(f3,2); % number of stops that meet the standard with respect to a specific stop

f9=f8>=1 ;%internal use to know where there is and where there is not

f10=f8>=1; %positions where if there is a stop

f11=(Tv(f10));, (T.lat(f10));, (T.lon(f10));,(f8(f10)); % stops with good pedestrian access

f12=f8<=0; %internal use shows me where there are no stations in range

f13=(Tv(f12));, (T.lat(f12));, (T.lon(f12));,(f8(f12)); % stops without good pedestrian access

%plot2(T.lon(f12),T.lat(f12),'ko')

%plot3(T.lon(f10),T.lat(f10),'ko')

stop_address=(Tv(f10));

length=T.lon(f10);

latitude=T.lat(f10);

Amount_close_stops=f8(f10);

Stops_comply=table(stop_address,longitude,latitude,Amount_of_close_stops)

address_stop_=(Tv(f12));

length_=T.lon(f12);
```

latitude_=T.lat(f12);

Amount_nearby_stops_=f8(f12);

Area_scope_theoretical=Area_Study

Area_not_reached=Area_Study-totalarea %if they were separate buffers it would be that(f7*(pi*(v4^2)))

Stops_Not_fulfilled=table(address_stop_,longitude_,latitude_,Quantity_stop
as_close_)

metric_coordinates=table((Tv),(T.lon),(T.lat),(p5),(p4))

m24=(areatotal*100)/(Study_Area)

app.reachedareaEditField.Value=(m24)

app.whiteareainfluencenodosparadasEditField.Value=(totalarea)

app.side1.Value=(side1)

app.side2.Value=(Side2)

app.areatotal.Value=(Study_Area)

app.stops1.Value=(f7)

app.paradas2.Value=(f14)

app.totalstops.Value=(length(Tv))

%General_Data=table(

%table2cell covers any table to cell in case I get confused remember

writetable(metric_coordinates,'Results.xlsx')

writetable(Stops_comply,'Results.xlsx','sheet','stopscomply ','range','B2') Yes

writetable(Stops_Not_Compliant,'Results.xlsx','sheet','Stops Meet','range','B2') No

writematrix(d1,'Results.xlsx','sheet',' complete matrix','range','B2') distance

writematrix(f4,'Results.xlsx','sheet',' connection matrix','range','B2') distance

writematrix(f3,'Results.xlsx','sheet','matrix range','range','B2') stops in

```
end

% Value changed function: y111
function y111ValueChanged(app, event)
value = app.y111.Value;
end

% Callback function
function x3ValueChanged(app, event)
value = app.x3.Value;
end

% Callback function
function x1111ValueChanged(app, event)
value = app.x1111.Value;
app.Output1.Value=Study_Area
end

% Value changed function: x111
function x111ValueChanged(app, event)
value = app.x111.Value;
end

% Value changed function: b123
function b123ValueChanged(app, event)
value = app.b123.Value;
end
```

```
% Button pushed function: loadButtonImage
function uploadImageButtonPushed(app, event)
[ename,path1]=uigetfile('*.png','open data file');
if ename==0
return;
else
data1=strcat(path1,namee)
end
[eename,path2]=uigetfile('*.osm','open data file');
if eename==0
return;
else
data2=strcat(path2,eename)
end
imgmap=data1
opnstr=data2
[parsed_osm, osm_xml]=parse_openstreetmap(opnstr)
[connectivity_matrix,
intersection_node_indices]=extract_connectivity(parsed_osm)
action_nodes=get_unique_node_xy(parsed_osm, intersection_node_indices)
plot_way(gca, parsed_osm, imgmap)
start=3
target=5
[route, dist]=routeplanner(dg, start, target)
plot_route(gca, route, parsed_osm)
end
```

```
% Button pushed function: findButtonCoordinates

function findcoordinatesButtonPushed(app, event)

clc

clear

[name1,path3]=uigetfile('*.png','open data file');

if ename1==0

return;

else

data3=strcat(path3,name1)

end

[ename2,path4]=uigetfile('*.osm','open data file');

if namee2==0

return;

else

data4=strcat(path4,name2)

end

imgmapl=data3

opnstrl=data4

[parsed_osm, osm_xml]=parse_openstreetmap(opnstrl)

[connectivity_matrix,
intersection_node_indices]=extract_connectivity(parsed_osm)

X=parsed_osm.node.xy';

x=X(:,1);y=X(:,2);

[i,j,v]=find(connectivity_matrix);

links=[ij];

indX=unique([links(:,1) links(:,2)]);
```

```
fig=figure;
ax=axes('Parent',fig);
hold(ax,'on')
plot_way(ax, parsed_osm,imgmapl)
plot_way(ax, parsed_osm)
hold(ax, 'on')
dmin=0.11;
C=10
button=1;
xs=[];ys=[];dist=[];x=[];y=[];xcoor=[];ycoor=[],z1=[];z2=[];
while button==1
 [xm,ym,button]=ginput(1);
xcoor=[xcoor xm]; ycoor=[ycoor ym]; N=length(x);
hold(ax,('on'));
if button==N
break
end
xcoor
ycoor
lon=xcoor
lat=ycoor
j=[[lat'],[lon']]
t=table(j)
writetable(t,'Coordinates.xlsx')
end
end
```

```
% Value changed function: reachedAreaEditField

function areareachedEditFieldValueChanged(app, event)

value = app.reachedareaEditField.Value;

end


% Value changed function:

%whiteinfluenceareanodosstopsEditField

function whiteareainfluencenodosstopsEditFieldValueChanged(app, event)

value = app.whiteareainfluencenodosstopsEditField.Value;

end


% Button pushed function:

% Topological Measures of Accessibility Button

function TopologicalAccessibilityMeasuresButtonPushed(app, event)

%disp('enter the coordinate x1,x2,y1,y2 of the edges of the study area to know the total area in
meters')

x4=app.x11.Value

x5= app.x22.Value

y4= app.y11.Value

y5=app.y22.Value

v3=app.y111.Value%input('enter the inner range of the buffer')

v4=app.x111.Value%input('enter the upper range of the buffer')

v5=app.b123.Value

Top01=app.VelMedi.Value

Top02=app.VelMax.Value

lon = [x4 x5];

lat = [y4 y5];
```

```
lonlat = table(lon.',lat.');

llb = [fliplr(table2array(lonlat)) zeros(size(lonlat,1),1)]

I = lla2flat(llb,[min(llb(:,1)) min(llb(:,2))],90,0)

I1= I(:,1)

I2= I(:,2)

x1=I1(1)

x2=I1(2)

y1=I2(1)

y2=I2(2)

%v3=input('enter the inner range of the buffer')

%v4=input('enter the upper range of the buffer')

%v5=input('enter the buffer size in meters')

side1=sqrt((x1-x1)^2+(y2-y1)^2)

Side2=sqrt((x2-x1)^2+(y1-y1)^2)%*100000

Studio_Area=side1*side2

disp('table imported from excel')

[name,path]=uigetfile('*.xlsx','open data file');

if name==0

return;

else

data=strcat(path,name)

T=readable(data);

end

%T=readtable('mini2.xlsx')

[name01,path01]=uigetfile('*.xlsx','open data file');

if name01==0

return;
```

```
else

data=strcat(path01,name01)

T2=readable(data); % Here you must import the route measurement file in meters in order

end

H = table(T.lon,T.lat);

plot(T.lon,T.lat,'ko')

U=length(T.lon);

n=U;

J = table(T.lon,T.lat);

%E = J{:,:}

lla = [fliplr(table2array(J)) zeros(size(J,1),1)]

position = lla2flat(lla,[min(lla(:,1)) min(lla(:,2))],90,0)

% same as before

%v5 =300 ;

r = v5 ;

C = position(:,1:2); %locations(x,y)

p = 10; % padding

s = ceil([(max(C(:,2))-min(C(:,2))),(max(C(:,1))-min(C(:,1)))] + r*2 + p*2);

C = round(C - [min(C(:,1)) min(C(:,2))] + r + p);

m = false(s);

m(sub2ind(s,C(:,2),C(:,1))) = 1;

m22 = bwdist(m)<=r;

totalarea = sum(m22(:)) % total number of white pixels = area

m23 = bwdist(m)>=r;

totalarea2 = sum(m23(:))

