

# **MASTER'S FINAL PROJECT**

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



<text><text><text>

# Polytechnic University of Valencia

engineering school of Roads, Canals and Ports

Presented by: Ramirez Cajigas, David Alejandro

To obtain the

Master in Transport, Territory and Town planning









# 1. Introduction



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# **Problem to attend?**

How to 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.





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# Urbanism is understood as an integrality, where transport it is a fundamental aspect.

**Justification** 

Measure the topological and spatial accessibility of a transport system.

To be able to do better urban planning.

Capable of facilitating transportation systems in operation or in project

It must be capable of processing the information that is entered and output data that is easily interpretable by developers

Define the organization of public transport routes.

define stops



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

Establish the guiding parameters that the urban planner must use to support mobility in 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.

3 Objectives





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The concept of city was studied, 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. individual and collective terms.

The city concept of 5Km/h, this speed refers to the speed of a pedestrian walk fast (Gehl, 2014),

cities for the people

Matlab was used to program the software.

Once a designed and structured program capable of working was achieved, the required validation was carried out, taking the city of Santiago de Cali, located in the department of Valle del Cauca, in Colombia, as the setting.



4. Methodology





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A. Relativa

a ij

Relative and comprehensive accessibility. (Caceres, 1988)

A. Integral

 $A_{i} = \sum_{j=1}^{4} a_{ij}$ 



# Topological measures of accessibility

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

**path factor (**): This indicator allows to measure the quality (quality is understood in this case, as the route that most resembles a straight line between two nodes)

$$= \frac{1}{n\ddot{y}1} \qquad \qquad = \frac{1}{n\ddot{y}1} \frac{1}{\ddot{y}\ddot{y}_{1}} \frac{1}{d\ddot{y}ij} \qquad \qquad = \frac{\ddot{y} d ij}{\ddot{y} d \ddot{y}ij}$$

**Absolute indicator of global time:** "This indicator measures the sum of the time it takes to travel each vehicle in the transportation system, from each node to all the others, thus, the point with the smallest sum is the best statement" (dajome, 2016) citing (Izquierdo, 1991).



It is a variety of the path factor, the highest values correspond to the most inaccessible areas.





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

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Area de servicio	800m	800m	800m	1,000m	2,000m+	
Captación personas por parada	320 - 640	480 a 1760	1680 a 3120	4800 a 9000	24000	

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



# 5. State of the art





# 6. Design and development of software to measure topological and spatial accessibility









# 6.1 Program structure



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Development time: January 2021 to August 2021, 8 months approximately

Development platform: Matlab R 2020 by R2021 a

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# 6.1.1 Programming in Matlab





# 6.1.2 Instructions for use of the software

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It is recommended to watch a video on YouTube called **How to use Dgis?** In the following link <u>https://www.youtube.com/watch?v=FVs8sLwRb8</u>

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By David Alejandro Ramirez Ca	ajigas			ERSIT	
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Dgis software has a user manual, to which can be accessed by clicking the button Manual de usuario







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Communal population database transport network "MetroCali" 2018.





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







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



Routes and stops under a Bing map using AutoCAD Civil





Commune 22 public transport routes in Google Earth.







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Public transport system throughout the city of Cali area of influence 300 and 400 meters

# 6.2.2 Development and analysis within the commune 22

By	/ David Alejandro Ramirez Cajigas	
	area blanca de influencia nodos/paradas	23513905
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	Numero de paradas con al menos otra er	n rango
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	lado 2, metros	9802
	lado 1, metros	9078
	% area alcanzada 26.42%	26.42



Commune 22 public transportation system area of influence 300 and 400 meters.





# 6.2.3 Analysis of a new neighborhood in the commune

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Figure 1 Aerial view of the neighborhood, large empty parks, blocks of buildings separated from each other and enclosed by bars Source Google Earth.

Figure 3 Large and numerous parks, empty

sidewalks that do not invite walking Source

Google Earth.



Figure 2 Sidewalks between 90 cm and 150 cm wide, with light poles in the middle Source Google Earth.

Figure 4 Distances Source Google Earth.



Bochalema neighborhood public transportation system area of influence 300 and 400 meters



# 6. Design and development of software to measure topological and spatial accessibility



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Figure 1 sidewalks of 150 cm in the area.



Figure 3 streets without sidewalks surrounded by gated communities.



