GT-Panama Thesis Series

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Georgia Institute of Technology
MS in Supply Chain Engineering

Mapping and Analysis of Bus Transportation System in Panama

Capstone Project

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Mapping and Analysis of Bus Transportation System in Panama

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Executive Summary

This project provides an analysis and evaluation of the current situation of traffic flow, timing, and stops of three routes of the bus transportation system of Panama City. Methods of analysis include the use of GPS devices to track bus movements along critical routes, and a Python code that analyzes different factors about the performance of buses in a route. The GPS devices are capable of recording information about location, speed, heading, stops, and timing. All calculations and results of the Python code can be found along the report and appendices.

Results of the data analyzed, specifically in the routes "La Doña – Via España – Albrook" (City Bound), "Ciudad del Saber", and "Iglesia del Carmen", show that heavy traffic slows buses on trunk routes so that they are mostly idle and that with the actual 20 second GPS measurement frequency of MIBUS, almost 70% of events are not visible in every route studied. Also, in the case of the trunk route analysis, traffic data suggest that the bus is static around 50% of the total time of bus transit and that the bus is stopped in heavy traffic jams throughout the city 27% of the trip time.

Our analysis finds the performance of the bus operation is not positive. Since it is very difficult for buses to keep up with a schedule due to heavy traffic, at least providing users with visibility would allow them to schedule and relieve their frustration. Findings suggest the following actions as recommendations:

- Offer visibility to users by enabling a mobile app to watch where is the bus.
- Join the Google Transit Partner Program.
- Improve the Albrook National transport terminal and "paid zones" to avoid disorder and user confusion.
- Implement a user claim system and add the bus driver's names to the LED displays inside buses.

The analysis conducted has limitations. Some of the limitations include:

1. Although we could diagnose problems of the bus transportation system and a very important route, we do not have enough data to represent the reality of the whole system.

2. Time is an important limitation because each round-trip of the most important routes takes an average of 3 hours. Taking in consideration the fact that our analysis is only of peak hours, a round-trip takes the whole timespan of a peak hour. Therefore, we can only record data of 1 or 2 round-trips per day.
3. To record data, the team needed to take the bus in areas that are considered "red zone" or dangerous. The security limited the hours that we could take the bus. We could not take the bus at nighttime, since it could put in jeopardy our security.
4. The analysis just compares our data with MiBus in some factors but not all.

Even though the report shows a good picture of the traffic flows and the performance of the bus transportation system, a better analysis and implementation of the recommendations in all the routes of the system, could take years. Thus, the report suggests further research in the following areas:

- Implement a bus dedicated lane by inverting a lane on peak hours on the zones identified in the report with heaviest traffic.
- Eliminate or lower frequency of routes that go over the subway (Linea 1) lane.
- Replace long trunk routes with shorter routes using consolidation points e.g. (El Parador, Fernandez de Cordoba)
- Re-evaluate the number of bus stops, their names, their locations and the concept of every bus stopping at every bus stop on its way.
- Unifying all public transport companies and unions (CANATRA, SICOTRAC, METROBUS) into one or interconnect their systems.
- Dedication and semi-dedication of buses to certain routes at certain times.

Acknowledgements

This thesis would not have been completed without the guidance and help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

First and foremost, we offer our sincerest gratitude to Dr. John Bartholdi and Dr. Humberto Álvarez, for their continuous support, patience and scientific guidance for the development of this research. In addition, we would like to thank the Georgia Tech Logistics Innovation and Research Center of Panama for providing us their facilities and their staff for their assistance and hospitality.

Furthermore, we would like to express our deepest recognition to Mi Bus Company for their willingness and collaboration.

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1. Problem Statement

Panama's public bus service performance and availability of information does not meet customers' expectations which does not allow users to plan appropriately causing frustration and lack of trust in the system.

2. Objectives

a. Measure the performance of a sample of Metro bus routes.
b. Identify congestion problems in traffic affecting a sample of Metro bus routes.

3. Deliverables

a. Tool to analyze buses' performance and determine traffic patterns on Metro bus routes using buses' GPS data.
b. Manual on how to use this tool.
c. Study of two types of routes.

4. Background

To explain better Panama's public transportation problem, it is necessary to understand its beginnings. On 1973, Panama's military government initiated a public transport system where the state gave an individual operation permit to every bus owner (ACAN-EFE). This lead to the appearance of the well known Red devils – or is Spanish - "Diablos Rojos (Figure 1)", converted secondhand Bluebird school buses from the United States, covered with artistic designs and anything that could make it the flashiest between other buses. Their name was not just because of their looks, but also for their bad reputation. The main characteristics of these buses where the lack of maintenance and reckless driving, that often lead to traffic accidents and fatalities.

Red devils, beside all the disorganization and hazards, served as the main resource of transportation in Panama City for almost 40 years. On March of 2013, the hope for a better public bus transportation system increased when all the buses where finally replaced, a move that started on 2010, by a new bus fleet (Figure 1) and a private entity was awarded with the concession to control and operate the system. Every Red devil owner received 25,000 dollars as compensation to hand their buses to the government. The only problem was that this new system, called Metrobus, by contract, was to carry out the same route and bus stops from the previous system without the possibility to change none of it. At the end,

it is safe to say that mostly the only change was in the buses model, and not in the system carried earlier by individual bus drivers and independent bus drivers' unions established on the 70's, while the city kept growing at an unexpected rate, mostly in the construction and real state sectors.

FIGURE 1: A METROBUS(LEFT) AND A "RED DEVIL" (RIGHT) DURING THE TRANSITION PERIOD FROM 2010 TO 2013.

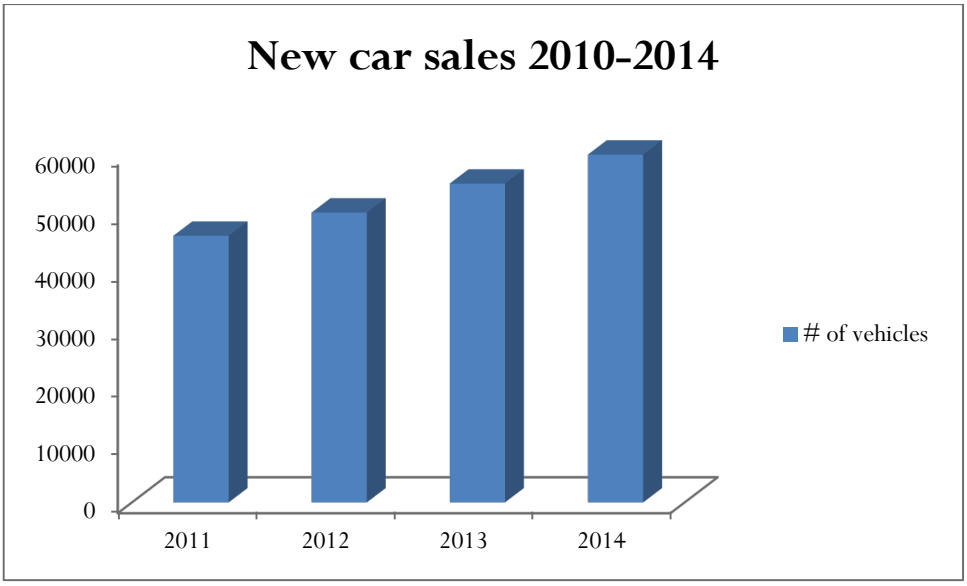
The main improvement was the reduction of traffic accidents and deaths by traffic accidents. But other problems arose. For example, many of the bus drivers, known by their recklessness, that once drove the Red devils, were hired by the new company and were now part of the new system. Also, the lack of information about routes and bus stops has proven to be a problem.

5. Current Situation

The new system has found many difficulties to provide a good and reliable service. Heavy traffic has been one of the main reasons (Figure 2). Every year the car sales increase while the road infrastructure does not. According to a report from the Superintendence of Banks

[1] *Source:* (www.elnuevoherald.com/noticias/article1915255.html)

of Panama, the total sold cars for the first five months of 2014 showed a 67% increase (Graph 1) compared to the same period on 2010 (Superintendencia de Bancos de Panamá).



GRAPH 1: NEW CAR SALES 2010 - 2014

[2]

FIGURE 2: HEAVY TRAFFIC IN PANAMA CITY

[2] *Source:* (profesionalespanama.net/nacionales/medidas-anti-tranque-no-surten-efectos-conductores-se-quejan/)

The need for transport has pushed population to rely on other options. Today, Metrobus is not the only responsible for transporting people on Panama City. Buses, similar to the Red devils, that operate from the suburbs to and through the city, called The “Green devils” (Figure 3) and “pirates” (Figure 4), 4-door vans that illegally charge money to transport people, share the demand.