%imshow('map(5).png')
```

```
imshow(m22)
m24=(totalarea*100)/(totalarea+totalarea2)
p4=position(:,1);
p5=position(:,2);
p89=table(p4,p5);%new X from the code
X = p89{:,:}
for i=1:n-1
for j=i+1:n
d{i}(ji) = norm(X(i,:)-X(j,:));
end
end
(d);
size(d{2});
d1 = zeros(n, n);
for i=1:n-1
for j=i+1:n
d1(i, j) =norm(X(i,:)-X(j,:));
end
end
disp('distance array in meters')
d1 %this is the matrix
k1=find(d1>v3 & d1<v4); %array of positions where if stop exists, internal use

length(k1);
%traverse the array
%[f,c]=size(d1);
%for p=1:c
```

```
% for b=1:f
%disp(d1(b,p));
% end
%end
k2=(d1(k1));
length(d1(k1));
f3=(d1>v3 & d1<v4);% condition of excluded distances
disp('distance matrix in meters, between stops that meet the condition')
f4=d1.*f3 %%matrix of distances that meet the range
f5=sum(f4);
f6=find(f5>1);
disp('Total stops that meet the condition')
f7=length(f6) %stops that are between 200 and 450 meters away
disp('Total stops that do not meet the condition')
f14=n-f7
f8=sum(f3,2); % number of stops that meet the standard with respect to a specific stop

f9=f8>=1 ;%internal use to know where there is and where there is not
f10=f8>=1; %positions where if there is a stop
f11=(Tv(f10));, (T.lat(f10));, (T.lon(f10));,(f8(f10)); % stops with good pedestrian access

f12=f8<=0; %internal use shows me where there are no stations in range
f13=(Tv(f12));, (T.lat(f12));, (T.lon(f12));,(f8(f12)); % stops without good pedestrian access

%plot2(T.lon(f12),T.lat(f12),'ko')
%plot3(T.lon(f10),T.lat(f10),'ko')
stop_address=(Tv(f10));
length=T.lon(f10);
```

```
latitude=T.lat(f10);

Amount_close_stops=f8(f10);

Stops_comply=table(stop_address,longitude,latitude,Amount_of_close_stops)


address_stop_=(Tv(f12));

length_=T.lon(f12);

latitude_=T.lat(f12);

Amount_nearby_stops_=f8(f12);

Area_scope_theoretical=Area_Study

Area_not_reached=Area_Study-totalarea %if they were separate buffers it would be that(f7*(pi*(v4^2)))


Stops_Not_fulfilled=table(stop_address_,longitude_,latitude_,Number_of_close_stops_)


Top1=length(d1)



%Tap2=Top1+1

z123=T2(1:Top1,2:Top1+1)

Top3=table2array(z123) %matrix path distance

Top4=sum(Top3,2) %vector sum row distance path

Speed=60 % shows travel time in minutes, just for my internal conversion


AverageSpeed=Top01

Top6=(squareform(pdist(X)))./1000 %straight line distance

Top5=sum(Top6,2)%vector sum distances line

Top7=Speed/MediumSpeed

Top8=Top6*Top7 % array time minutes, straight line

Top9=Top3*Top7 %time minutes array, enroute

Top10=sum(Top8,2) ;% sum time rows straight

Top11=sum(Top9,2); % sum time rows path
```

```
Top12=repmat(0:Top1-1,[Top1 1]) - repmat((0:Top1-1)',[1 Top1]); %generate matrix 0 to n

%Top13=ones(Top1);

%Top14=tril(Top15);

%Top16=tril(ones5,-1);

Top17=(tril(Top12,-1)*-1);

Top18=Top17+Top12;

Top19=Top17+Top18 %shimbel matrix

Top20=sum(Top19,2); %sum rows shimbel

Top21=Top3./Top6; %path factor array with diagonal NaN

Top21(isnan(Top21))=0 %matrix path factor with NaN = 0 diagonal

Top23=sum(Top21,2); %sum matrix path factor

Top24=Top3-Top6 ; % matrix differences

Top25= (Top24*100)./Top3; %matrix of percentages between route and line

Top25(isnan(Top25))=0 %array of percentages between route and straight

Top26=Top9/Top8; %Tracing index – Speed (Tv)

Top27=sum(Top23,2); %sum Trace Index – Velocity (Tv)

Sum_straight_distance=Top5

Path_distance_sum=Top4

Sum_route_time=Top11

Sum_time_straight=Top10

Sum_Shimbel=Top20

Sum_Factor_path=Top23

Sum_Indice_TrazadoTv=Top27

Stop_name=Tv

Trip_time_to_node_min=Top9(:,Top1)% Route array end time

%one_split_n_less_1=(1/(Top20-1)) %perbar if 1/n-1 works
```

```
for rrrrr=1:Top1

rrre(rrrrr) = (1/((Top20(rrrrr))-1))

one_divided_n_less_1=rrre'

end

one_divided_n_minus_1

Ri=one_divided_n_minus_1.*Top23

one_split_n=1./Top20

sum_times_route_times_straight=Top11./Top10

plot_speed_node=one_split_n.*sum_times_path_times_straight

Total_route_factor=Top4./Top5

Absolute_Global_Time=Sum_route_time

copila=table(Nombre_parada,Suma_distancia_recta,Suma_distancia_ruta,Suma_tie
mpo_recta,Suma_tiempo_ruta,Suma_Indice_TrazadoTv,Suma_Shimbel,Suma_Factor_ru
ta,uno_dividido_n_menos_1,Ri,uno_dividido_n,suma_tiempos_ruta_tiempos_recta,
trazado_velocidad_nodo,Absoluto_Tiempo_Global,Tiempo_viaje_hasta_nodo_min,Fa ctor_ruta_total)


%for me super important Top6=table2array(z123) becomes double data

%General_Data=table(

%table2cell covers any table to cell in case I get confused remember


%for me super important Top6=table2array(z123) becomes double data

%General_Data=table(

%table2cell covers any table to cell in case I get confused remember

w1234=tasktotal

m24=(totalarea*100)/(totalarea+totalarea2)

%app.reachedareaEditField.Value=(m24)

app.whiteareainfluencenodosstopsEditField.Value=(w1234)

app.side1.Value=(side1)

