Revista Científica Interdisciplinaria Investigación y Saberes
2022, Vol. 12, No. 2 e-ISSN: 1390-8146
Published by: Universida Técnica Luis Vargas Torres

Efficiency of urban mobility in La Troncal canton using computational tools

Eficiencia de la movilidad urbana del cantón La Troncal usando herramientas computacionales

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Received 2021-11-11
Revised 2022-02-09
Accepted 2022- 04-01
Published 2022-05-04
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Pages: 29-48

Abstract

In this paper we describe the importance of computational tools to optimize the efficiency of passenger mobility within an urban network. The main objective is to identify the best route of the urban network to mobilize passengers. For the study, as a reference we took a single origin of the routes located at the bus terminal in the center of the city. On the other hand, as a destination we selected random locations in the six farthest neighborhoods, where travel times are longer and more significant. On the other hand, the means of urban transport chosen were cabs and motorcycle cabs because they are more in demand by travelers. The data used for development were travel time, distance, fare, travel frequency and the latitude and longitude coordinates of the origin and destinations. Among the results, the most suitable routes to mobilize travelers were identified. These routes were plotted on the respective maps of the urban network to motivate the generation of public policies. It was determined that the travel times calculated by the computational algorithms differed from those obtained in the direct surveys of drivers. These differences remain under discussion if they are due to the poor state of the roads and conditions of the means of transportation versus the criteria or parameters with which we evaluated in the algorithms.

How to cite this article (APA): Gómez, E. (2022) Efficiency of urban mobility in La Troncal canton using computational tools, *Revista Científica Interdisciplinaria Investigación y Saberes, 12(2)* 29-48.

Keywords: urban mobility, travel times, short routes, algorithms, La Troncal.

Resumen

En este artículo describimos la importancia de las herramientas computacionales para optimizar la eficiencia de la movilidad de los viajeros dentro de una red urbana. El objetivo principal es identificar la mejor ruta de la red urbana para movilizar a los pasajeros. Para el estudio, como referencia tomamos un solo origen de las rutas ubicado en el terminal de buses en el centro de la ciudad. En cambio, como destino seleccionamos lugares aleatorios de los seis barrios más alejados, donde, los tiempos de viaje son mayores y más significativos. Por otro lado, los medios de transporte urbano elegidos fueron taxis y mototaxis por tener mayor demanda de los viajeros. Los datos utilizados para desarrollo fueron, tiempo de viaje, distancia, tarifa, frecuencia de viajes y las coordenadas de latitud y longitud del origen y destinos. Dentro de los resultados se identificaron las rutas más idóneas para movilizar a los viajeros. Estas rutas trazamos en los respectivos mapas de la red urbana para motivar a generar políticas públicas. Se determinó que los tiempos de viaje calculados por los algoritmos computacionales difieren de los levantados en las encuestas directas a los conductores. Estas diferencias quedan en discusión si se debe al mal estado de las vías y condiciones de los medios de transporte contra los criterios o parámetros con que evaluamos en los algoritmos.

Palabras clave: movilidad urbana, tiempos de viaje, rutas cortas, algoritmos, La Troncal.

Introduction

The study deals with the efficiency of urban mobility to improve population accessibility. Taking into account that public transportation is the main engine of mobility, being the most used by citizens. Therefore, it is proposed to apply ICTs to achieve better travel and reduce traffic congestion.

Urban mobility is an issue of importance, because currently due to population growth, traffic in large cities has become chaotic. According to a report presented by the UN, currently 54% of the world's population lives in urban areas and it is considered that by the year 2050, it will increase to 66% (United Nations, 2018)

Studies show that in Latin America and the Caribbean, 80% of the population lives in urban areas, which do not have an efficient public transportation service. (ECLAC, 2019)A clear example is Santiago de Chile, 65% of citizens use public transportation for their mobility.

In Venezuela there is a high demand for public transportation to meet the mobility needs of citizens, since 75% use this means of transportation, something similar occurs in Peru, since 57% of people use public transportation. (ECLAC, 2021)

In Ecuador, 73% of the population uses public transportation, followed by Colombia with 66.5%, who use this type of transportation as their main means of transportation According to the data indicated above, public transportation is the most used in Latin American countries, despite the fact that it has several drawbacks such as non-compliance with schedules, long waiting time at stops, slow travel, and lack of transportation in all areas of the cities, causing loss of time for citizens in their travels.