6.2.4 Analysis of an old neighborhood of commune 22

Figure 2 sidewalks with obstacles and empty streets.



Figure 4 streets without sidewalks.



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



Dgis used to evaluate the 400 meter area of influence.



6.2.5 A possible public transportation route in the Pance Northwest Subarea



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In red the route generated in AutoCad Civil.

The coordinate points of the bus stops are searched for. buses using Dgis software.





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% Come in route and straight	Stop 1	stop to 2	Stop 3	Stop 4	stop 5	Stop 6
stop 1	0.00	10.27 8.0	00 10.26 85	.83 0.00	49.22	68.09
stop 2	5.71 9.	73 65.55	5 85.15 0.00	9.30	57.78	58.11
stop 3					54.70	46.97
Stop 4 40.9	6 68.21 8	7.12 0.00	) #2.12	0,00	2.10	4.00
Stop 5 42.8	84 72.64 8	4.32 85.0	)2		0.00	5.46
Stop 6 37.9	8 65.41 6	6.41 65.6	67	65,67	85.79	0.00

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

Area with current Dgis routes 43.13% occupancy

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 24.5	3 0.00	0,00	3.86	7.40 <b>0.60</b>	11.17	11.17
Stop 3 20.6	6 24.54		24.87	0.00	7.30	11.01
Stop 4 17.1	3 21.00	21,00	21.10	24.6317.39	3.77	7.48
Stop 5 13.3	6 17.23		20.92		0.00	3.71
Stop 6 9.65	13.52	13.57	17.39	20.92	24.69	0.00

In this matrix we have the theoretical travel time that a vehicle would take to go from one node to another following the actua route of the route.

Increase in spatial accessibility in the area from 43.13% to 72.54%. which represents an increase of 29.41%.



# Zone with the route evaluated 72.54%.



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southeast.



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Proposed linear route, southeast area.





Obtaining coordinates in the southeast area with Dgis.

-76.515

Longitude (<sup>0</sup>

-76.51







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Southeast area is missing without a new route.

% Come in route and straight	Stop 1	Stop wo	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7
stop 1	0.000 8	.274 21.108	29.641 48.4	37 56.925 5	4.400		
stop 2	8,274 0	,000 34,665	40,351 62,7	97 63,179 5	7,294	63.179	\$7,294
Stop 3 21,108	34,665 0,0	00 3,302 36	6,814 31,391	37,179			
Stop 4 29,641	40,351 3,3	02 0,000 26	6,707 26,235	43,879	26, 307	26.235	43,879
Stop 5 48,437	62,797 36,	814 26,707	0,000 17,90	5 36,593			
Stop 6 56,925	63,179 31,	391 26,235	17,905 0,00	0 32,098	17.90%	0.000	12,098
Stop 7 54,400	57,294 37,	179 43,879	36,593 32,0	98 0,000			

Percentage difference that exists between the current route and the theoretical ideal

time en route								
100	Stop	Stop	Stop	Stop	Stop	Stop	Stop	
Minute	1	two	3	4	5	6	7	
stop 1	0.000	7.895 15.3	66 19.04	7 22.226 2	5.590 29.8	33		
stop 2	7,895	0,000 7,47	1 11,152	14,332 17	,695 21,93	8	0. 21,95	
stop 3	15,366 7	15,366 7,471 0,000 3,681 6,860 10,224 14,467						
stop 4	19,047	11,152 3,6	81 0,000	3,179 6,54	3 10,786	13. 6.54	10, 24, 79	
stop 5	22,226 1	14,332 6,8	60 3,179	0,000 3,36	4 7,607			
stop 6	25,590 1	17,695 10,	224 6,54	3 3,364 0,0	00 4,243	1.	81.4.24	
stop 7	29,833 2	21,938 14,	467 10,7	86 7,607 4,	243 0,000			

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

In this matrix we have the theoretical travel time that a vehicle would take to go from one node to another following the actual path of the route



A route is generated new bus,

supplies the what is needed in the are southeast, you have now an area

75.81% instead of 61.08%, increase by 14.73%



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Aerial view of the circular route studied.

C

# 6.2.9 Improving existing routes

One-way old circular route It was analyzed with Dgis **Results:** 

- Maximum travel time: 32.5 minutes
- Maximum percentage difference between theoretical and real minimum travel, 97.39%



Two non-circular routes replace the circular one.