FIGURE 3: A “GREEN DEVIL”, A BUS NOT INCLUDED IN THE REPLACEMENT DUE TO REGIONAL REASONS.

FIGURE 4: A "PIRATE" WAITING TO DEPART.

Currently, complains and discontented users are considered part of daily life. None of these actors, including the government, have successfully addressed the situation and many argue the causes of this problem. While the public transportation system problem may or may

not be a combination of many different factors, heavy traffic patterns is surely a subject that could be rewarding to analyze and help to better understand the situation.

6. Constraints

a) Time constraints:

The project consists in the analysis and results observed within the 4th of May and 24th of July of 2015.

b) Scope constraints:

The observation and analysis that took place have the exclusive purpose to provide a quantitative diagnosis of the current situation of the transportation system.

c) Geographic constraints:

The area of study is limited to the southeast part of Panama City, Republic of Panama; Focusing around the "Via España" trunk route.

d) Security constraints:

Due to the natural insecurity at the biggest boarding zones, the samples taken were at peak hours in the morning only.

e) Information constraints:

The data being used on the analyses were taken directly by our team due to the lack of information fields available on the documents (speed) that were being provided to us and the time lapse between GPS readings.

7. Justification

According to General Comptroller of Republic of Panama, the number of vehicles has increased 36.21% from 2005 to 2011 and the trend will continue to increase, which traduces in more traffic. Nevertheless, expanding the length of the road network at the same rate is not reliable as space is becoming more exclusive and limited. Therefore, the first step to completely understand the system and its flaws is to make a tool that analyzes bus movements in each part of the road, from origin to destination.

Since congestion is an important problem for road transport and a main challenge for transport policy at all levels, this will be the focus of this research.

The methodology presented here aims to measure and monitor road congestion across the entire route and determine bus performance, in order to take better decisions that will make the transport network more efficient allowing a better utilization of resources, reduction in bunching and compounding delays, among other benefits.

7.1 Visual Evidence

Figure 5, presented in the next page gives a picture of the existing situation in Panama City:

a) Empty Bus (poor utilization of resources).
b) Users enter in the backside of the bus without paying
c) Long lines
d) Delayed bus

All of these events added reduce the quality of "Metro bus" Service and consequently the desire of using public transportation.

FIGURE 5: VISUAL EVIDENCE OF CURRENT PROBLEMS

8. Methodology

a) Criteria to determine the critical routes to be studied:

- Demand
- # of stops per route (we choose the routes that contain the majority of stops)
- Typical traffic per day and peak hours.

b) Map routes and bus stops using GPS devices that record position every second and riding the buses in peak hours. It is important to mention that Metrobus' GPS record data every 20 seconds.

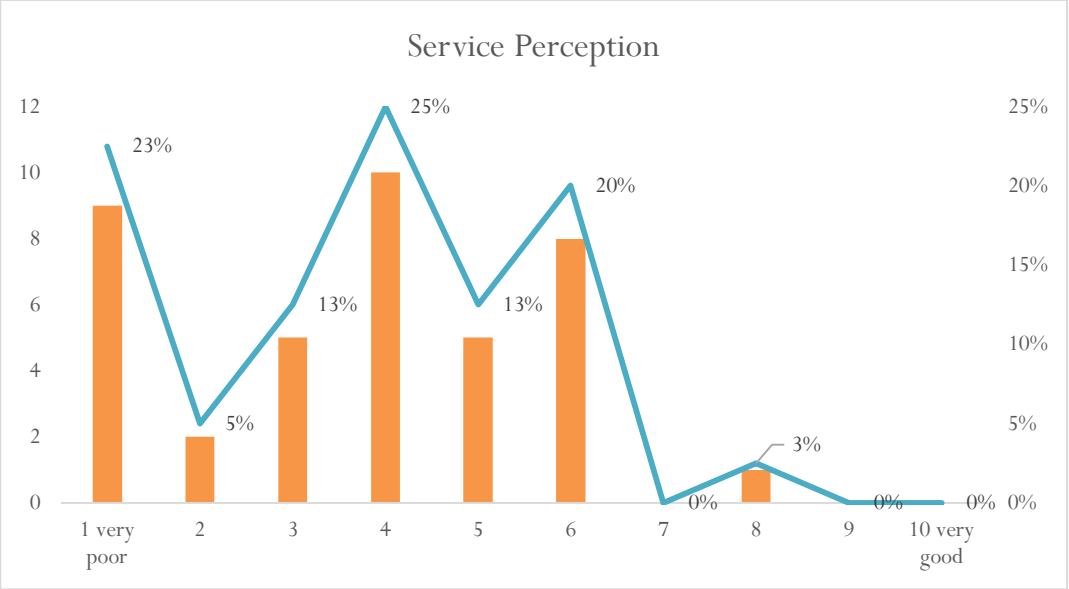
c) Analyze and determine performance of selected routes.

8.1 Survey Results

In order to achieve a better understanding of 'what is' the problem, and what everyday users believe that are the problems that exist in MetroBus operation, we created a survey. The surveyed asked 40 people about different factors that affect the bus operation. The people who took the survey are from the first bus stop of the route "La Doña – Via España – Albrook". This route has the characteristic of being one of the longest routes, as well as, one of the most troublesome. The survey included 6 questions:

1. How do you evaluate the Metrobus Service? (1 is really poor, 10 is very good)
2. Are you confident that this is the right bus stop to take your bus?
3. Usually, how long do you wait for a bus in this stop?
4. Possible problem of the MetroBus?
5. How valuable would it be to you to have access to a mobile application where you can see where the bus is? (1 is not valuable at all, 10 it is highly valuable)
6. How valuable would it be to you to have access to a Schedule, stops and routes of the buses? (1 is not valuable at all, 10 it is highly valuable)

1. The first question gave the following results:



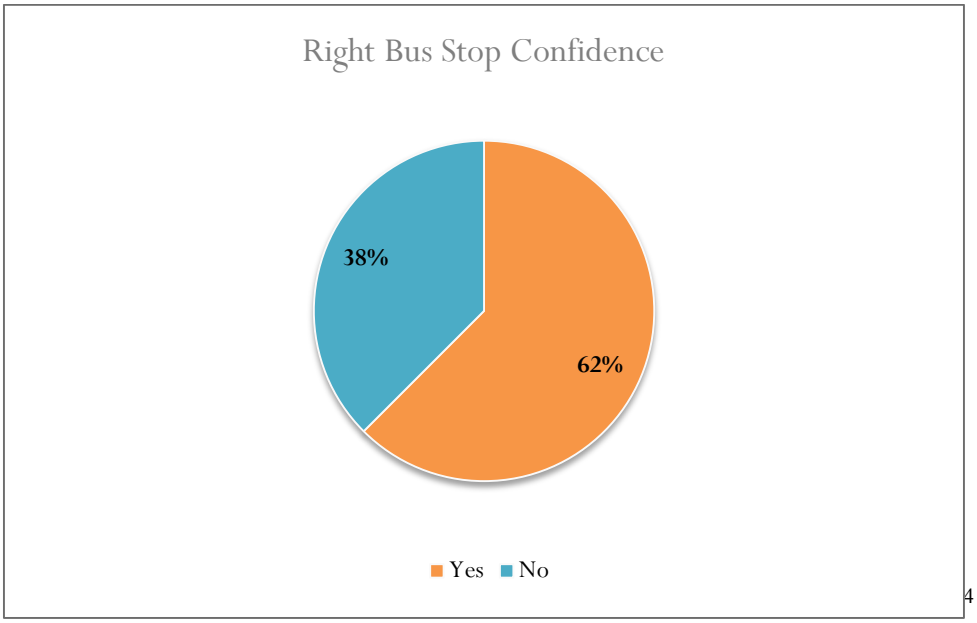
[3]

GRAPH 2:SURVEY RESULT OF THE SERVICE QUALITY PERCEPTION

According to the surveyed people, the service rating is in average of 3.7 out of 10. Taking in consideration that around 25-35% (according to MiBus data) of Panama City's population use the bus, the perception of the quality is extremely negative. There is a strong relationship among the negative service perception and the time people spend from the point they go out of there house to the point where they arrive their destination. The more people wait for a bus; the less satisfaction they will have.

[3] Source: Elaborated by the author.