For this reason, the use of ICT is proposed to maximize public transportation service, since the use of technology can increase operational efficiency, as well as the quality and safety of the service. In this regard Finquelevich, and KIsilevsky (1996)state that ICTs play a very important role in public transport management, since they intervene efficiently between the vehicles and the control center in a fast and safe manner.

Taking into account that urban mobility and population accessibility are very important issues since people move from one place to another, while accessibility refers to citizens seeking ease of access to a certain place. For Bouskela, et al (2016)citizens increasingly feel the need to move around, whether for work, study or commerce, so accessibility to urban areas is becoming more and more important.

In many countries of the world, Information and Communication Technologies (ICT) are used to relieve traffic congestion, so that people can reach their destination without delay. Therefore, the use of ICT not only improves urban mobility, but also population accessibility. The objective of using information and communication technologies (ICT) is to reduce traffic, to make roads safer, and to monitor the speed of vehicles by placing access control traffic lights or highways.

In Ecuador, urban mobility in the main cities is a serious problem, due to the increase of the population which has generated problems for the displacement and the increase of time to move from one place to another, since the vehicle traffic is excessive especially in rush hours. Therefore, the use of technology is considered necessary to make urban mobility more efficient, comfortable and safe for citizens to reach their destinations. The research problem is to evaluate how information technologies work to improve urban mobility in the canton of La Troncal by applying geospatial data analysis through computational tools?

Currently, due to population growth, traffic in large cities has become a chaos, since public transportation is the main engine of mobility, being the most used by citizens. Therefore, it is proposed to apply ICT, to achieve a better displacement as well as to reduce traffic congestion.

In Ecuador, the population uses public transportation as its main means of transportation, despite the fact that these have several drawbacks such as non-compliance with schedules, waiting time at stops is high, the route is slow, there is no transportation in all areas of the cities, causing loss of time for citizens in their travels.

For this reason, the use of ICT is proposed in order to maximize public transportation service, since the use of technology can increase operational efficiency, as well as the quality and safety of the service.

The study on the efficiency of urban mobility in the canton of La Troncal using computational tools, aims to improve the public transport service through the use of Information and Communication Technologies ICT, for which sources from various authors will be analyzed in order to make known their views on urban mobility, centralized traffic control, route integration, traffic light management, camera systems, congestion, vehicle flows and the use of communication technology for traffic analysis of different types of transport:

Urban mobility is defined as the set of movements of people and goods in different means of transportation, in an efficient and safe manner. (Avelar, 2014)

In other words, urban mobility refers to the movement of people and goods in an efficient and safe manner, which means that urban mobility is a means that must guarantee the accessibility of citizens to certain destinations. In this aspect, Information and Communication Technology (ICT) plays a fundamental role because technology allows public transportation to go to the place where this service is required. Likewise, traffic lights are calculated in real time to decongest a road.

All these advantages mean that technology can be used to provide a better public transportation service, since it can become an efficient, comfortable and safe means of transportation for users to travel to different parts of the city to carry out their activities.

Information and Communication Technologies (ICT) allow the control of traffic management in real time. This control consists of regulating the routes of transportation units from a digital platform. The centralized traffic control is previously programmed for each route, from where it is possible to stop, back up, control speed and distance. (Ochoa, 2015).

Route integration consists of creating matrices of real distances per race, thus saving time to get to a certain place. In addition, it improves the waiting time, improving the quality of the transportation service and making the customer feel satisfied.

Among the advantages of route integration are:

Transportation arrival and departure schedules are adhered to

Improves the agility of the transport service

In route integration it is essential to have real-time traffic information, this provides information about traffic jams, road works, accidents, closed roads. All these factors must be taken into account with the aim of avoiding blockage points to estimate arrival time (PTV Group, 2019)

From the traffic management center, the operator can manage the mobility of public and private vehicles by regulating traffic lights in real time, in order to adapt them to traffic conditions, modifying phases, traffic light cycles and synchronization between intersections.

The detectors are generally installed at key points on different streets, as they can measure the intensity of traffic from the number of vehicles passing over the detector. (SUMP, 2020)

Large cities have integrated cameras located in strategic places that collect information through cameras that take pictures and videos of the vehicles in transit, with this data it is possible to plan the traffic and take other routes or avenues.

Congestion and vehicle flows are directly related to the start of school and work activities, which occur around 7 - 9 in the morning and from 4 - 7 in the afternoon. Use of communication technology for vehicular traffic analysis of different types of transportation.