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6.2.9 Improving existing routes Route B and Route C

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 13.67 minutes, which is equivalent to 14 minutes. about.

Ruta B

# Ruta C

Note the travel time that has been significantly shortened, the simulation being run at an average of 13 kilometers per hour, giving the longest time of 12.28 minutes, which is equivalent to approximately 13 minutes.

It is evident then the superiority that exists in linear routes (unless in this particular case), with respect to circular routes, 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, while in the worst case with the new routes the passenger will have to travel a maximum of 14 minutes, which represents a significant reduction in travel time for the user of 56.92%.



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Assertiveness level when measuring the accessibility level of the different areas in those cities to who require move around them using

public and pedestrian transport, information that necessarily must have a team

developer to reorganize the accessibility of a city

favor of its residents and visitors.

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6.3 Applicability of the software to multiple cities around the world

The database will be used

Qgis as API Data Extractor,

Excel as txt database filter

Overpass should be used because city databases can be up to 2 gigabytes in

size, which makes it impossible to use

while Overpass can support between 0 and 600,000 nodes.

the OpenStreetMap base exporter, which only supports up to 5000 nodes,

OpenStretMaps together with the Overpass API,

extracted from Qgis and later the Software created in this work as an

iterator.







iniciar 2

nota: iniciar 2, no genera archivo xisx solo arrola resultados inicialer



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

6.3.1 Thirty-four cities analyzed using Dgis

graph

reliene los valores , puede	e revisar el manual	Manual de usuario Recomendaciones	DE VALÈNCIA
limite inferior	20	% area alcanzada	24.96
limite superior	300	lado 1, metros	3.314e+04
area de influencia en metros	400	lado 2, metros	1.957e+04
DpenStreetMap	Editar - Hist	Area estudiada metros cuadrados	648620111
Buscar	Norske està esta? Ir	Numero de paradas con al menos otra	en rango 1409
		Numero de paradas sin al menos otra e	n rango 383
Exportar		numero paradas/nodos a eviauar	1792
y1 51.183	22	area blanca de influencia nodos/paradas	161866303
x1 -114.18709 x1 y2 50.885	x2 -113.90900 X2 28 Y2	1	
		velocidad media 0 Lo n velocidad maxima 0 Lo n	ormal es que el valor sea 13km/h ormal es que el valor Solumite e 60 km/t
	agen encontrar co	ordenadas Medidas Topologicas de Accesib	Bidad
	sectors i derecteres oo	in a share share share a share	

By David Alejandro Ramirez Cajigas

		CALGARY-CANADA
	UNIVERSITAT Politecnica de València	
24.96		
314e+04		
1.957e+04		
648620111		
1409		
383		
1792		
61866303		
s que el 1	valor sea 13km/h	g er
	valor	
o 60 km/H		
Linkov	- 173	
LINKed	Linkedin	

City	Country	Continent	Analyzed area	Percentage area reached by public transport in the area
1	· ·	· ·	· ·	an is some 🔻
amsterdam	Netherlands	Europe	City	72.64
Athens	Greece	Europe	City	83.8
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 Downt	own neighborhood	97.95
Calgary	Canada	North America Perip	heral neighborhood	54.78
Calgary	Canada	North America City	L selled	24.96
Copenhagen	Denmark	Europe	Centric district	98.81
Copenhagen	Denmark	Europe	City	44.83
Denver	United States of America North Am	erica Downtown neight	orhood	79.68
Denver	United States of America North Am	erica City	E united	4.96
Dublin	Ireland	Europe	City	88.94
Stockholm	Sweden	Europe	City	94.3
Helsinki	Finland	Europe	City	99.52
Kansas	United States of America North Am	erica City	1 united	6.33
weather vane	malt	Europe	City	84.35
Lisbon	Portugal	Europe	City	97.19
Ljubljana	Slovenia	Europe	City	94.25
The Angels	United States of America North Am	erica Peripheral neighb	orhood	73.98
Luxembourg	Luxembourg	Europe	City	94.62
Madrid	Spain	Europe	downtown berrio	96.6
Madrid	Spain	Europe	City	77.88
Nicosia	Cyprus	Europe	City	22.88
omaha	United States of America North Am	erica Downtown neight	orhood	30.66
omaha	United States of America North Am	erica City	i whet	10
Paris	France	Europe	Centric district	99.83
Paris	France	Europe	City	96.12
prague	czech republic latvia	Europe	City	85.51
Riga		Europe	City	74.11
Rome	Italy	Europe	City	95.34
Santiago de ChileChile	1.7 B	South America	Centric district	99.98
santiago cali colombia		South America	Peripheral neighborhood	34.27
santiago cali colombia	La prilia	South America	City	50.84
Sofia	Bulgaria	Europe	City	93.59
Tallinn	Estonia	Europe	City	78.21
warsaw	Poland	Europe	City	66.65
Vienna	Austria	Europe	City	90.96
Vilnius	Lithuania	Europe	City	85.36
Zagreb	Croatia	Europe	City	76.03