app.side2.Value=(Side2)
```

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```
app.areatotal.Value=(Study_Area)

app.stops1.Value=(f7)

app.paradas2.Value=(f14)

app.totalstops.Value=(length(Tv))

metric_coordinates=table((Tv),(T.lon),(T.lat),(p5),(p4))

writetable(metric_coordinates,'Topology.xlsx')

writetable(Stops_fulfill,'Topologicas.xlsx','sheet','stops meet','range','B2')

writetable(Stops_Not_fulfilled,'Topologicas.xlsx','sheet','Stops met','range','B2')    No

writematrix(d1,'Topologicas.xlsx','sheet',' complete    distance
matrix','range','B2')

writematrix(f4,'Topologicas.xlsx','sheet',' connection    distance
matrix','range','B2')

writematrix(f3,'Topologicas.xlsx','sheet','matrix range','range','B2')    stops    in

writematrix(Top3,'Topologicas.xlsx','sheet','matrix route','range','B2')    distance
%dis route

writematrix(Top6,'Topologicas.xlsx','sheet','matrix straight','range','B2')    distance    line
% dis straight

writematrix(Top8,'Topologicas.xlsx','sheet',' straight    weather    line
matrix','range','B2') %straight line time

writematrix(Top9,'Topologicas.xlsx','sheet',' route matrix','range','B2')    weather
%route time

writematrix(Top19,'Topologicas.xlsx','sheet',' Shimbel matrix','range','B2') %shimbel

writematrix(Top21,'Topologicas.xlsx','sheet','path factor ' ,'range','B2') %path factor

writematrix(Top24,'Topologicas.xlsx','sheet',' difference    of
matrix','range','B2') %difference matrix

writematrix(Top25,'Topologicas.xlsx','sheet',' % path and line','range','B2') %difference matrix %

writetable(copy,'Topologicas.xlsx','sheet','sum rows','range','B2')
```

```
end

% Image clicked function: Image3
function Image3Clicked(app, event)
end

% Callback function: Hyperlink
function HyperlinkClicked(app, event)
end

% Button pushed function: UserManualButton
function UserManualButtonPushed(app, event)
winopen('USER_MANUAL.pdf')
end

% Button pushed function: RecommendationsButton
function RecommendationsButtonPushed(app, event)
winopen('Recommendations.pdf')
end

% Button pushed function: start2Button
function start2ButtonPushed(app, event)
%disp('enter the coordinate x1,x2,y1,y2 of the edges of the study area to know the total area in
meters')
x4=app.x11.Value
x5= app.x22.Value
y4= app.y11.Value
y5=app.y22.Value
```

```
v3=app.y111.Value%input('enter the inner range of the buffer')

v4=app.x111.Value%input('enter the upper range of the buffer')

v5=app.b123.Value

lon = [x4 x5];

lat = [y4 y5];

lonlat = table(lon.',lat.');

llb = [fliplr(table2array(lonlat)) zeros(size(lonlat,1),1)]

I = lla2flat(llb,[min(llb(:,1)) min(llb(:,2))],90,0)

I1= I(:,1)

I2= I(:,2)

x1=I1(1)

x2=I1(2)

y1=I2(1)

y2=I2(2)

%v3=%input('enter the inner range of the buffer')

%v4=%input('enter the upper range of the buffer')

%v5=input('enter the buffer size in meters')

side1=sqrt((x1-x1)^2+(y2-y1)^2)

Side2=sqrt((x2-x1)^2+(y1-y1)^2)%*100000

Studio_Area=side1*side2

disp('table imported from excel')

[name,path]=uigetfile('*.xlsx','open data file');

if name==0

return;

else

data=strcat(path,name)

T=readable(data);
```

```
end

%T=readtable('mini2.xlsx')

H = table(T.lon,T.lat);

%plot(T.lon,T.lat,'ko')

U=length(T.lon);

n=U;

J = table(T.lon,T.lat);

%E = J{:,:}

%lla = [fliplr(table2array(J)) zeros(size(J,1),1)]

%position = lla2flat(lla,[min(lla(:,1)) min(lla(:,2))],90,0)

% same as before

%r = ;

lon3 = T.lon;

lat3 = T.lat;

lonlat1 = table(lon3,lat3);

% boundary

box = [x4 y4; x5 y5]; % lon/lat

% process table & box; convert to meters

lla1 = [fliplr(table2array(lonlat1)) zeros(size(lonlat1,1),1)];

position = lla2flat(lla1,[min(lla1(:,1)) min(lla1(:,2))],90,0);

boxpos = lla2flat([fliplr(box) [0, 0]],[min(lla1(:,1)) min(lla1(:,2))],90,0);

boxpos = boxpos(:,1:2);

% same as before

r = v5;

C = position(:,1:2); %locations(x,y)

p = 10; % padding

s = ceil([(max(C(:,2))-min(C(:,2))),(max(C(:,1))-min(C(:,1)))] + r*2 + p*2);
```

```
refpoint = [min(C(:,1)) min(C(:,2))];
C = round(C - refpoint + r + p);
corners = round(boxpos - refpoint + r + p);
m = false(s);
m(sub2ind(s,C(:,2),C(:,1))) = 1;
m = bwdist(m)<=r;
m(:,[1:corners(1,1) corners(2,1):end]) = 0;
m([1:corners(1,2) corners(2,2):end],:) = 0;
size(C,1)*round(pi*r^2)
totalarea = sum(m(:)) % total number of white pixels = area
imshow(m); hold on
plot(corners([1 2 2 1 1],1),corners([1 1 2 2 1],2),':')
%w1234=totalarea % white area
%totalarea2 = sum(m23(:))
p4=position(:,1);
p5=position(:,2);
p89=table(p4,p5);%new X from the code
X = p89{:,:}
for i=1:n-1
for j=i+1:n
d{i}(ji) = norm(X(i,:)-X(j,:));
end
end
(d);
size(d{2});
d1 = zeros(n, n);
for i=1:n-1
```

```
for j=i+1:n
d1(i, j) =norm(X(i,:)-X(j,:));
end
end
disp('distance array in meters')
d1 %this is the matrix
k1=find(d1>v3 & d1<v4); %array of positions where if stop exists, internal use

length(k1);
%traverse the array
%[f,c]=size(d1);
%for p=1:c
% for b=1:f
%disp(d1(b,p));
% end
%end
k2=(d1(k1));
length(d1(k1));
f3=(d1>v3 & d1<v4);% condition of excluded distances
disp('distance matrix in meters, between stops that meet the condition')
f4=d1.*f3 %%matrix of distances that meet the range
f5=sum(f4);
f6=find(f5>1);
disp('Total stops that meet the condition')
f7=length(f6) %stops that are between 200 and 450 meters away
disp('Total stops that do not meet the condition')
f14=n-f7
```

```
f8=sum(f3,2); % number of stops that meet the standard with respect to a specific stop

f9=f8>=1 ;%internal use to know where there is and where there is not

f10=f8>=1; %positions where if there is a stop

f11=(Tv(f10));, (T.lat(f10));, (T.lon(f10));,(f8(f10)); % stops with good pedestrian access

f12=f8<=0; %internal use shows me where there are no stations in range

f13=(Tv(f12));, (T.lat(f12));, (T.lon(f12));,(f8(f12)); % stops without good pedestrian access

%plot2(T.lon(f12),T.lat(f12),'ko')

%plot3(T.lon(f10),T.lat(f10),'ko')

stop_address=(Tv(f10));

length=T.lon(f10);

latitude=T.lat(f10);

Amount_close_stops=f8(f10);

Stops_comply=table(stop_address,longitude,latitude,Amount_of_close_stops)

address_stop_=(Tv(f12));

length_=T.lon(f12);

latitude_=T.lat(f12);

Amount_nearby_stops_=f8(f12);

Area_scope_theoretical=Area_Study

Area_not_reached=Area_Study-totalarea %if they were separate buffers it would be that(f7*(pi*(v4^2)))

Stops_Not_fulfilled=table(stop_address_,longitude_,latitude_,Number_of_close_stops_)

metric_coordinates=table((Tv),(T.lon),(T.lat),(p5),(p4))

m24=(areatotal*100)/(Study_Area)

app.reachedareaEditField.Value=(m24)

app.whiteareainfluencenodosparadasEditField.Value=(totalarea)
```

```
app.side1.Value=(side1)

app.side2.Value=(Side2)

app.areatotal.Value=(Study_Area)

app.stops1.Value=(f7)

app.paradas2.Value=(f14)

app.totalstops.Value=(length(Tv))

%General_Data=table(

%table2cell covers any table to cell in case I get confused remember

% writetable(metric_coordinates,'Results.xlsx')

%writetable(Stops_comply,'Results.xlsx','sheet','stopscomply','range','B2')                    Yes

%writetable(Stops_Not_Compliant,'Results.xlsx','sheet','Stops Meet','range','B2')              No

%writematrix(d1,'Results.xlsx','sheet','complete matrix','range','B2')               distance

%writematrix(f4,'Results.xlsx','sheet','connection matrix','range','B2')             distance

%writematrix(f3,'Results.xlsx','sheet','range matrix','range','B2')          stops          in

end

end


% Component initialization

methods (Access = private)


% Create UIFigure and components

function createComponents(app)


% Create UIFigure and hide until all components are created
```

```
app.UIFigure = uifigure('Visible', 'off');

app.UIFigure.Position = [100 100 846 680];

app.UIFigure.Name = 'MATLAB App';


% Create Image

app.Image = uiimage(app.UIFigure);

app.Image.Position = [6 227 344 251];

app.Image.ImageSource = 'exampleopen.png';


% Create x1EditFieldLabel

app.x1EditFieldLabel = uilabel(app.UIFigure);

app.x1EditFieldLabel.HorizontalAlignment = 'right';

app.x1EditFieldLabel.Position = [1 284 25 22];

app.x1EditFieldLabel.Text = 'x1';


%Create x11

app.x11 = uieditfield(app.UIFigure, 'numeric');

app.x11.ValueDisplayFormat = '%.5f';

app.x11.ValueChangedFcn = createCallbackFcn(app, @x11ValueChanged, true);

app.x11.Position = [41 284 74 22];


% Create x2EditFieldLabel

app.x2EditFieldLabel = uilabel(app.UIFigure);

app.x2EditFieldLabel.HorizontalAlignment = 'right';

app.x2EditFieldLabel.Position = [200 284 25 22];

app.x2EditFieldLabel.Text = 'x2';
```

```
%Create x22

app.x22 = uieditfield(app.UIFigure, 'numeric');

app.x22.ValueDisplayFormat = '%.5f';

app.x22.ValueChangedFcn = createCallbackFcn(app, @x22ValueChanged, true);

app.x22.Position = [240 284 100 22];


% Create y1EditFieldLabel

app.y1EditFieldLabel = uilabel(app.UIFigure);

app.y1EditFieldLabel.HorizontalAlignment = 'right';

app.y1EditFieldLabel.Position = [70 325 25 22];

app.y1EditFieldLabel.Text = 'y1';


%Create y11

app.y11 = uieditfield(app.UIFigure, 'numeric');

app.y11.ValueDisplayFormat = '%.5f';

app.y11.ValueChangedFcn = createCallbackFcn(app, @y11ValueChanged, true);

app.y11.Position = [117 325 100 22];


% Create y2EditFieldLabel

app.y2EditFieldLabel = uilabel(app.UIFigure);

app.y2EditFieldLabel.HorizontalAlignment = 'right';

app.y2EditFieldLabel.Position = [77 239 25 22];

app.y2EditFieldLabel.Text = 'y2';


%Create y22

app.y22 = uieditfield(app.UIFigure, 'numeric');

app.y22.ValueDisplayFormat = '%.5f';
```

```
app.y22.ValueChangedFcn = createCallbackFcn(app, @y22ValueChanged, true);

app.y22.Position = [117 239 100 22];


% Create fill in the values you can review the manual Label

app.fillinthevaluesyoucanreviewthemanualLabel = uilabel(app.UIFigure);

app.fillinthevaluesyoucanreviewthemanualLabel.FontSize = 15;

app.fillinthevaluesyoucanreviewthemanualLabel.FontWeight = 'bold';

app.fillinthevaluesyoucanreviewthemanualLabel.Position = [15 604 325 24];

app.fill in the values you can check the manual Label.Text = 'fill in the values you can check the ,
manual';


% Create startButton

app.launchButton = uibutton(app.UIFigure, 'push');

app.startButton.ButtonPushedFcn = createCallbackFcn(app,
@startButtonPushed, true);

app.startButton.Position = [28 88 100 22];

app.startButton.Text = 'start';


% Create lowerboundEditFieldLabel

app.bottomEditFieldLabel = uilabel(app.UIFigure);

app.bottomEditFieldLabel.HorizontalAlignment = 'right';

app.bottomEditFieldLabel.Position = [93 562 74 22];

app.lowerboundEditFieldLabel.Text = 'lowerbound';


%Create y111

app.y111 = uieditfield(app.UIFigure, 'numeric');

app.y111.ValueChangedFcn = createCallbackFcn(app, @y111ValueChanged, true);

app.y111.Position = [182 562 106 22];
```

```
% Create upperlimitEditFieldLabel
app.upperlimitEditFieldLabel = uilabel(app.UIFigure);
app.upperlimitEditFieldLabel.HorizontalAlignment = 'right';
app.upperlimitEditFieldLabel.Position = [94 528 80 22];
app.upperlimitEditFieldLabel.Text = 'upper limit';

%Create x111