Nowadays in digital cities communicational technology, offers a number of advantages in vehicular transport networks of different types of transport. Due to population growth, transportation has become increasingly a problem for people to move from one place to another. In this regard, Zárate et al, (2018) point out that nowadays the distance separates the places where economic and social activities are carried out. All this requires that people need more time to move around, especially during rush hours. Therefore, the use of Information and Communication Technologies is required to improve the mobility of the different types of transportation.

The following is a description of the state of the art of the study on urban mobility efficiency in La Troncal using computational tools. The study used sources of scientific articles and journal publications related to the topic of the study.

Arjona, García. (2018)conducted a study on new sources and challenges for the study of urban mobility. The study highlights that, in the 21st century, urban mobility is one of the greatest challenges faced by large cities. In this sense, Information and Communication Technologies (ICT) allow much more efficient travel, since they improve the capacity of the transportation system by making a traffic light calculate the real time to decongest a road. From the above, it can be pointed out that ICTs are an excellent tool to offer citizens mobility efficiency.

Mafla, Beltrán, Mora (2021)The study is a study on urban mobility analysis in the city of Tulcán - Ecuador. The study highlights that efficient urban mobility makes the city much more competitive. However, to achieve this, the transportation system must have certain regulations to be accessible, safe and sufficient for its inhabitants. It also points out that in this city, citizens use public transportation for their mobility, followed by cabs and private transportation, to move to their different activities.

Paredes, Berbey - Álvarez. (2018), conduct a study on the current situation of the transportation system in the city of Quito, Ecuador: a proposal for improvement. The study reveals the difficult mobility situation that exists in the capital of Ecuador, especially during rush hours (7 - 9 a.m.), (4 - 7 p.m.). These authors propose the application of Information and Communication Technologies (ICT) to improve urban mobility.

Methodology

For the study on the efficiency of urban mobility in the canton La Troncal using computational tools, the quantitative type was used, in which methods such as observation, critique and analysis and interpretation of information were employed, for the main use of the method of bibliographic review of primary and secondary sources, since information will be sought from various sources such as articles from duly authorized indexed journals and other documents. Authors such as Hernández, Fernández and Baptista (2014)mention that bibliographic research is characterized by the use of secondary data as a source of information, the purpose of which is to find a solution to the problems posed by means of a two-way analysis, in which data that already exist and come from different sources are related.

Followed by the descriptive one, since it will allow a detailed description of the study. In this regard Guevara, Verdesoto, and Castro (2020) descriptive research allows to clearly describe each one of the components of reality and to explain in a clear way, which are the causal relationships that allow to approach a specific problem and try to determine which are the causes that originate it. Such is the case of the study on the efficiency of urban mobility in the canton of La Troncal using computational tools, for which the serious mobility problem that exists in the canton will be described.

On the other hand, field research was used to investigate, implement and test methods used to reinforce the results and conclusions. Finally, applied design was used because, once the aforementioned processes were continuously carried out, a prototype was evaluated to demonstrate the final results.

Results

Applying the methodology described above, the different neighborhoods of the canton were explored, where 6 of them were considered, because they are densely populated and their roads are not paved, so the analysis of routes was performed, where the number of nodes, times, distances and representative routes of each neighborhood were obtained, whose results are shown below.

La Troncal canton network with its 6 most important neighborhoods, being the Santa Rosa neighborhood yellow, 2 de Octubre pink, 15 Hectarias green, Roberto Isaias red, Abdala Bucaram orange and Martha de Roldos turquoise (See figure 1).

Figure 1: Network of the canton La Troncal with its 6 neighborhoods

On the other hand, 3 sub-networks were extracted to represent each of the neighborhoods such as: Santa Rosa, 2 de Octubre (See Figure 2), 15 Hectarias, Roberto Isaias (See Figure 3), Abdala Bucaram and Martha de Roldos (See Figure 4).