2. Results of the second question state the following:



[4]

GRAPH 3: SURVEY RESULT OF THE USER'S CONFIDENCE ON THE PICKUP LOCATIONS

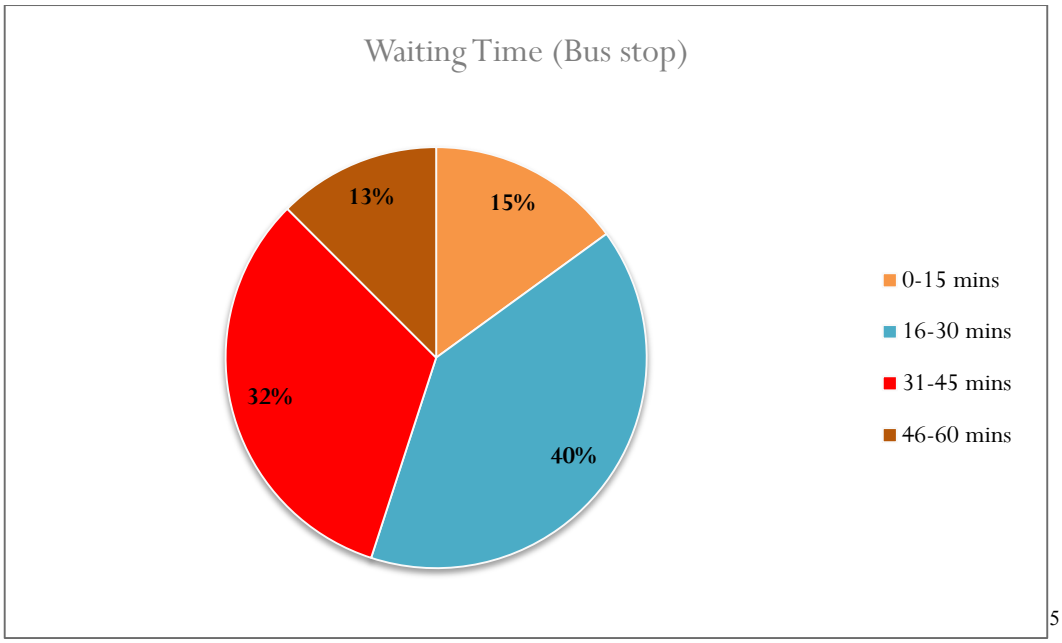
The intention of this question revolves on the fact that there is little to none information about bus stops and bus routes available for the people. People use a bus stop or use a route because this place is what "they are used to". As you can be seen from the Graph 3 above, 62% of the people feel confident that they are in the right bus stop, or the most suitable for them.

Particularly, one of the surveyed bus stop has the characteristic of having another bus stop 200 meters away. Yet, people walk against traffic from one bus stop to another. The study can infer that the lack of information is making people move to the bus stop that they think

[4] Source: Elaborated by the author.

is best for them, but there are actually other options that could be better fitted for their needs.

3. When asked regarding waiting times for the next bus, users respond the following:



[5]

GRAPH 4: SURVEY RESULT OF THE PERCEIVED WAITING TIME

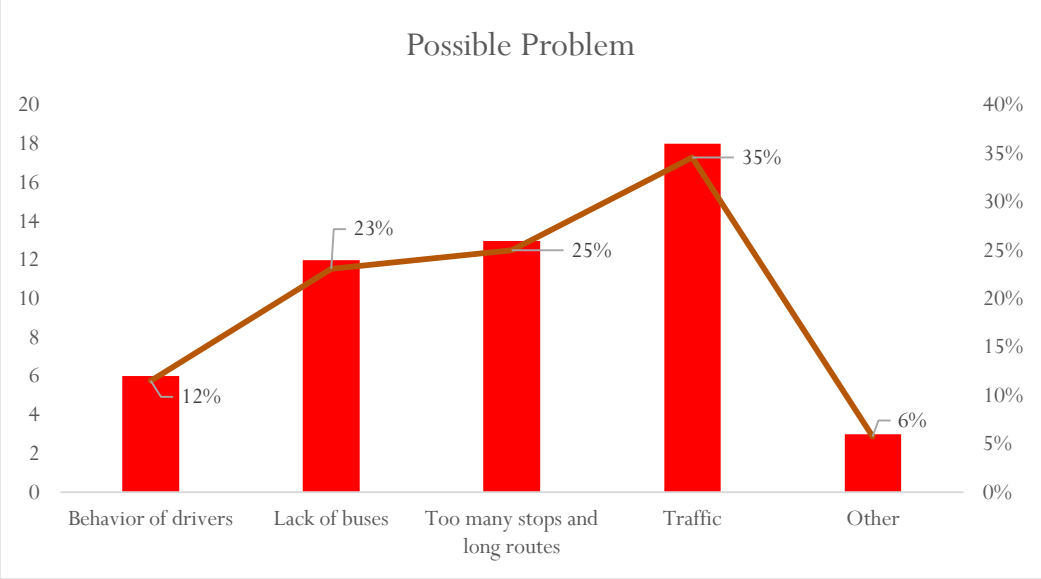
40% of the users allege to be waiting more than 15 minutes for a bus to go to their destination. When put in context, 85% of the people had been waiting more than 15 minutes for a bus. As previously pointed out by this report, the waiting times are strongly related to the service perception. 45% of the users alleged to be waiting more than 30 minutes.

Research in UC Berkeley shows that when people has to wait around for a bus or train, users will start giving up on public transportation because it becomes unreliable (Holleywell). Results also pointed out that people values more consistency in the frequency

[5] Source: Elaborated by the author.

of buses getting to a bus stop, rather than long trips. Reliability in the bus transportation system of Panama is extremely negative. According to research people start to become impatient after waiting 15 minutes for the bus.

4. When asked about the opinion about what are the problems of Metrobus people responded:



[6]

GRAPH 5: SURVEY RESULT OF THE USER'S PERCEPTION OF THE PROBLEM

The results say that 35% of the users agree that "traffic" is the most important problem. When ranking the three most important problem we find:

1. Traffic
2. Too many stops and long routes – 25%
3. Lack of Buses – 23%

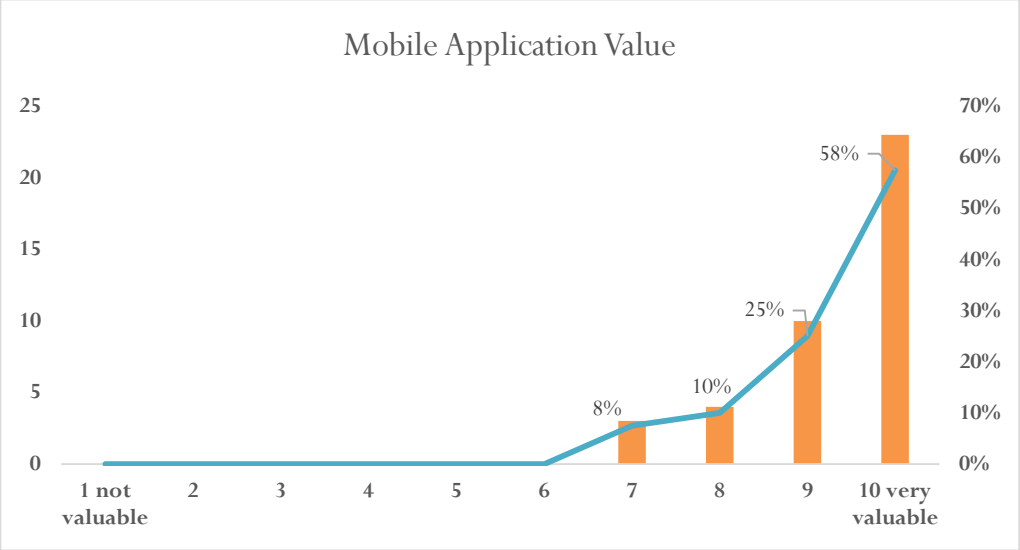
According to the study on UC Berkeley already mentioned, the unreliability is making people use cars more often. On the long run, the switch from public transportation to private

[6] Source: Elaborated by the author.

(owning a car), is contributing to the #1 reason users think is the problem of the public transportation; traffic.

The number 2 reason is related to what people value the most, frequency at bus stops. People think that great unreliability of the frequencies are due to the fact that operations need more buses to achieve a desired frequency. It is true that the old system of "Red Devils" had almost 3 times as many buses as the Metro Bus system. It is also true that the capacity of the Metro Bus "exceeds" that of Red Devils.