Summary of the analyzes carried out



and



Index 6.3.2 Analysis of cities 1. Introduction 2. Context and iustification cities 3. Objectives •They have an area reached by the transport system very close to 100%. 4. Methodology european 5. State of the art 6. Design american development of They have an area reached by the acceptable transportation system only in the downtown area. software to measure •Peripheral areas, these cities have a percentage of area close to only 10% topological and spatial cities The pedestrian in the background, a city has been designed for cars and they lack attractiveness to accessibility measure that separates from the central zone, rectifying what the authors of the theoretical framework say. 6.1 Structure of the Program Canadian 6.2 Practical •They follow the same American scheme, although their area reached was close to 24%. application to •The pedestrian in the background, a city has been designed for cars and they lack attractiveness as it is Cali (Colombia) cities separated from the central area, rectifying what the authors of the theoretical framework say. 6.3 Thirty-four cities analyzed using Dgis. South 7. Conclusion •Santiago de Cali-Colombia, Santiago de Chile-Chile and Brasilia-Brazil, present a union between the and future lines of European city and the North American city, reaching a percentage of 50% to 100% of total area. research American cities •However, they lack attractors for the daily life of the citizen, who thus does not enjoy his city, since it was 8.Bibliography not made for the people.



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7. Conclusion and future research



He studied allowed, 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 human interdependence forces

Recognizing the reality of cities in their existing organization, regardless of how well or poorly planned they are urbanistically, the citizens who move in it expect a direct human interconnection as fluid and easy as possible, before which it was necessary to generate a 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.

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 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, in order to the urban planner establishes the public transport stops fulfilling the premise that they have the key places required by the citizens within a radius of 400 meters on foot.

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, of 29.41%, only by implementing a new transport route.

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



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By replacing an existing circular route in commune 18 with two linear routes, the travel time was reduced, where a substantial improvement in maximum travel times is evident, 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 to day life.

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 around the world, to demonstrate the scope of the third specific objective.

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. They must be planned through routes that facilitate mobility, lead to the interaction of people, thanks to the fact that public transport and walking complement each other amicably, with the aim of getting people to socialize with each other because they live in urbanized cities for 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.

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. Object of new research that allows the analysis of this type of variables







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# 6.3.3 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 the category AXIS C: Urban and metropolitan agenda; towards healthier cities and territories, AXIS C-3: Sustainable intra-urban mobility and metropolitan. Within the poster category and the presentation/communication category.

EJE C.3: Movilidad sostenible intraurbana y metropolitana
Escenarios participativos para la movilidad sostenible. Caso de Madrid
Efecto estructurante de los transportes en un área metropolitana y sus implicaciones para la movilidad sostenible
Carmen Zornoza Gallego, Julia Salom Carrasco y Juan Miguel Albertos Puebla
Movilidad sostenible y saludable en bicicleta (MSSB) en el Área Metropolitana de València. Horizonte 2030. ¿Utopía o realidad?1013 Javier Iturrino-Guerrero
Dgis: Software de análisis y diseño de transporte urbano e interurbano basado en accesibilidad1031 David Alejandro Ramírez Cajigas
Mejora de la accesibilidad territorial de áreas rurales con acceso a estaciones ferroviarias de alta velocidad a través de un procedimiento intermodal
Dgis: Software de análisis y diseño de transporte urbano e interurbano basado en accesibilidad (póster)
Mejora de la accesibilidad territorial de áreas rurales con acceso a estaciones ferroviarias de alta velocidad a través de un procedimiento intermodal (póster)

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