app.x111 = uieditfield(app.UIFigure, 'numeric');
app.x111.ValueChangedFcn = createCallbackFcn(app, @x111ValueChanged, true);
app.x111.Position = [189 528 100 22];

% Create ByDavidAlejandroRamirezCajigasLabel
app.ByDavidAlejandroRamirezCajigasLabel = uilabel(app.UIFigure);
app.ByDavidAlejandroRamirezCajigasLabel.FontSize = 25;
app.ByDavidAlejandroRamirezCajigasLabel.FontWeight = 'bold';
app.ByDavidAlejandroRamirezCajigasLabel.Position = [2 650 487 31];
app.ByDavidAlejandroRamirezCajigasLabel.Text = 'By David Alejandro Ramirez Cajigas';


% Create area of influence in meters Label
app.influence area in metersLabel = uilabel(app.UIFigure);
app.influence area in meters Label.HorizontalAlignment = 'right';
app.influence area in meters Label.Position = [21 489 157 22];
app.area of influence in meters Label.Text = 'area of influence in meters';

%Create b123
app.b123 = uieditfield(app.UIFigure, 'numeric');
```

```
app.b123.ValueChangedFcn = createCallbackFcn(app, @b123ValueChanged, true);

app.b123.Position = [193 489 100 22];


% Create areareachedEditFieldLabel

app.reachedareaEditFieldLabel = uilabel(app.UIFigure);

app.reachedareaEditFieldLabel.HorizontalAlignment = 'right';

app.reachedareaEditFieldLabel.Position = [384 570 105 22];

app.areareachedEditFieldLabel.Text = '% area reached ';


% Create areareachedEditField

app.reachedareaEditField = uieditfield(app.UIFigure, 'numeric');

app.areareachedEditField.ValueChangedFcn = createCallbackFcn(app,
@areareachedEditFieldValueChanged, true);

app.reachedareaEditField.Editable = 'off';

app.reachedareaEditField.Position = [619 562 100 22];


%CreateImage2

app.Image2 = uiimage(app.UIFigure);

app.Image2.Position = [646 562 202 168];

app.Image2.ImageSource = 'marca_UPV_principal_color300.png';


% Create side1metersLabel

app.side1metersLabel = uilabel(app.UIFigure);

app.side1metersLabel.HorizontalAlignment = 'right';

app.side1metersLabel.Position = [394 528 82 22];

app.side1metersLabel.Text = 'side 1, meters';


% Create side1
```

```
app.side1 = uieditfield(app.UIFigure, 'numeric');

app.side1.Editable = 'off';

app.side1.Position = [610 528 100 22];


% Create side2metersLabel

app.side2metersLabel = uilabel(app.UIFigure);

app.side2metersLabel.HorizontalAlignment = 'right';

app.side2metersLabel.Position = [388 489 82 22];

app.side2metersLabel.Text = 'side 2, meters';


% Create side2

app.side2 = uieditfield(app.UIFigure, 'numeric');

app.side2.Editable = 'off';

app.side2.Position = [604 489 115 22];


% Create Study areasquare metersLabel

app.StudyAreasquaremetersLabel = uilabel(app.UIFigure);

app.Study areasquare metersLabel.HorizontalAlignment = 'right';

app.Study areasquare metersLabel.Position = [366 456 201 22];

app.Study areasquare metersLabel.Text = squares';            'Area studied meters


% Create total area

app.areatotal = uieditfield(app.UIFigure, 'numeric');

app.areatotal.ValueDisplayFormat = '%.0f';

app.areatotal.Editable = 'off';

app.areatotal.Position = [597 456 122 22];
```

```
% Create NumberofstopswithatleasttrainrangeEditFieldLabel

app.NumberofstopswithatleasttrainrangeEditFieldLabel =
uilabel(app.UIFigure);

app.NumberofstopswithatleasttrainrangeEditFieldLabel.HorizontalAlignment = 'right';

app.NumberofstopswithatleasttrainrangeEditFieldLabel.Position = [388 422 264 22];

app.Number of stops with at least one other in range EditFieldLabel. Text = 'Number of stops with at least one other in range';

% Create stops1

app.paradas1 = uieditfield(app.UIFigure, 'numeric');

app.stops1.Editable = 'off';

app.stops1.Position = [661 422 58 22];

% CreateNumberofstopswithoutatleastbringinrangeEditFieldLabel

app.NumberofstopswithoutatleastinrangeEditFieldLabel =
uilabel(app.UIFigure);

app.NumberofstopswithoutatleasttrainrangeEditFieldLabel.HorizontalAlignment = 'right';

app.NumberofstopswithoutatleastotherinrangeEditFieldLabel.Position = [388 380 260 22];

app.NumerodestopswithoutatleastotherinrangeEditFieldLabel.Text = 'Number of stops without at least one other in range';

% Create stops2

app.paradas2 = uieditfield(app.UIFigure, 'numeric');

app.paradas2.Editable = 'off';

app.stops2.Position = [651 380 73 22];
```

```
% Create numberparadasnodosaevlauarLabel

app.numerostopsnodosaevlauarLabel = uilabel(app.UIFigure);

app.numerostopsnodosaevlauarLabel.HorizontalAlignment = 'right';

app.numeroparadasnodosaevlauarLabel.Position = [423 341 182 22];

app.numeroparadasnodosaevlauarLabel.Text = 'number of stops/nodes to evlauar';


% Create totalstops

app.totalstops = uieditfield(app.UIFigure, 'numeric');

app.stopstops.Editable = 'off';

app.totalstops.Position = [624 346 100 22];


% Create uploadImageButton

app.loadImageButton = uibutton(app.UIFigure, 'push');

app.loadImageButton.ButtonPushedFcn = createCallbackFcn(app,
@loadImageButtonPushed, true);

app.loadimageButton.Position = [141 88 100 22];

app.loadimageButton.Text = 'load image';


% Create findcoordinatesButton

app.findorderedArchButton = uibutton(app.UIFigure, 'push');

app.findorderButton.ButtonPushedFcn @findorderButtonPushed, = createCallbackFcn(app,
true);

app.findorderedArchButton.Position = [259 88 142 22];

app.encontrarcoordinadasButton.Text = 'find coordinates ';


% Create whiteareainfluencenodosstopsEditFieldLabel

app.whiteareainfluencenodosstopsEditFieldLabel = uilabel(app.UIFigure);
```

```
app.whiteareainfluencenodosstopsEditFieldLabel.HorizontalAlignment 'right';                =

app.whiteareainfluencenodosstopsEditFieldLabel.Position = [374 313 224 22];

app.areablancadeinfluencianodosparadasEditFieldLabel.Text = 'white area of influence nodes/stops';


% CreatewhiteareainfluencenodosstopsEditField

app.whiteareainfluencenodosstopsEditField = uieditfield(app.UIFigure, 'numeric');

app.whiteareainfluencenodosstopsEditField.ValueDisplayFormat = '%.0f';

app.areablancadeinfluencenodosparadasEditField.ValueChangedFcn                              =
createCallbackFcn(app, @areablancadeinfluencenodosparadasEditFieldValueChanged,
true);

app.whiteareainfluencenodosstopsEditField.Editable = 'off';

app.whiteareainfluencenodosstopsEditField.Position = [619 313 100 22];


% Create averagespeedEditFieldLabel

app.averagespeedEditFieldLabel = uilabel(app.UIFigure);

app.averagevelocityEditFieldLabel.HorizontalAlignment = 'right';

app.averagespeedEditFieldLabel.Position = [373 176 92 22];

app.averagespeedEditFieldLabel.Text = 'average speed';


% Create VelMedi

app.VelMedi = uieditfield(app.UIFigure, 'numeric');

app.VelMedi.Position = [480 176 92 22];


% Create TopologicalAccessibilityMeasuresButton

app.TopologicalAccessibilityMeasuresButton = uibutton(app.UIFigure, 'push');
```

```
app.MedidasTopologicasdeAccesibilidadButton.ButtonPushedFcn =
createCallbackFcn(app, @MedidasTopologicasdeAccesibilidadButtonPushed, true);

app.MedidasTopologicasdeAccessibilidadButton.Position = [423 88 218 22];

app.MedidasTopologicasdeAccesibilidadButton.Text = 'MedidasTopologicasdeAccesibilidad';



% Create maxspeedEditFieldLabel

app.maxspeedEditFieldLabel = uilabel(app.UIFigure);

app.maxspeedEditFieldLabel.HorizontalAlignment = 'right';

app.maxspeedEditFieldLabel.Position = [363 135 102 22];

app.maxspeedEditFieldLabel.Text = 'maxspeed';


% Create VelMax

app.VelMax = uieditfield(app.UIFigure, 'numeric');

app.VelMax.Position = [479 135 93 22];


% Create Lonormalesqueelvalueis13kmhLabel

app.Usuallythevalueis13kmhLabel = uilabel(app.UIFigure);

app.Usually the value is 13kmhLabel.FontSize = 15;

app.Usually the value is 13kmh Label.FontWeight = 'bold';

app.Usually the value is 13kmh Label.Position = [571 175 277 24];

app.Lonormalesqueelvalorsea13kmhLabel.Text = 'Normally, the value is 13km/h';



% Create LonormalesthantheLabelvalue

app.LonormalisLabelvalue = uilabel(app.UIFigure);

app.LonormalisLabel.FontSize value = 15;

app.LonormalisvalueLabel.FontWeight = 'bold';
```

```
app.LonormalisvalueLabel.Position = [576 135 185 33];

app.LonormalesqueelvalorLabel.Text = 'Lonormalesqueelvalor';


% Create noteStart2does not generatexlsxLabelfile

app.noteStart2does not generatexlsxfileLabel = uilabel(app.UIFigure);

app.noteStart2does not generatexlsxLabel.FontSize = 9;

app.noteStart2does not generatexlsxfileLabel.FontWeight = 'bold';

app.noteStart2doesnotgeneratexlsxfileLabel.Position = [28 14 310 33];

app.notaStart2does not generatexlsxfileLabel.Text = 'note: Launch 2, does not generate .xlsx file,
only returns initial results';


% CreateHyperlink

app.Hyperlink = uihyperlink(app.UIFigure);

app.Hyperlink.HyperlinkClickedFcn = createCallbackFcn(app, @HyperlinkClicked, true);


app.Hyperlink.URL = 'www.linkedin.com/in/david-alejandro-ramirez-cajigas';

app.Hyperlink.Position = [760 10 55 22];

app.Hyperlink.Text = 'Linkedin';


%Create Image3

app.Image3 = uiimage(app.UIFigure);

app.Image3.ImageClickedFcn = createCallbackFcn(app, @Image3Clicked, true);

app.Image3.Position = [661 10 93 32];

app.Image3.ImageSource = 'linkedin(1).svg';


%CreateImage4

app.Image4 = uiimage(app.UIFigure);

app.Image4.Position = [548 6 35 41];
```

```
app.Image4.ImageSource = 'instagram-5.svg';

% CreateHyperlink2
app.Hyperlink2 = uihyperlink(app.UIFigure);
app.Hyperlink2.URL = 'https://www.instagram.com/davidalejan67/';
app.Hyperlink2.Position = [589 15 63 22];
app.Hyperlink2.Text = 'Instagram';

% Create UserManualButton
app.UserManualButton = uibutton(app.UIFigure, 'push');
app.UserManualButton.ButtonPushedFcn = createCallbackFcn(app,
@UserManualButtonPushed, true);
app.UserManualButton.Position = [334 605 114 22];
app.ManualdeusuarioButton.Text = 'User Manual';

% Create RecommendationsButton
app.RecommendationsButton = uibutton(app.UIFigure, 'push');
app.RecommendationsButton.ButtonPushedFcn = createCallbackFcn(app,
@RecommendationsButtonPushed, true);
app.RecommendationsButton.Position = [458 605 115 22];
app.RecommendationsButton.Text = 'Recommendations';

% Create start2Button
app.start2Button = uibutton(app.UIFigure, 'push');
app.start2Button.ButtonPushedFcn = createCallbackFcn(app,
@start2ButtonPushed, true);
app.start2Button.Position = [28 57 100 22];
app.start2Button.Text = 'start 2';
```

```
% Create LonormalesqueLabel_2 value
app.LonormalisLabel_2 value = uilabel(app.UIFigure);
app.LonormalisLabel_2.FontSize value = 15;
app.LonormalesthevalueLabel_2.FontWeight = 'bold';
app.LonormalisLabel_2.Position value = [596 115 185 33];
app.LonormalesqueelvalorLabel_2.Text = 'Lonormalesqueelvalor';
% Show the figure after all components are created
app.UIFigure.Visible = 'on';
end
end
% App creation and deletion
methods (Access = public)
%Construct app
function app = app1
% Create UIFigure and components
createComponents(app)
% Register the app with App Designer
registerApp(app, app.UIFigure)
if nargout == 0
clear app
end
end
% Code that executes before app deletion
function delete(app)
% Delete UI Figure when app is deleted
delete(app.UIFigure)
```