5. When asked about how valuable a mobile application that tells where a bus is and when it is coming, people answered the following:



[7]

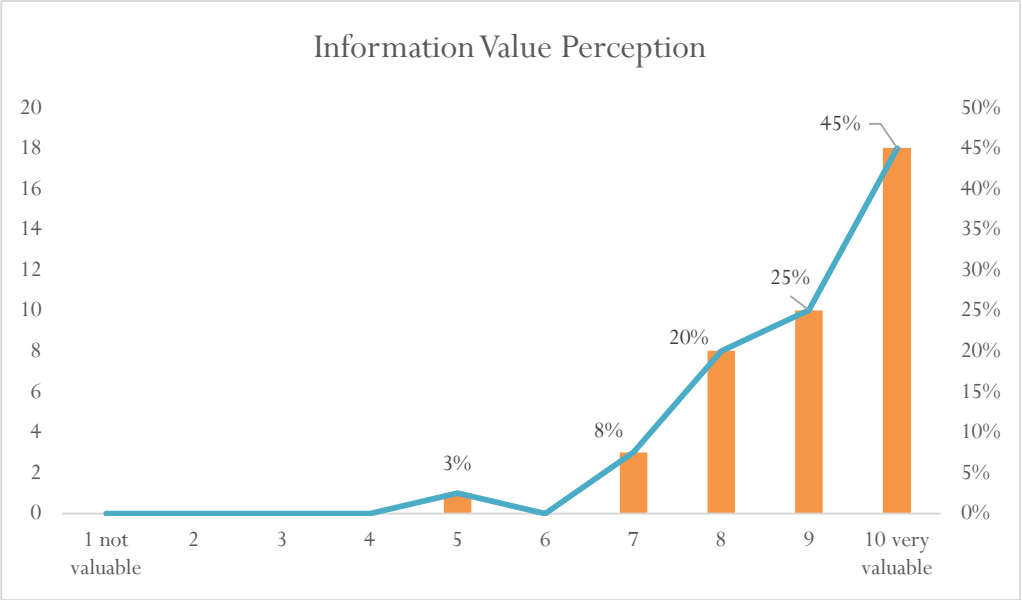
GRAPH 6: USER'S PERCEIVED VALUE OF A VISIBILITY APP.

[7] Source: Elaborated by the author.

After ranking from 1 to 10, where 10 the most valuable, 58% of surveyed users answered that more information would be very valuable for them. When put into context, users think that a mobile application can be helpful for their everyday bus ride.

People know that information is important for mass transit. Having a mobile application can help the public transportation system to benefit from customer service. If a person has transit information whenever, wherever, and however they want, empowers user of public transportation with accuracy of arrival predictions, provides transit authorities or operators with a more reliable way to manage fleets and communicate with passengers in real time, and reduces the great uncertainty that comes when waiting for public transportation.

6. The last questions of the survey consisted of asking about the perception of the amount of information that is available for the users, and how aware they are of the need of information. When asked to rank (from 1 to 10) how helpful it would be to have all kind of information; including route maps at bus stops, schedules, and stops, people answered the following:



[8]

GRAPH 7: USER'S VALUE PERCEPTION OF A VISIBLE SCHEDULE

45% of the surveyed users claim that it would be very valuable to have information as previously explained in the report. When seeing the results, we can assume that around 95% of the users say that information is very useful when taking a bus in Panama. Some people who answered the survey were aware that they need information, but they claim that they could not trust the information they would get because they are sure that it will contain some kind of errors.

It is true that having information available for users should be a priority in the operations of the bus transportation system. It is also true that having information available could not be helpful if you cannot trust or rely on it.

8.2 Choice of Routes

Since our research focused on determining traffic patterns from two opposite types of routes, we chose:

- La Doña-Vía España-Albrook (trunk route)

[8] Source: Elaborated by the author.

- Ciudad del Saber- Albrook (circular route)
- Estacion del Carmen-CSS (circular route)

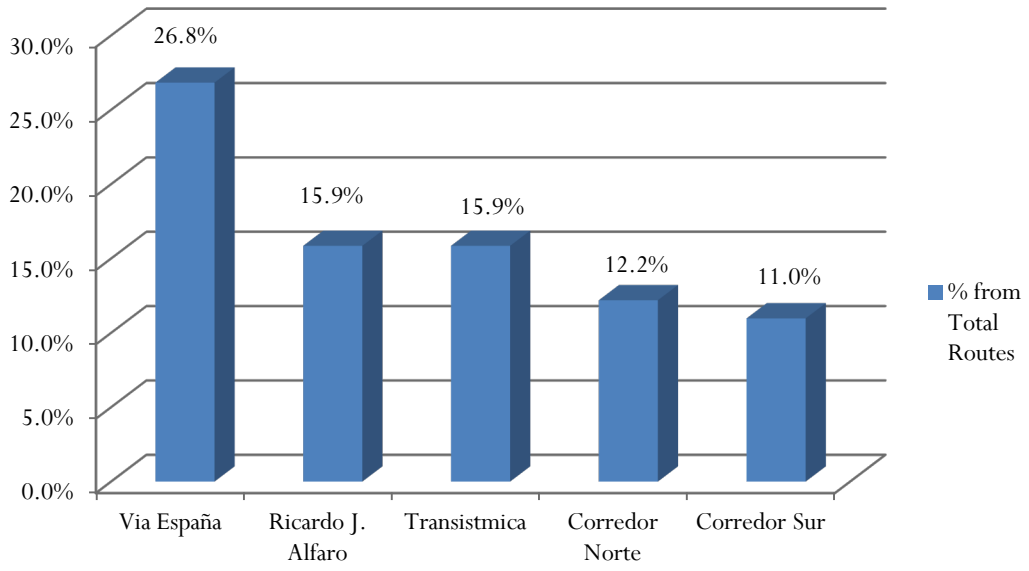
The following *assumptions* were considered before evaluating which routes to choose:

- Redundant routes are not taken into account
- Routes from the north are not included due to changes in infrastructure
- Transfer routes are not considered because they are shorter versions of the regular ones.

The *criteria* to determine these routes was based on the following elements:

a) Main roads:

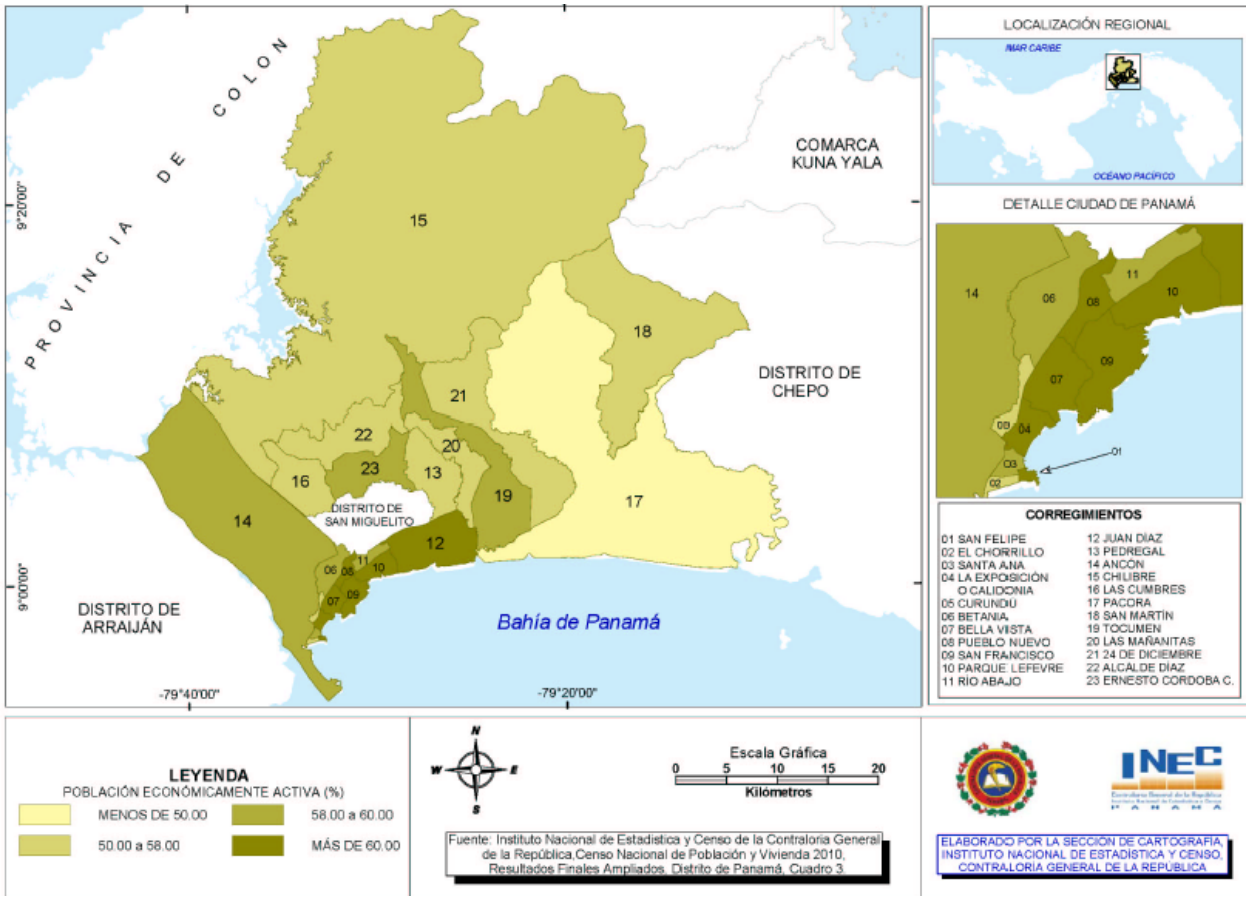
As shown in graph 8, Via España classifies as the road that moves the biggest amount of population:26.8%