Figure 2: Santa Rosa and 2 de Octubre Sub-network

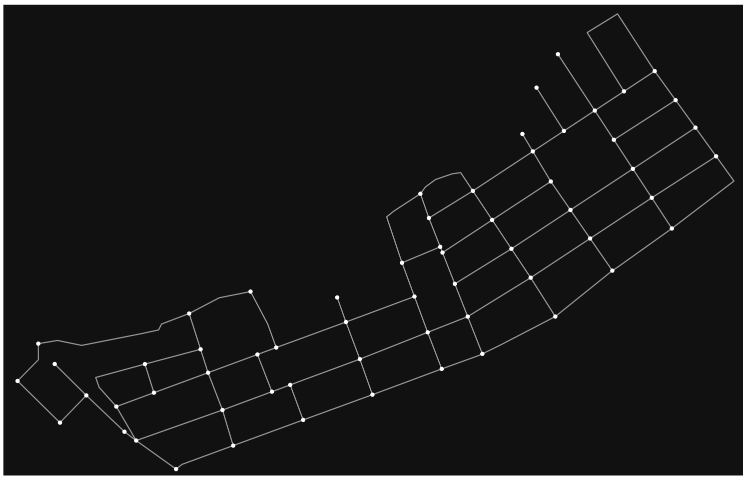


Figure 3: 15 Hectare and Roberto Isaias Subnetwork

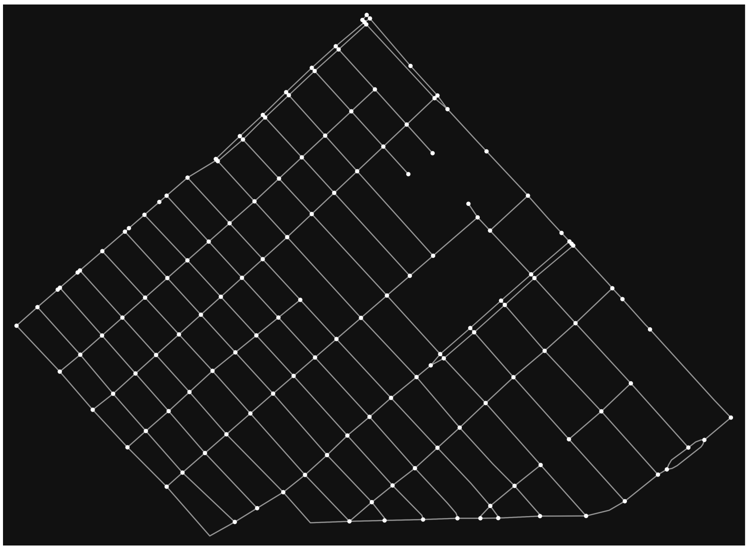
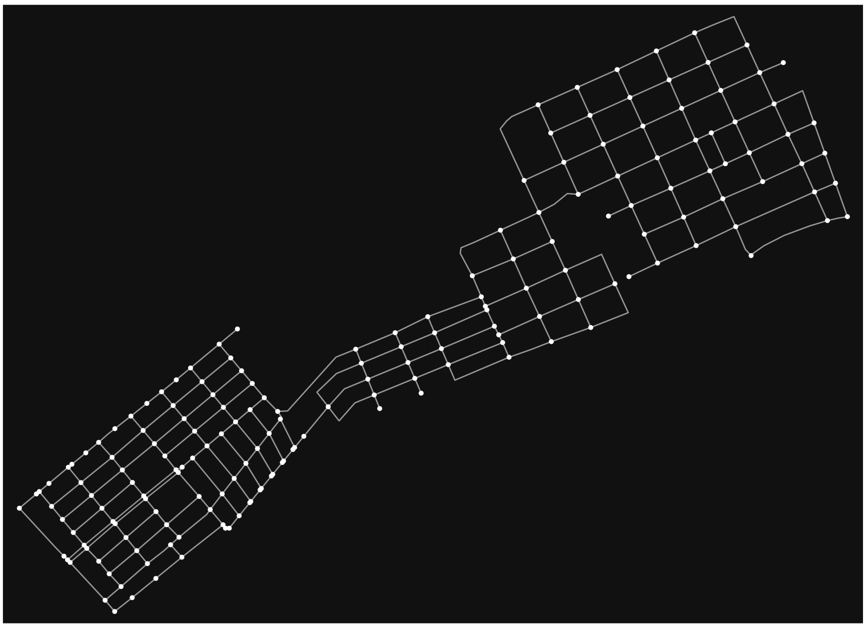


Figure 4: Abdala Bucaram and Martha de Roldos Sub-network



With the extraction of sub-networks, the number of nodes in each neighborhood was determined, which allows calculating the time and distance from the center of the canton to each of the different nodes.

In the Santa Rosa and 2 de Octubre neighborhoods, 61 nodes were obtained, the minimum time was 1,683 minutes and the maximum 3,983 minutes, while the shortest distance was 1,106 km and the longest 2,389 km. The average time was 3,157 minutes and the distance was 1,902 km versus the reality, which was 3,536 minutes. This large margin of error is due to the fact that this tool has a deviation of 0.43; since it considers that the roads are in good condition, however, the reality is different, since the roads are not paved, which is why it takes longer and the distance is longer to get to each place. In addition, the average cost per freight is $2.72 cents (See Table 1).