end

end

end

11.1 Relationship with the Sustainable Development Goals of the 2030 Agenda.

Relationship of the TFG/TFM "Development of the Dgis tool, for the evaluation of the accessibility of collective public transport. Practical application to Santiago de Cali (Colombia)" with the Sustainable Development Goals of the 2030 Agenda.

Degree of relationship of the work with the Sustainable Development Goals (SDG).

Sustainable Development Goals	Tall	Medium	Low	Not Applicable
End of poverty.		X		
Zero hunger.				X
Health & Wellness.	X			
Quality education.	X			
Gender equality.	X			
Clean water and sanitation.				X
Affordable and non-polluting energy.				X
Decent work and economic growth.	X			
Industry, innovation and infrastructures.			X	
Reduction of inequalities.		X		
Sustainable cities and communities.	X			
Responsible production and consumption.				X
Climate action.		X		
Submarine life.				X

Life of terrestrial ecosystems.			X	
Peace, justice and solid institutions.			X	
Alliances to achieve goals.				X

Description of the alignment of the TFG/M with the SDGs with a higher degree of relationship.

SDG 1. End of poverty. **Medium**

Ending poverty in all its forms around the world: Cities designed for people, 15-minute cities, increase people's economic gains (Gehl, 2014) (Arup Group, 2016)., Dgis is a software that helps to plan this type of cities, if it is implemented it would contribute to the end of poverty.

SDG 2. Zero hunger. **Nope** **proceeds**

End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. : although the reduction of poverty contributes to the reduction of hunger, a direct correlation between using Dgis and eliminating world hunger cannot be assured

SDG 3. Health and well-being. **Tall**

Guarantee a healthy life and promote well-being for all at all ages. : With Dgis, you can design a transportation system based on spatial accessibility, giving influence area parameters, promoting walking within the city, generating citizens who will have health and well-being, both because of the walking promoted by these transportation systems, and for the mental health generated by having access to work, educational and leisure opportunities generated by a spatially accessible transportation system.

In a nutshell "DGIS helps to plan cities for people (Gehl, 2014))

SDG 4. Quality education. **Tall**

Guarantee an inclusive, equitable and quality education and promote lifelong learning opportunities for all: Dgis is offered free of charge and can be used by people from anywhere in the world, the TFM and Dgis, have a user guide and a link to an audiovisual tutorial on YouTube. The software is a great tool that can be used to teach in classrooms around the world.

SDG 5. Gender equality. **Tall**

Achieve gender equality and empower all women and girls. It is undeniable that there is gender inequality in transport (Greed, 1999), women have been disadvantaged and have lost opportunities throughout history, egalitarian public transport is our greatest weapon as a society to combat female segregation for decades generated by individual transportation, Dgis helps to design routes, improving the accessibility of women to transportation.

SDG 6. Clean water and sanitation. proceeds **Nope**

Guarantee the availability of water and its sustainable management and sanitation for all.

ODS 7. Affordable and clean energy. proceeds **Nope**

Guarantee access to affordable, secure, sustainable and modern energy for all.

SDG 8. Decent work and economic growth. **Tall**

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Cities for people promote economic growth, generate more job opportunities and make the city more productive (Gehl, 2014) (Arup Group, 2016).,

ODS 9. Industry, innovation and infrastructures. **Bass**

Build resilient infrastructure, promote sustainable industrialization and encourage innovation. When an accessible transport system is built, industry, commerce and innovation are promoted, since new businesses are born throughout the accessible system, where citizens can arrive, however, the TFM has not focused on the industrial impact, therefore, it is low.

SDG 10. Reduction of inequalities. **Medium**

Reduce inequality within and between countries Accessibility in transport contributes to reducing inequalities, but the enormous gaps that exist between the economies of the different countries of the world need something more than just an accessible transport model, which is why, although contributes to reducing inequalities, does not have such a huge impact a priori and is considered medium

SDG 11. Sustainable cities and communities. **Tall**

Make cities and human settlements inclusive, safe, resilient and sustainable. The TFM reviews cities through history, reviews the urban planning theories and recommendations of various authors, to finally propose, from that knowledge, a software capable of contributing to improving spatial accessibility and topological accessibility of transport, thus generating cities. safer, walkable, inclusive and of course sustainable.