GRAPH 8: NUMBER OF VEHICLES PER ROUTE.

b) Population of passenger demand:

The percentage of economically active population in the district of Panama segmented by township from census 2010 as shown in figure 6 indicates that "Juan Díaz" has more than 60% and has the biggest size regarding territory from that category.



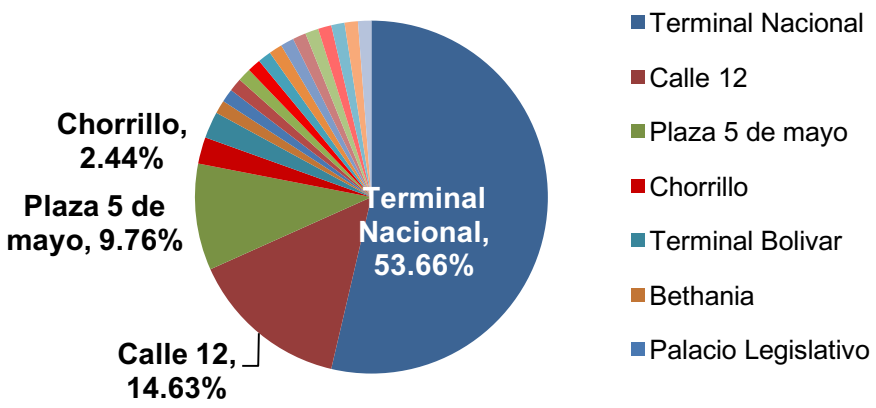
[9]

FIGURE 6: ECONOMICALLY ACTIVE DEMOGRAPHICS.

c) Main destinations:

Terminal Nacional de Albrook, which is the destination of the two chosen routes, represents 53.66% among the destinations Metrobus buses travel as shown in Graph 9.

[9] Source: Elaborated by the Cartography Department, National Institute of Statistics and Census 2010,General Comptroller of Panama Republic



[10]

GRAPH 9. MAIN DESTINATION OF METROBUS ROUTES

d) # of stops per route:

As shown in table 1, we ranked the routes per number of stops from smallest to largest.

Route Name	Number of Stops
Estación Marañón - Albrook	7
Estación Iglesia del Carmen - CSS	12
Estación Vía Argentina - Punta Pacífica	14
Ciudad del Saber - Albrook	19
Paitilla - Plaza Edison	20
La Doña - Corredor Sur	27
Villa Rica - Vía Porras	34
Costa del Este - Corredor Sur - Estación Marañón	37

[10] Source: MiBus Company

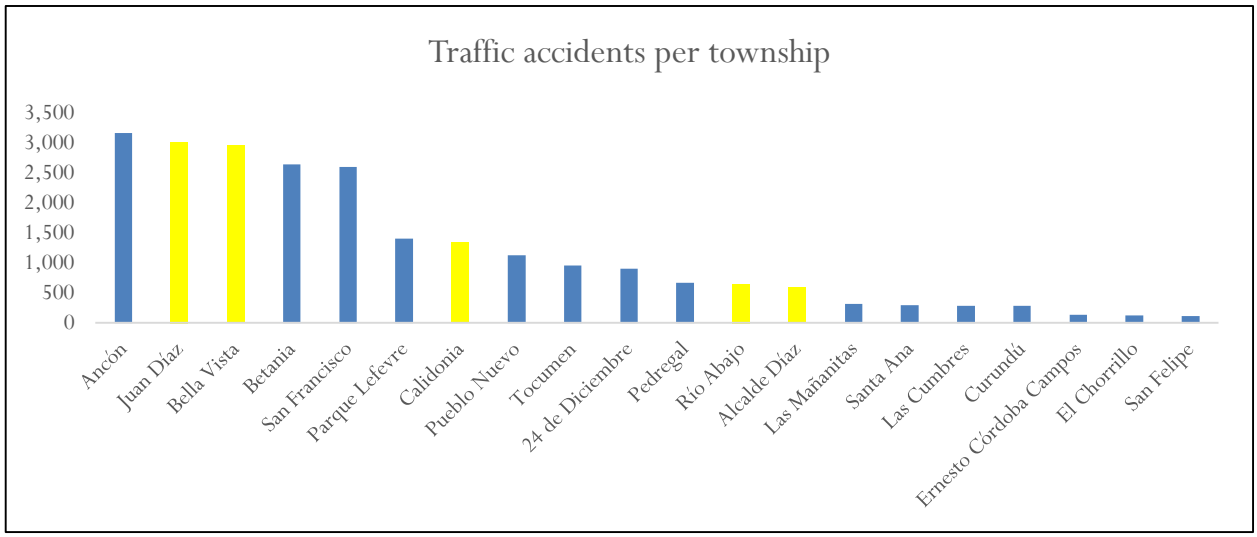
Tocumen - Corredor Sur	39
La Doña - Vía España	82
La Doña - Transístmica	83
La Doña - Tumba Muerto	83
Don Bosco - Transístmica	89
Don Bosco - Vía España	101
Tocumen - Transístmica	103
Tocumen - Tumba Muerto	105
Tocumen - Vía España	113 [11]

TABLE 1: ROUTE NAMES AND NUMBER OF BUS STOPS

e) # of accidents per route:

Traffic accidents increase the level of vehicular congestion in the roads. As detailed in graph 10, Juan Diaz and Bella Vista classify as the townships with the 2nd and 3rd biggest quantity of accidents. Both of these townships are included in La-Doña-Via España-Albrook route. In addition, the 3 remaining townships colored in yellow are included in this route.

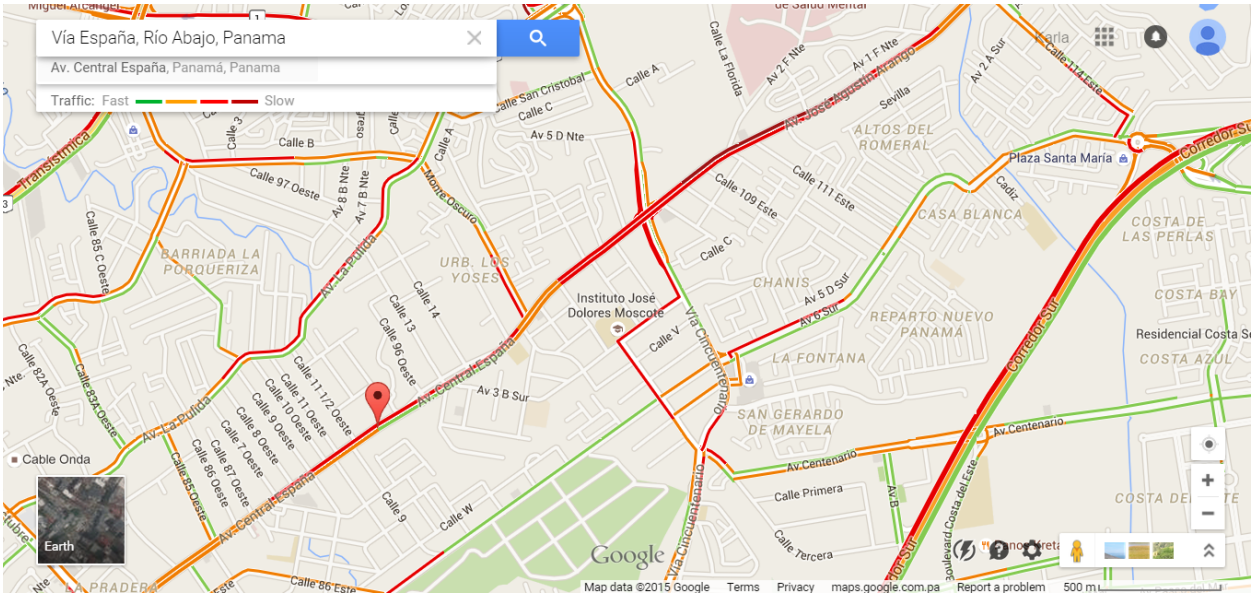
[11] Source: Elaborated by the author



GRAPH 10: TRAFFIC ACCIDENTS PER TOWNSHIP

f) Typical traffic per day in peak hours.