Table 1: *Times and distances from the center of the canton to each of the nodes in the Santa Rosa and 2 de Octubre neighborhoods.*

Nº	TIEMPO	DISTANCIA
1	3.383	2.056
2	3.983	2.389
3	3.683	2.233
4	3.900	2.342
5	3.983	2.389
6	3.783	2.288
7	3.516	2.292
8	3.666	2.231
9	3.566	2.175
10	3.783	2.288
11	3.550	2.174
12	3.500	2.274
13	3.550	2.199
14	3.050	1.999
15	3.350	2.063
16	3.200	2.015
17	3.516	2.177
18	3.350	2.083
19	3.233	2.054
20	2.933	1.891
21	3.316	2.112
22	3.316	2.063
23	3.066	1.938
24	3.150	1.975
25	3.050	1.928
26	2.650	1.736
27	3.150	1.998
28	3.300	1.931
29	2.966	1.877
30	2.166	1.447

Nº	TIEMPO	DISTANCIA
31	2.916	1.813
32	2.416	1.624
33	2.983	1.885
34	2.016	1.348
35	2.916	1.817
36	2.700	1.706
37	2.800	1.755
38	1.683	1.106
39	2.350	1.551
40	2.083	1.395
41	2.783	1.761
42	2.366	1.578
43	2.650	1.646
44	2.250	1.361
45	2.183	1.483
46	2.683	1.695
47	2.116	1.432
48	2.133	1.152
49	2.366	1.492
50	2.316	1.526
51	2.433	1.576
52	2.200	1.302
53	2.450	1.586
54	2.300	1.448
55	2.266	1.473
56	2.066	1.177
57	2.033	1.217
58	2.066	1.245
59	1.916	1.251
60	2.400	1.531

In the neighborhood 15 Hectarias and Roberto Isaias 148 nodes were obtained, the minimum time was 2.466 minutes and the maximum 5 minutes, while its shortest distance is 1.056 km and the longest 2.349 km. The average time was 3,422 minutes and the distance was 1,741 km versus the reality, which was 4,122 minutes. In addition, the average cost per freight is $1.52 cents (See Table 2).

Table 2: *Times and distances from the center of the canton to each of the nodes in the 15 Hectarias and Roberto Isaias neighborhoods.*

Nº	TIEMPO	DISTANCIA
1	2.75	1.061
2	2.783	1.074
3	2.683	1.126
4	3.016	1.261
5	2.9	1.179
6	2.966	1.219
7	3.0	1.237
8	3.116	1.272
9	3.083	1.292
10	3.116	1.296
11	3.2	1.33
12	3.166	1.344
13	3.283	1.358
14	3.066	1.355
15	3.05	1.305
16	3.216	1.386
17	3.4	1.637
18	3.333	1.417
19	3.416	1.47
20	2.55	1.568
21	3.3	1.435
22	3.416	1.47
23	3.2	1.457
24	2.483	1.522
25	3.35	1.49
26	2.466	1.507
27	3.433	1.571
28	3.45	1.514
29	2.516	1.54
30	3.433	1.574
31	2.75	1.672
32	2.6	1.573
33	3.333	1.54
34	2.616	1.582
35	3.316	1.537
36	3.566	1.577
37	3.4	1.562
38	2.65	1.627
39	3.4	1.562
40	2.7	1.631
41	3.6	1.671
42	2.883	1.753
43	2.766	1.643
44	2.766	1.681
45	2.783	1.686
46	3.666	1.639
47	3.65	1.722
48	2.766	1.708
49	2.85	1.687
50	3.516	1.661
51	2.833	1.724
52	2.85	1.729
53	3.733	1.772
54	2.95	1.724
55	2.916	1.734
56	3.583	1.686
57	3.916	1.969
58	3.6	1.711
59	2.983	1.773
60	2.916	1.768
61	2.916	1.797
62	2.933	1.786
63	3.85	1.829
64	3.65	1.752
65	3.15	1.823
66	3.7	1.779
67	3.8	1.753
68	2.983	1.817
69	2.983	1.843
70	3.416	1.831
71	4.033	2.056
72	3.05	1.853
73	3.15	1.874
74	3.05	1.868
75	3.016	1.887
76	3.2	1.902
77	3.116	1.914
78	3.2	1.926
79	3.083	1.935
80	3.966	1.899
81	5.0	2.174
82	3.416	1.951
83	3.2	1.964
84	3.4	1.943
85	4.083	1.954
86	3.366	1.997
87	3.683	2.174
88	3.25	2.007
89	3.45	2.107
90	3.566	2.086
91	3.8	2.301
92	3.75	2.257
93	3.65	2.206
94	3.566	2.159
95	3.516	2.11
96	3.45	2.063
97	3.883	1.847
98	4.1	2.016
99	3.566	2.177
100	3.766	2.266
101	3.866	2.185
102	4.083	2.234
103	4.55	2.222
104	3.966	1.951
105	4.666	2.213
106	2.766	1.056
107	2.833	1.084
108	4.316	1.952
109	4.65	2.029
110	4.783	2.104
111	4.283	2.349
112	4.15	2.262
113	3.933	2.222
114	3.966	2.222
115	3.616	1.65
116	3.716	1.72
117	3.783	1.779
118	3.883	1.851
119	2.933	1.167
120	3.0	1.233
121	3.016	1.241
122	3.8	1.82
123	3.883	1.887
124	3.6	1.994
125	3.45	2.045
126	3.466	2.082
127	3.6	2.129
128	3.583	2.139
129	2.8	1.065
130	2.883	1.128
131	2.95	1.18
132	3.033	1.24
133	3.116	1.295
134	3.2	1.346
135	3.383	1.637
136	3.383	1.637
137	3.916	1.869
138	4.733	2.088
139	4.483	2.009
140	4.183	2.279
141	4.1	2.307
142	4.6	2.139
143	4.45	2.089
144	4.133	2.027
145	4.216	1.959
146	4.183	1.887
147	3.466	1.566