ODS 12. Responsible production and consumption. proceeds **Nope**

Guarantee sustainable consumption and production modalities: although it is true that mass public transport systems reduce the purchase and use of private cars and therefore contribute to sustainable consumption and production, this TFM does not deal with this issue, it is specific because it leaves of your reach.

SDG 13. Climate action. **Medium**

Adopt urgent measures to combat climate change and its effects: Mass public transport helps to get cars out of traffic, in fact, the TFM has the chapter

6.1.12 that deals with the subject, however, does not emphasize which transport system to use, combustion or not, because Dgis can be used with any transport system.

SDG 14. Life below water. **Nope** **proceeds**

Conserve and sustainably use the oceans, seas and marine resources for sustainable development: Although it is true that, by using mass transportation, the environmental impact is reduced and therefore the world's climate is less affected. This TFM does not focus on this topic, therefore, it is not applicable.

ODS 15. Life of terrestrial ecosystems. **Bass**

Sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss. When cities for people are planned, cities recommended by authors such as Gelh and Jacobs, terrestrial ecosystems are less affected than in expansive models such as the garden city and the models proposed by Le Corbusier, this issue is addressed in the text, although short.

Even so, there are the most common models of land distribution in the city according to Kurt and DGIS itself proposes walkable cities with the system of areas of influence.

SDG 16. Peace, justice and strong institutions. **Short**

Promote just, peaceful and inclusive societies. Accessible public transport brings with it fairer societies where its inhabitants can access study, health, work and leisure. A transport system can be the difference between whether there is social segregation or not, and social segregation is known to generate conflict.

SDG 17. Alliances to achieve objectives. **Nope** **proceeds**

Revitalize the Global Partnership for Sustainable Development.

11.2 Annex, Poster presented to the congress X CIOT 2021 10 Congress International Spatial Planning

Urban and interurban transport analysis and design software based on accessibility

ABSTRACT

In order to contribute to improving intra-urban and metropolitan sustainable mobility, the Dgis software was designed, applicable by urban planners to measure accessibility in cities, for those who need to move around them using public transport, with average distances of 400 meters for the pedestrian accepted by modern urban planning. The guiding principle was to ensure that urbanism has as its goal to create or reorganize cities for the happiness of the people.

Urban planning, Transport, Public transport, Walkable city, city for people, city planning, software.

ABSTRACT In

order to contribute to improving sustainable intra-urban and metro politan mobility, the Dgis software was designed, applicable by urban planners to measure accessibility in cities, for those who need to move in them using public transport, with average distances of 400 meters for pedestrians. accepted by modern urbanism. The guiding principle was to ensure that urban planning aims to create or reorganize cities for the happiness of the people

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X CONGRESO Internacional de Ordenación del Territorio
10th International Congress for SPATIAL PLANNING
"Recuperación, transformación y resiliencia: el papel del territorio"
10 ciot 2021 X congreso internacional de ordenación del territorio Valencia/España
GENERALITAT VALENCIANA
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Theme C, URBAN AND METROPOLITAN AGENDA; TOWARDS HEALTHIER CITIES AND TERRITORIES.

C.3. Sustainable intra-urban and metropolitan mobility.

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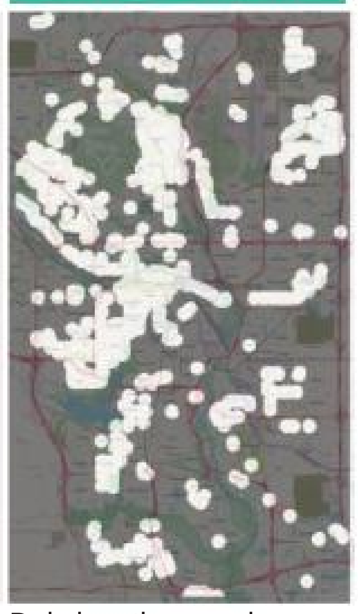
Civil Engineer Pontifical Javeriana University Cali Colombia
Master's student Transport Territory and Urbanism Polytechnic University of Valencia Spain

34 cities analyzed

CALGARY-CANADÁ

DUBLÍN-IRLANDA

ESTOCOLMO-SUECIA



Dgis was born with the aim of proposing software that facilitates urban mobility planning based on the measurement of the level of accessibility of the different areas in each city of the world for those who need to get around them using public and pedestrian transport.
Based on the key concept of spatial and topological accessibility of the transport system.
The software has been developed based on the principles of theorists such as Jane Jacobs, William H Whyte, Jahn Gelh, Clara H. Greed, Andrés Monzón de Cáceres, among others. During its elaboration, a historical review of urban planning and cities was carried out, resorting to authors such as Carlos G Vázquez. A previous investigation carried out in 2018 by the author of Dgis "Design of the spatial distribution of the routes of the MIO system according to the quality of service perceived in commune 18" was taken as presented.

The software was developed in Matlab and runs as a desktop application on Osx Mac 10.14 and on Windows 10, a version of Dgis can be downloaded from the following web link.

Link for operating system Mac OSx 10.14 = https://drive.google.com/file/d/1EQLW9KBiO0rTNM56npzMevAqlctlihOW/view?usp=sharing
Link for Windows 10 OS = https://drive.google.com/file/d/1m-U1b_e-QoXIKg9_gBeMqmA6qkj1WqUs/view?usp=sharing

Dgis has three main components that help the urban planner, each component is designed to be interpreted by anyone, even if they do not have any mathematical training.

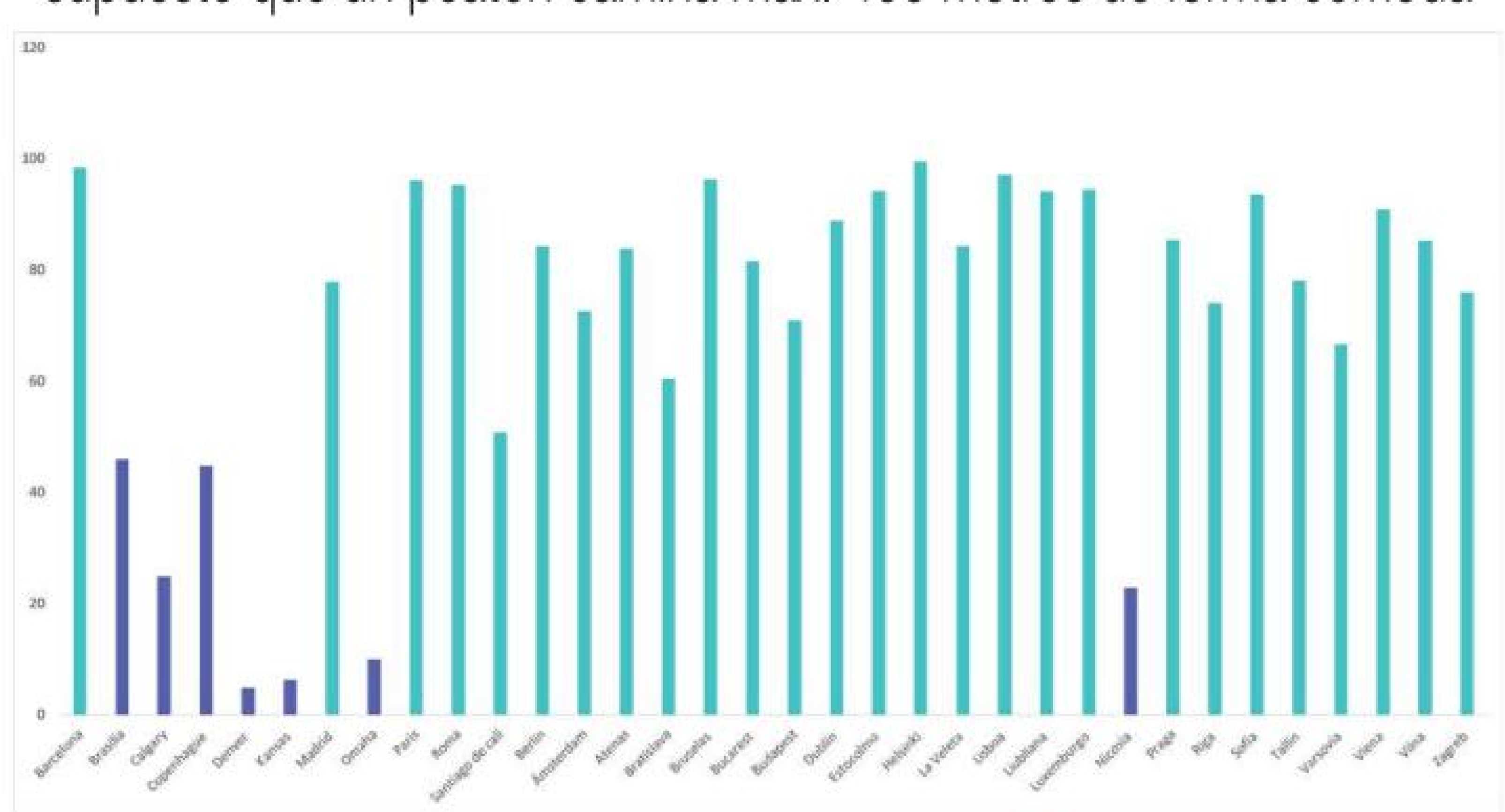
The first component is the calculation of zones of influence or buffers within a city. The input data is the coordinates of the stations to be evaluated.
This information can be obtained from private databases of traffic institutions, surveyed in the field with topographic stations or using public databases such as Openstreetmap, the output data are results in the form of a diagram showing the area in black. without access to public transport and the white one has access, summary of results on the main screen and finally an xlxs file (Excel) with metadata and results of mathematical calculations

The second component is a tool capable of finding coordinates of an area in the city, it is very useful to test where to put new stations, eliminate old ones or find new transport routes, the coordinates are thrown in an xlxs file (Excel) and to running this function only requires free data obtainable from openstreet map.