Google Maps platform helped us to identify which were the roads with the slowest typical traffic in Panama during peak hours. Figure 7 shows that Via España is one of the roads with the slowest typical traffic at peak hours.

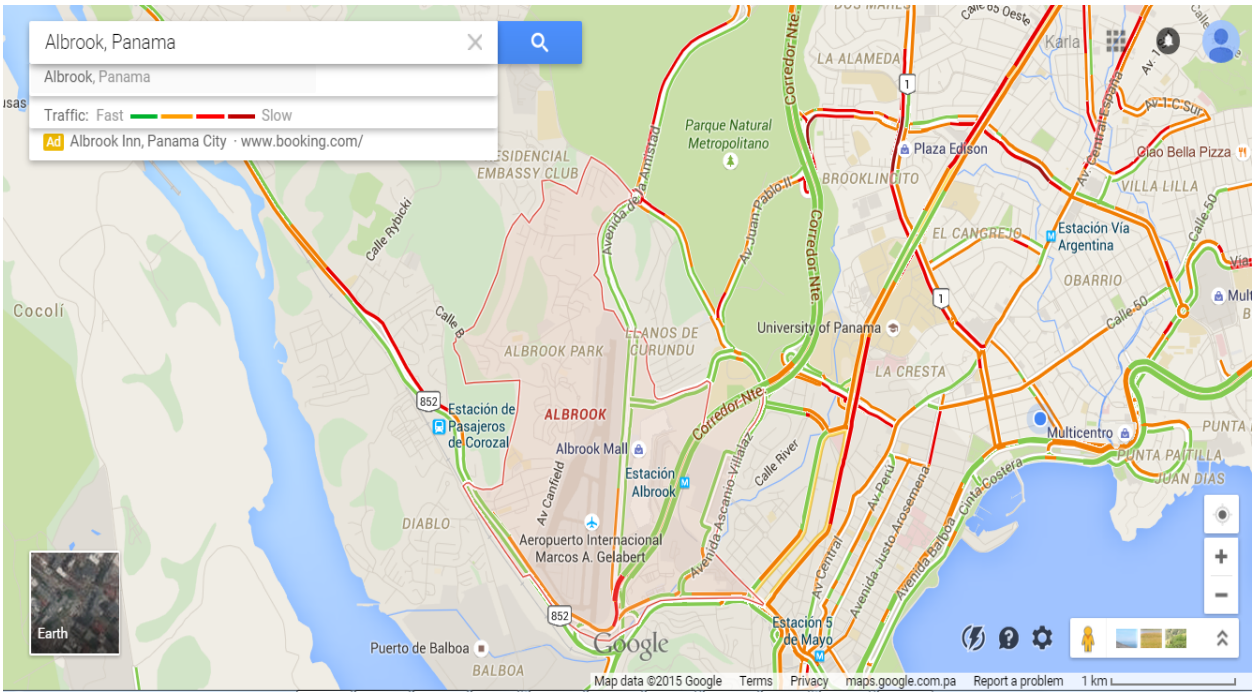


12

FIGURE 7: VIA ESPAÑA AVENUE TYPICAL TRAFFIC AT PEAK HOUR

[12] Source: Google Maps

In the contrary, figure 8 shows the area of Ciudad del Saber-Albrook with faster typical traffic than the previous one.



13

FIGURE 8: ALBROOK AVENUE TYPICAL TRAFFIC AT PEAK HOUR

[13] Source: Google Maps

9. Data Analysis

After collecting GPS readings and running the Python file: "Real3" (see Annex) we can infer the following:

The approach used for this analysis allows the quantification of congestion levels by detail in every part of the road. As explained previously in the methodology section, the project focused in two types of routes:

9.1 Trunk Route: La Doña-Via España-Albrook (City Bound)

La Doña – City bound

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FIGURE 9: AVERAGE SPEED OF THE WHOLE TRIP

Figure 9 is the representation of the readings of one transversal of the route "La Doña – City Bound" plugged into the GPS Visualizer tool. The route is translated into five groups

[14] Source: Elaborated by the author in www.gpsvisualizer.com

of colors; red, yellow, green, blue, and magenta. The colors represent ranges of speed in Kilometers per hour (Km/h), where Red is the slowest (0.0 Km/h) and Magenta is the fastest (50 Km/h). At first glance, the visualizer image shows the color red as the predominant color along the route. When the reading shows speed in red, it means that the bus has stopped for some reason. The analysis labels three general reasons for the bus to stop:

1. The bus arrives to an official bus stop
2. The bus stops for a traffic light
3. The bus is in traffic jams

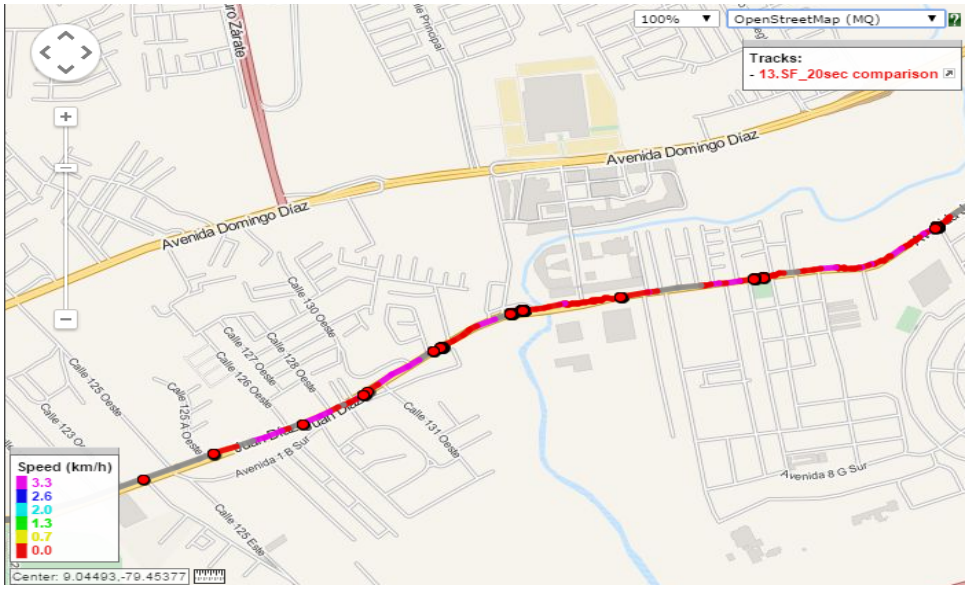

FIGURE 10: CONGESTION VISUALIZATION IN THE SEGMENT OF JUAN DIAZ (RED DOTS ARE BUS STOPS)

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The Figure 10 zooms into Juan Diaz, one of the most problematic segments of the route "La Doña – City Bound". In this case, the visualizer segments speed in the ranges of 0

[15] Elaborated by the author in www.gpsvisualizer.com

Km/h and 3.3 Km/h. The red dots represent official bus stops along this segment. This segment also ignores speed above 3.3 Km/h.

When analyzing Juan Diaz, the bus is completely stopped before, during, and after entering the bus stops. Considering that an average person walks 5 Km/h, in almost every bus stop of this segment a person would be able to walk faster than a moving bus.