In the Abdala Bucaram and Martha de Roldos neighborhood, 177 nodes were obtained, the minimum time was 1.011 minutes and the maximum 9.95 minutes, while its shortest distance is 1.753 km and the longest 5.211 km. The average time was 6,124 minutes and the distance was 3,166 km versus the reality, which was 7,139 minutes. In addition, the average cost per freight is $2.32 cents (See Table 3).

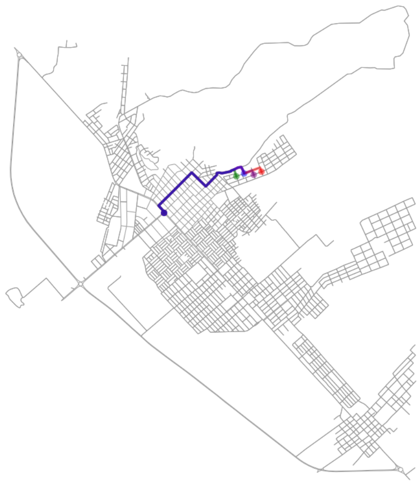
Table 3: *Times and distances from the center of the canton to each* of the nodes in the Abdala Bucaram and Martha de Roldos neighborhoods.

Nº	TIEMPO	DISTANCIA
1	7.0	3.552
2	6.55	3.335
3	7.066	3.607
4	5.016	2.603
5	6.55	3.337
6	7.133	3.662
7	4.933	2.532
8	6.3	3.227
9	6.55	3.337
10	5.983	3.095
11	4.983	2.579
12	5.95	3.079
13	6.55	3.338
14	5.05	2.63
15	6.3	3.229
16	5.8	3.15
17	4.95	2.47
18	5.116	2.68
19	4.65	2.307
20	6.3	3.23
21	5.033	2.522
22	5.8	3.15
23	5.166	2.735
24	4.55	2.25
25	4.666	2.358
26	5.683	3.081
27	4.9	2.679
28	5.8	3.15
29	4.983	2.678
30	4.45	2.189
31	5.35	2.823
32	4.9	2.622
33	4.466	2.239
34	4.783	2.566
35	5.233	2.779
36	4.8	2.564
37	5.483	2.966
38	4.166	2.063
39	4.633	2.497
40	4.716	2.507
41	5.566	2.912
42	5.1	2.721
43	5.4	2.914
44	4.583	2.449
45	4.25	2.119
46	4.616	2.451
47	5.283	2.863
48	5.3	2.87
49	5.083	2.681
50	3.966	1.958
51	3.933	1.944
52	4.333	2.168
53	5.283	2.821
54	5.283	2.816
55	4.866	2.632
56	4.4	2.216
57	4.033	2.004
58	3.783	1.869
59	5.05	2.769
60	5.033	2.764
61	3.733	1.83
62	4.883	2.587
63	3.716	1.819
64	4.116	2.054
65	4.683	2.493
66	4.283	2.264
67	4.983	2.719
68	4.983	2.721
69	3.85	1.883
70	3.6	1.753
71	4.283	2.201
72	4.766	2.544
73	4.416	2.315
74	5.066	2.671
75	3.933	1.934
76	4.15	2.15
77	4.5	2.365
78	4.9	2.616
79	4.1	2.084
80	4.55	2.42
81	4.283	2.205
82	4.0	2.034
83	4.383	2.256
84	3.883	1.977
85	4.333	2.296
86	4.066	2.133
87	4.166	2.191
88	4.333	2.144
89	4.1	2.094
90	4.0	2.041
91	4.15	2.153
92	4.283	2.265
93	4.516	2.397
94	3.866	1.966
95	4.516	2.395
96	4.533	2.409
97	4.116	2.177
98	4.65	2.44
99	4.166	2.195
100	4.316	2.287