The third component is capable of measuring the topology (geometric study) of an urban or interurban public transport route, giving as input the matrix of distances along the route and the coordinates of the stations. The result is given as an xlxs file (Excel) and contains parameters easily comparable and interpretable with other routes, which saves money and time when planning routes.

The validation of the program has been carried out in two parts, firstly, an area of the city of Santiago de Cali Colombia was analyzed using data provided by the entity that controls transport in the city. Within this validation, the three main components of Dgis were tested, including generating routes and finding coordinates.
Second, 34 cities in the world were analyzed, including the 27 capitals of the 27 member states of the European Union, in order to test the computational power of Dgis, analyze the spatial accessibility of transport in these cities, for these cities public data obtained from openstreetmap was used.

Porcentaje área alcanzada por el transporte público en la ciudad, bajo el supuesto que un peatón camina máx. 400 metros de forma cómoda



The practical uses of the software are wide

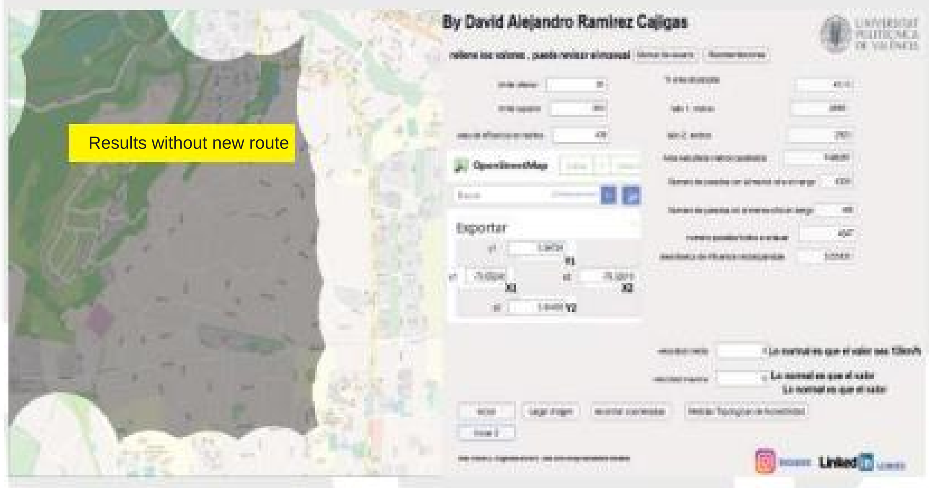
- Measures the percentage of area reached by public transport within the study area.
- It allows to add stops in a transport network and evaluate the area of influence of these saving on costs.
- You can add to the simulation, other transport items different from public transport stops, such as parking for electric scooters, parking for cars, and in addition, the study buffer can be modified as the user wishes. , therefore, what the user needs can be studied.
- You can measure how accessible its transport network is for the inhabitants of a building, since you can put the coordinates as explained in the previous title, and thus evaluate how accessible that building is to the network.
- You can measure the accessibility of an area with respect to other areas, thanks to the spatial location of coordinates offered by the program.
- You can put the coordinates of a series of clients, to whom merchandise must be delivered and thus make decisions on its distribution.
- It can be used to measure areas of influence of various phenomena of city life, for example, the spread of a virus such as covid 19 could be estimated, taking into account that it knows the transport network and its influence.
- You can evaluate the connectivity of a new urban project, such as a park, a convention center, a stadium, etc.
- You could plan evacuation locations within cities where there is an earthquake risk, such as Santiago de Chile, Mexico City, Los Angeles, California, Tokyo or Cali.
- If you know the zone of influence of contamination radiated by an industrial chimney, you will be able to locate it on the coordinate plane using the tool provided by the program and you will be able to see the total area that a set of chimneys pollutes.
- If you know an estimate of decibels that are produced at points in the city, you will be able to measure the total area of the city that has noise pollution with the buffers.

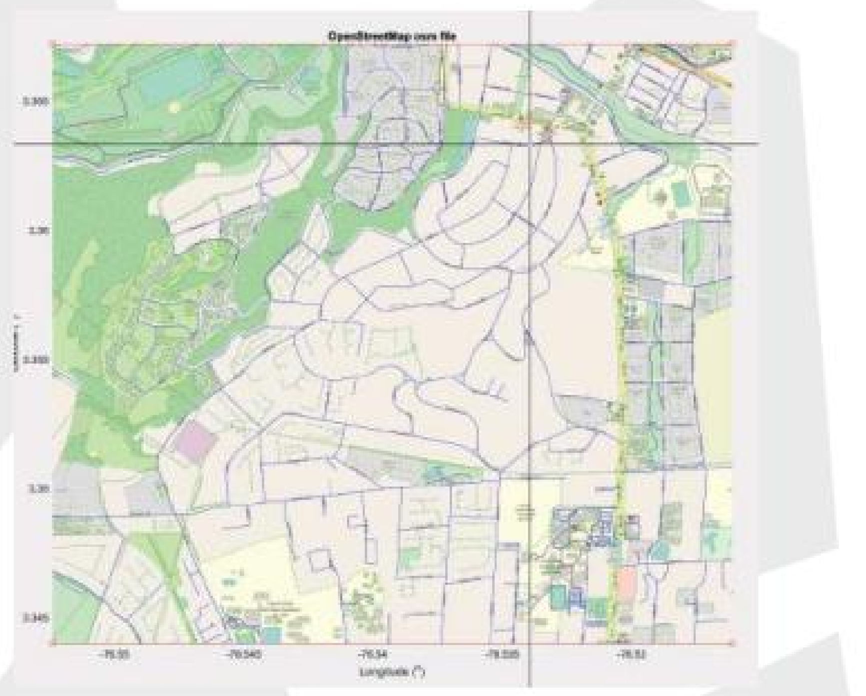
It is a tool with multiple uses, it is an open letter for professionals, urban planners, students and professors to use it within their research area.

Results

City	Country	Conjnent	Analyzed area	area percentage reached by him public transport in the zone
Amsterdam	Netherlands	Europe	City	72.64
Athens	Greece	Europe	City	63.6
Barcelona	Spain	Europe	City	98.43
Berlin	Germany	Europe	City	84.29
brasilia	Brazil	South America	City	46.07
Bratislava	Slovak Republic	Europe	City	60.48
Brussels	Belgium	Europe	City	96.35
Bucharest	Romania	Europe	City	81.67
Budapest	Hungary	Europe	City	70.97
Calgary	Canada	North America	Downtown neighborhood	97.95
Calgary	Canada	North America	Peripheral neighborhood	54.78
Calgary	Canada	North America	City	24.96
Copenhagen	Denmark	Europe	Centric district	98.81
Copenhagen	Denmark	Europe	City	44.83
Denver	United States of America	North America	Downtown neighborhood	79.65
Denver	United States of America	North America	City	4.96
Dublin	Ireland	Europe	City	86.94
Stockholm	Sweden	Europe	City	94.3
Helsinki	Finland	Europe	City	99.52
Kansas	United States of America	North America	City	6.33
weather new	Haiti	Europe	City	84.35
Lisbon	Portugal	Europe	City	87.19
Ljubljana	Slovenia	Europe	City	94.25
The Angels	United States of America	North America	Peripheral neighborhood	73.96
Luxembourg	Luxembourg	Europe	City	84.62
Madrid	Spain	Europe	Downtown barrio	96.6
Madrid	Spain	Europe	City	77.88
Nicosia	Cyprus	Europe	City	22.69
omaha	United States of America	North America	Downtown neighborhood	30.65
omaha	United States of America	North America	City	10
Paris	France	Europe	Centric district	99.83
Paris	France	Europe	City	74.11
Prague	czech republic	Europe	City	96.12
Riga	Latvia	Europe	City	85.51
Rome	Italy	Europe	City	97.19
Santiago de Chile	Chile	South America	City	95.34
Santiago de Cali Colombia		South America	Downtown neighborhood	99.99
Santiago de Cali Colombia		South America	Peripheral neighborhood	94.77
Santiago de Cali Colombia		South America	City	50.84
Sofia	Bulgaria	Europe	City	93.59
Tallinn	Estonia	Europe	City	79.21
Warsaw	Poland	Europe	City	66.65
Vienna	Austria	Europe	City	90.95
Vilnius	Lithuania	Europe	City	85.36
Zagreb	Croatia	Europe	City	76.03