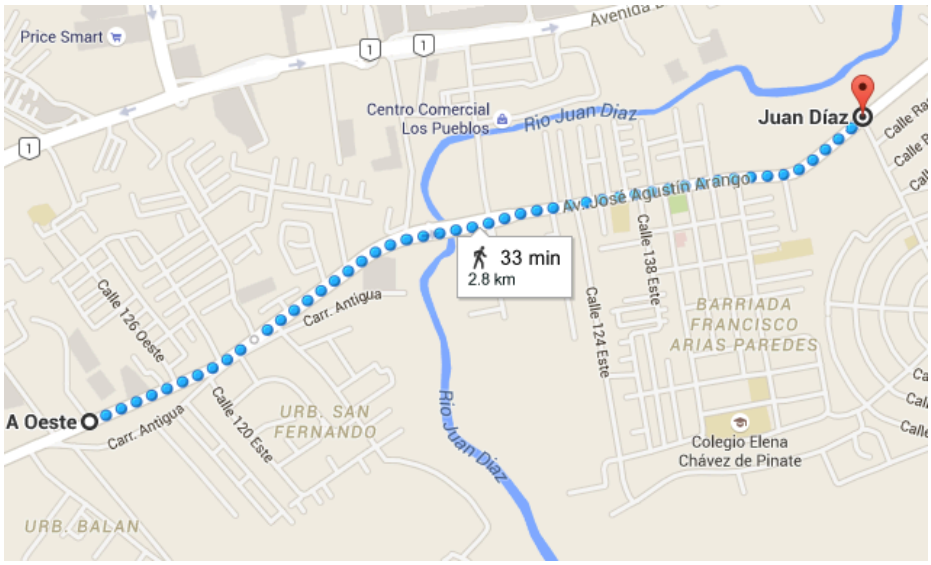

FIGURE 11: JUAN DIAZ SEGMENT LENGTH AND WALKING TIME

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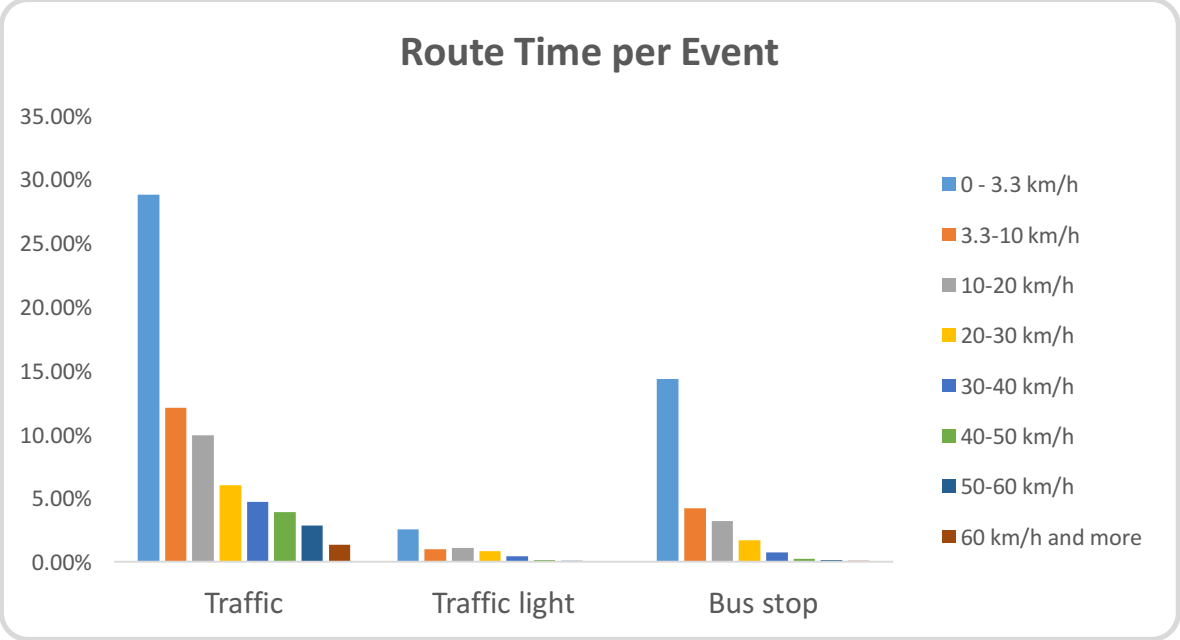
As previously mentioned, a person walks faster than the bus in this segment. Figure 11 shows that the length of this segment if 2.8 Km long. Assuming that the average speed of the bus in this segment is 3.3 Km/h, the optimistic time for the bus to complete this segment is around 1 hour. According to Google Maps, a person would take 33 minutes to complete this segment. It is safe to say that a person can complete a round trip of Juan Diaz in the same time of a bus completing half of the "round trip".

[16] Source: Google Maps

Route time per event representation:

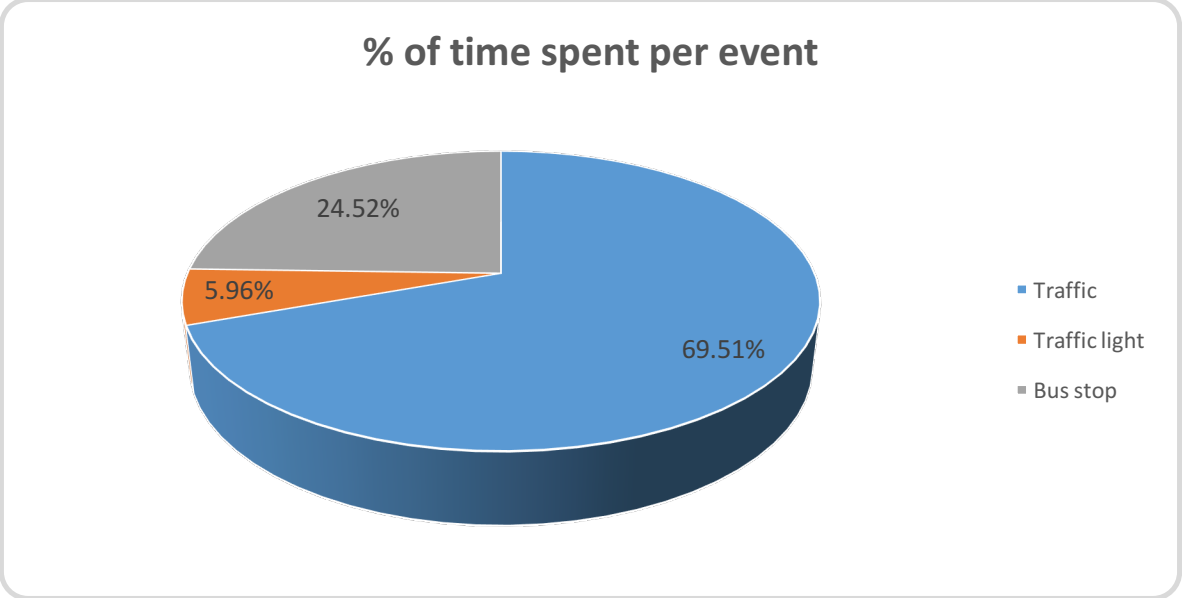


GRAPH 11: PERCENTAGE OF TIME SPENT BY EVENT AND SPEED [17]

As already mentioned, the events where a bus can stop are traffic, traffic light, and bus stop. On graph 11, the y-axis represents the percentage of total time of trips. The predominant speed in all the events was in the range of 0-3.3 Km/h. According to the findings, around 30% of the total trip time was spent on 'traffic' and had a speed in the range of 0-3.3 Km/h, 2.5% of the time was spent on a 'traffic light' with speed in the range of 0-3.3Km/h, and 14% of the time was spent inside a 'bus stop' with a speed in the range of 0-3.3 Km/h.