101	8.783	4.505
102	9.366	4.789
103	7.4	3.877
104	9.95	5.108
105	9.933	5.104
106	7.2	3.693
107	8.166	4.193
108	8.433	4.325
109	8.683	4.455
110	8.95	4.583
111	9.2	4.711
112	9.2	4.713
113	8.95	4.583
114	8.683	4.453
115	8.433	4.324
116	8.166	4.194
117	7.4	3.789
118	7.9	4.063
119	7.083	3.636
120	9.2	4.713
121	9.783	5.015
122	8.016	4.118
123	8.166	4.194
124	8.433	4.324
125	8.683	4.453
126	8.95	4.584
127	9.6	4.917
128	9.583	4.911
129	7.4	3.877
130	8.416	4.323
131	8.683	4.453
132	9.766	5.008
133	8.95	4.584
134	8.95	4.583
135	8.95	4.583
136	1.013	5.211
137	1.011	5.202
138	8.683	4.454
139	8.683	4.452
140	8.683	4.455
141	8.416	4.322
142	8.433	4.325
143	8.433	4.325
144	7.083	3.636
145	7.4	3.877
146	8.166	4.193
147	6.95	3.509
148	7.35	3.707
149	7.6	3.835
150	6.983	3.541
151	7.4	3.877
152	8.0	4.184
153	7.35	3.773
154	7.1	3.635
155	7.083	3.575
156	7.2	3.706
157	8.1	4.271
158	7.883	4.088
159	7.6	3.896
160	7.5	3.852
161	7.466	3.816
162	4.3	2.127
163	4.083	2.013
164	4.916	2.633
165	4.5	2.389
166	4.866	2.604
167	5.3	2.791

In addition, 4 representative locations in each neighborhood were considered to calculate the shortest route from the center of the canton to each of these locations with their respective distances.

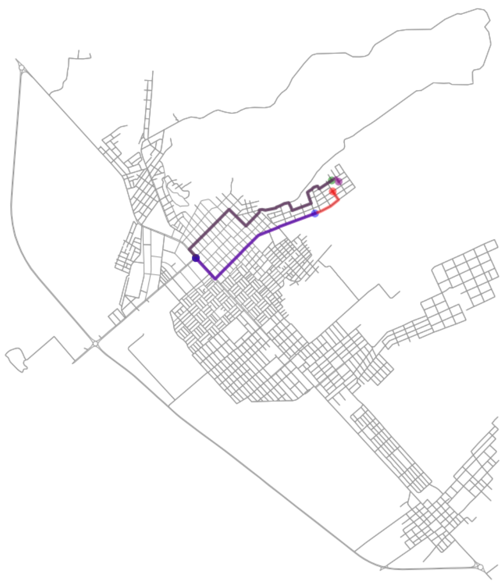
In the Santa Rosa neighborhood, we considered the court with its red route and distance of 1.71 km, the park with green route and distance of 1.44 km, Creaciones y reparaciones Manolo - Tienda de Muebles with purple route and distance of 1.6 km, and the voli court with blue route and distance of 1.55 km (see Figure 5).

Figure 5: Routes of the 4 representative sites in the Santa Rosa neighborhood



In the 2 de Octubre neighborhood, we considered the park with its red route and distance of 2.04 km, the United Pentecostal Church of Ecuador with its green route and distance of 2.19 km, the day care center with its purple route and distance of 2.21 km, and the Municipal Machinery Camp with its blue route and distance of 1.68 km (see Figure 6).