Generating routes





The coordinate points of the bus stops are searched using the Dgis software

1

Var1	lon	The t	x meters	and meters
stop 1	-76.533925	3.36328897	-1566.3887	1532.47631
stop 2	-76.539213	3.35903047	-1095.491	944.835019
stop 3	-76.544871	3.35471281	-618.05316	316.042376
stop 4	-76.547715	3.34912352	0	0
stop 5	-76.540561	3.34989242	-85.023186	795.044102
Stop 6	-76.533925	3.35156329	-269.78511	1532.47631

Geographic and Cartesian coordinates result Dgis Software

distance in route	stop 1	stop 2	stop 3	stop 4	stop 5	stop 6
stop 1	0	0.839258	1.67657	2.441902	3.258596	4.062709
stop 2	5.314205	0	0.837312	1.602645	2.419338	2.419338
stop 3	4.476893	5.31615	0	0.765332	1.582026	2.386139
stop 4	3.71156	4.550818	5.388131	0	0.816694	1.620807
stop 5	2.894867	3.734124	4.571437	5.336769	0	0.804114
stop 6	2.090753	2.930011	3.767323	4.532655	5.349349	0

Shows the distance from each to each column, in total travel

Distance straight line M	stop 1	Stop 2	Stop 3	Stop 4	Stop 5	stop 6
stop 1	0	753.038431	1542.41752	2191.35966	1654.76585	1296.60358
stop 2	0	0	789.510687	1446.65609	1021.50997	1013.46563
stop 3	0	0	0	694.170359	716.633521	1265.30714
stop 4	0	0	0	0	799.577429	1556.0423
stop 5	0	0	0	0	0	760.225777
stop 6	0	0	0	0	0	0

This matrix is calculated by the program from the coordinates, it is the distance in a straight line that exists between each result node Dgis Software

Weather straight line	stop 1	stop 2	stop 3	stop 4	stop 5	stop 6
stop 1	0	3.47556199	7.11885008	10.1139677	7.637380841	5.98432421
stop 2	3.47556199	0	3.64389548	6.67687426	4.714661386	4.67753367
stop 3	7.11885008	3.64389548	0	3,2038632	3.307539327	5.8398791
stop 4	10.1139677	6.67687426	3.2038632	0	3.690357367	7.18173371
stop 5	7.63738084	4.71466139	3.30753933	3.69035737	0	3.50873436
stop 6	5.98432421	4.67753367	5.8398791	7.18173371	3.508734358	0

In this matrix we have the theoretical travel time that a vehicle would take to go from one node to another in a straight line.

Weather route min	stop 1	Stop 2	Stop 3	Stop 4	Stop 5	stop 6
stop 1	0	3.87349846	7.73801538	11.2703169	15.0396738	18.7509646
stop 2	24.5271	0	3.86451692	7.39682308	11.1661754	11.1661754
stop 3	20.6625831	24.5360769	0	3.53230154	7.30165846	11.0129492
stop 4	17.1302769	21.0037754	24.8682969	0	3.76935692	7.48064769
stop 5	13.3609246	17.2344185	21.09894	24.6312415	0	3.71129538
stop 6	9.64962923	13.5231277	17.3876446	20.9199462	24.6893031	0

In this matrix we have the theoretical travel time that a vehicle would take to go from one node to another following the actual route of the route.

Route Factor	Stop 1	stop 2	stop 3	stop 4	stop 5	stop 6
stop 1	0	1.11449558	1.08697547	1.11433191	1.969218788	3.13334705
stop 2	7.05701699	0	1.06054549	1.10782722	2.368393925	2.38719294
stop 3	2.90251696	6.7334744	0	1.10251322	2.20758024	1.88581802
stop 4	1.69372471	3.14574973	7.76197216	0	1.021407021	1.04162142
stop 5	1.74941186	3.65549444	6.37904433	6.6744868	0	1.05773051
stop 6	1.61248437	2.89108078	2.97739804	2.91293816	7.036526725	0

This matrix gives the route factor, which is nothing more than the division between the route distance and the straight line distance, generating a quick way to see the similarity between the theoretical perfect straight line route and the real one.

% Come in route and straight	stop 1	stop 2	Stop 3	Stop 4	Stop 5	stop 6
stop 1	0	10.2733091	8.00160339	10.2601308	49.218441	68.0852461
stop 2	85.8297068	0	5.70890094	9.73321666	57.7772942	58.1097958
stop 3	65.5471436	85.148826	0	9.29814002	54.7015333	46.972614
stop 4	40.9585279	68.2110757	87.1166763	0	2.09583645	3.99583024
stop 5	42.8379318	72.6439195	84.3236706	85.0175747	0	5.45796026
stop 6	37.9838948	65.4108592	66.4136274	65.6704006	85.7884431	0

Percentage difference that exists between the current route and the theoretical ideal straight line in percentages

Column1	Column2	Column3	Column4	Column5	Column6
par_name ada	sum_dist ncia_straight	sum_dist ncia_route	Sum_em po_straight	Sum_em per_route	Sum_Index_Tr hoetv
Stop 1	7.43818504	12.279035	34.3300848	56.6724692	8.418368791
Stop 2	5.0241808	12.592838	23.1885268	58.1207908	13.98097657
Stop 3	5.00803922	14.52654	23.1140272	67.0455692	14.83190284
Stop 4	6.68780584	16.08801	30.8667962	74.2523538	14.66447504
Stop 5	4.95271254	17.341311	22.8586733	80.03682	19.51616794
Stop 6	5.89164443	18.670091	27.1922051	86.1696508	17.43042807

summary table of the calculations made, shows accessibility indicators seen in the theoretical framework

par_name ada	Sum_Shim bel	Fact_Sum r_path	one_divide o_n_less _1	Ri	one_divided_n
stop 1	fifteen	8.41836879	0.07142857	0.60131206	0.066666667
stop 2	eleven	13.9809766	0.1	1.39809766	0.090909091
stop 3	9	14.8319028	0.125	1.85398785	0.111111111
stop 4	9	14.664475	0.125	1.83305938	0.111111111
stop 5	eleven	19.5161679	0.1	1.95161679	0.090909091
stop 6	fifteen	17.4304281	0.07142857	1.24503058	0.066666667

summary table of the calculations made, shows accessibility indicators seen in the theoretical framework.

par_name ada	sum_em pos_route_ÿ time_rect a	trace_vel ocity_nod	Absolute_Ti time_Glob	travel_time e_until_no su_min	path_factor_tot
Stop 1	1.65081064	0.11005404	56.6724692	18.7509646	1.650810639
Stop 2	2.50644602	0.22785873	58.1207908	11.1661754	2.506446024
Stop 3	2.90064421	0.3222938	67.0455692	11.0129492	2.900644214
Stop 4	2.40557372	0.26728597	74.2523538	7.48064769	2.405573723
Stop 5	3.50137644	0.31830695	80.03682	3.71129538	3.501376437
Stop 6	3.16891001	0.21126067	86.1696508		0	3.168910009

summary table of the calculations made, shows accessibility indicators seen in the theoretical framework

Graphic representation of the route

2

3

Resultados

- The urban model that will survive will be the one that has as its beginning and end to make people's lives in cities friendlier, by aiming and ensuring that people do not suffer from the city, but rather enjoy it, by being or ganized so that the public moves in it in a pleasant way, as expressed in its planning, minimizing time, costs and effort. The cities, as the studied authors indicate, must be for the people, human cities, where man is the greatest joy of man.
- Contrary to popular proverbs, all past times were worse, as confirmed by studying the historical evolution of urbanism, thanks to the revisionism of the old, today its enormous defects are seen, including the damage caused to humanity by previous models. applied to urbanization, today urbanization is understood as an integrality, focused on people living better, without a doubt the old models made their positive contribution, since it improves over time, thanks to the knowledge gained, and in the modern urban planning the current point of convergence is that cities should be planned to make life easier for people, and in this, mobility is essential.
- The physical infrastructure of a city makes sense as long as people can enjoy it, for this they must be able to move around it easily, so the developer and his boss, the ruler, must plan to ensure that mass public transport and walking they are complementary, that is, they are harmonized, in such a way that people on obligatory routes can move within a maximum radius of 400 meters, when boarding the transport service and when getting off, both at the beginning and at the end of their trip.
- The essential purpose was achieved, structuring a software that facilitates planning urban mobility based on the measurement of the level of accessibility of the different areas in each city of the world for those who need to move around them using public and pedestrian transport.
- The final conclusion of convergence says that a software was provided capable of contributing to urban planning being an integrating concept, where the organization of the geographical space in each city with areas where homes, business and institutional premises interconnected by streets are or are built must be planned through routes that facilitate mobility, lead to the interaction of people, thanks to the fact that public transport and on foot complement each other amicably, in order to get people to socialize with each other because they live in urbanized cities for the people.

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