Figure 6: Routes of the 4 representative sites in the 2 de Octubre neighborhood

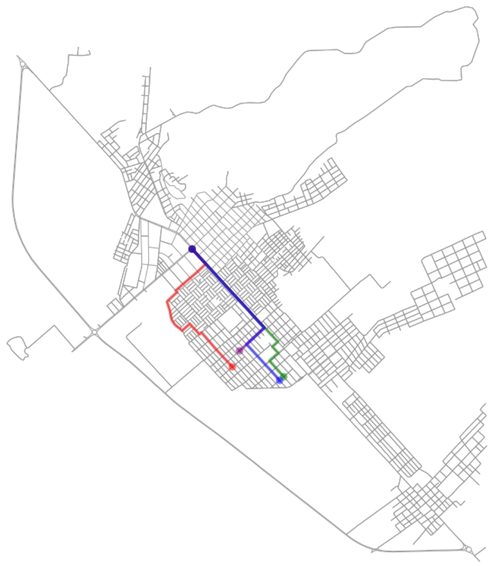


In the 15 Hectarias neighborhood, we considered the Ferreteria Quinteros "FERREQUINTE S.A." with its red route and distance of 1.35 km, the Universidad Católica de Cuenca Sede San Pablo de la Troncal with green route and distance of 1.59 km, the Siver Compu Sistem with purple route and distance of 1.51 km and the National Police District "LA TRONCAL" with blue route and distance of 1.45 km (See Figure 7).

Figure 7: Routes of the 4 representative sites in the 15 Hectares neighborhood

In the Roberto Isaias neighborhood, we considered the Mercedes Church with its red route and distance of 1.87 km, the soccer field Km. 72 with green route and distance of 2.02 km, the volleyball field "El Panita" with purple route and distance of 1.61 km and the Millennium Educational Unit "Nela Martinez Espinosa" with blue route and distance of 2.07 km (See Figure 8).

Figure 8: Routes of the 4 representative sites in the Roberto Isaias neighborhood

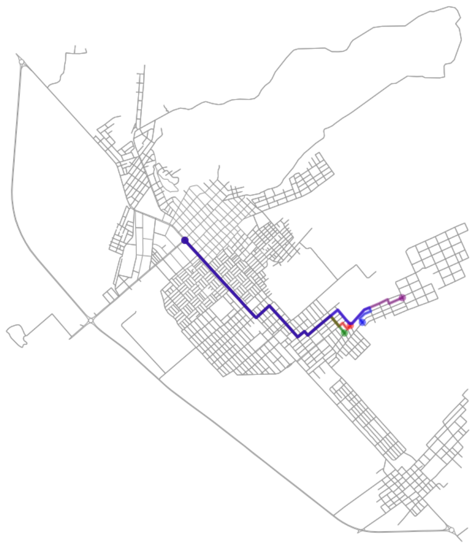


In the Abdala Bucaram neighborhood, we considered the "Froilan Octavio Navas Calle" Basic Education School with its red route and distance of 1.78 km, the La Troncal Coliseum with green route and distance of 2.5 km, the "Los Olivos" Clinical Laboratory-Branch with purple route and distance of 1.94 km, and the Church of Christ with blue route and distance of 2.6 km (see Figure 9).

Figure 9: Routes of the 4 representative places of the Abdala Bucaram neighborhood

In the Martha de Roldos neighborhood, we considered the Motocross track with its red route and distance of 2.83 km, the park with green route and distance of 2.73 km, the soccer field with purple route and distance of 3.57 km, and the community house with blue route and distance of 3.08 km (see Figure 10).

Figure 10: Routes of the 4 representative sites in the Martha de Roldos neighborhood



Throughout the study on the efficiency of urban mobility to improve population accessibility, the importance of the implementation of ICTs to improve urban mobility and population accessibility has been made known. A state of the art was presented in which the opinion of several authors was presented to show the problem of urban mobility.

For all these reasons, it is concluded that the implementation of ICT to improve the efficiency of urban mobility is an excellent option because these tools allow centralized traffic control, route integration, traffic light management, and a camera system to monitor congestion and vehicular flows.

Conclusions

The most salient point in this study is that achieving efficiency in the use of existing urban networks to improve urban mobility is of interest to large cities and a warning for small cities. The lack of a maintenance plan for access roads to the most remote sectors of the city further complicates motorized transport. Consequently, in this work we identify the routes with the lowest time and distance costs in the urban network to mobilize travelers.

We plotted these optimal routes on the georeferenced maps of the urban network with the intention of motivating new public policies for planning and maintenance. It was determined that the travel times calculated by the computational algorithms differed from those obtained in the direct surveys of drivers. These differences are under discussion if they are due to the poor state of the roads and conditions of the means of transport compared to the criteria and parameters used to evaluate the algorithms.

Therefore, it is recommended to carry out future works that apply Information and Communication Technologies (ICT), in order to improve urban mobility and therefore the population's accessibility.

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