[17] Source: Elaborated by the author

Percentage of time spent per event:



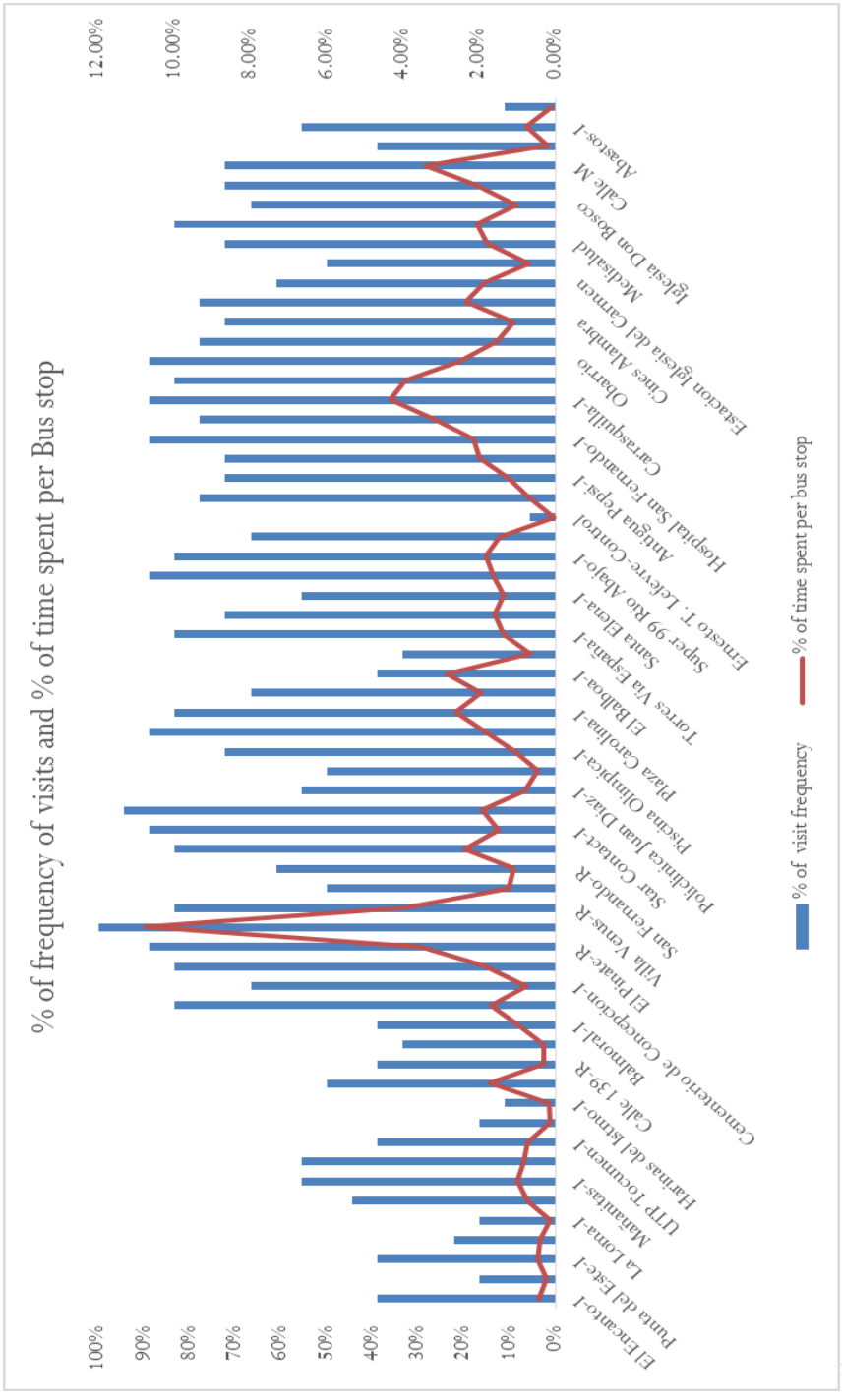
GRAPH 12: PERCENTAGE OF TOTAL TRIP PER EVENTS [18]

When comparing the time spent in each type of event, the most significant event if 'Traffic' with almost 70% of the total time. This results also mean that 70% of the time the bus is outside a bus stop and only around 25% it was spent picking or dropping people at bus stops. This results create the idea of: maybe the route is too long and the bus spends too much time moving from one bus stop to another.

Yet, considering the average completion time of the route "La Doña – City Bound" is of 2 and a half hours, 70% of the time is a lot of time for the bus to be outside the bus stops. This also means that there is a lot of heavy traffic along the route.

[18] Source: Elaborated by the author

Relevance of bus stops:



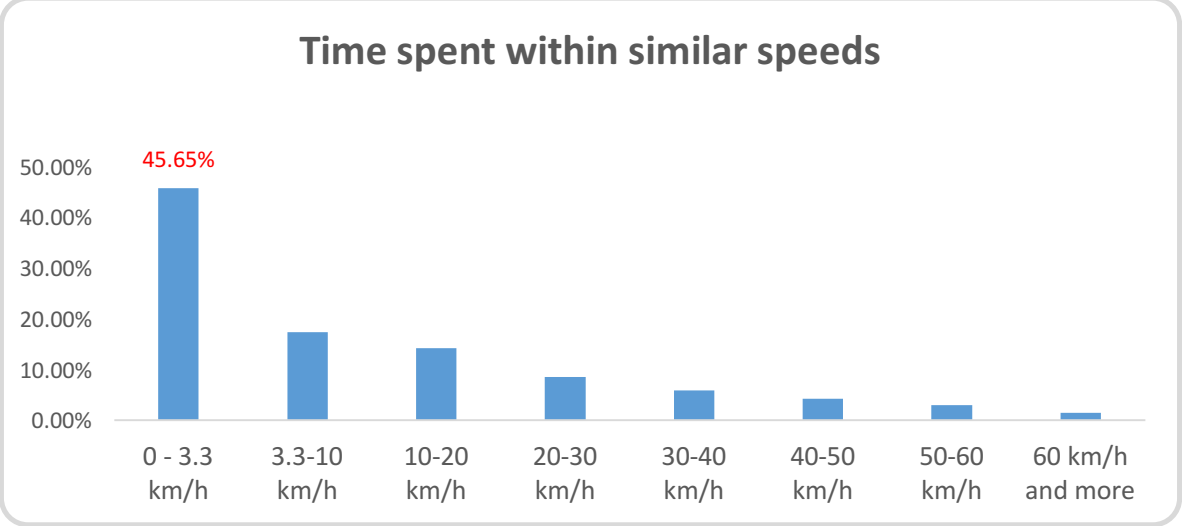
[19]

GRAPH 13: RELEVANCE OF BUS STOPS

[19] Source: Elaborated by the author

Graph 13 shows which bus stops can be considered as irrelevant for this route taking into consideration two criteria: Percentage of visit frequency per bus stop and percentage of total time spent per bus stop. In this case, "Estacion Juan Díaz" is considered as the most relevant since it has been visited always in every trip and have the highest duration of the trip compared to the other bus stops; 12%. Therefore, we can infer that this bus stop is proportional to the demand. On the contrary, "Harinas del Istmo"," Ernesto T. Lefevre" and "Policia Nacional" are insignificant since the bus visits it only 10% of the times.

Percentage of time spent per trip within similar speeds:

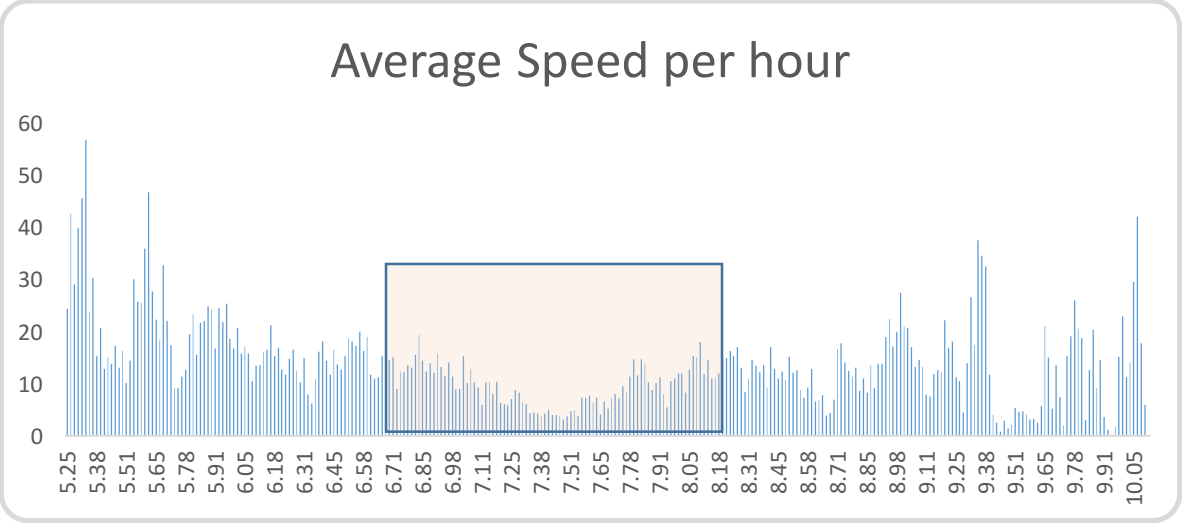


GRAPH 14: TOTAL TRIP TIME DIVIDED BY SPEEDS [20]

The predominant speed is that of the range of 0-3.3 Km/h. Graph 14 confirms the statement of the amount of heavy traffic that the buses undergo throughout the route. Almost 46% of the total time the bus is under the speed range of 0-3.3 Km/h.

[20] Source: Elaborated by the author

Peak hour identification:



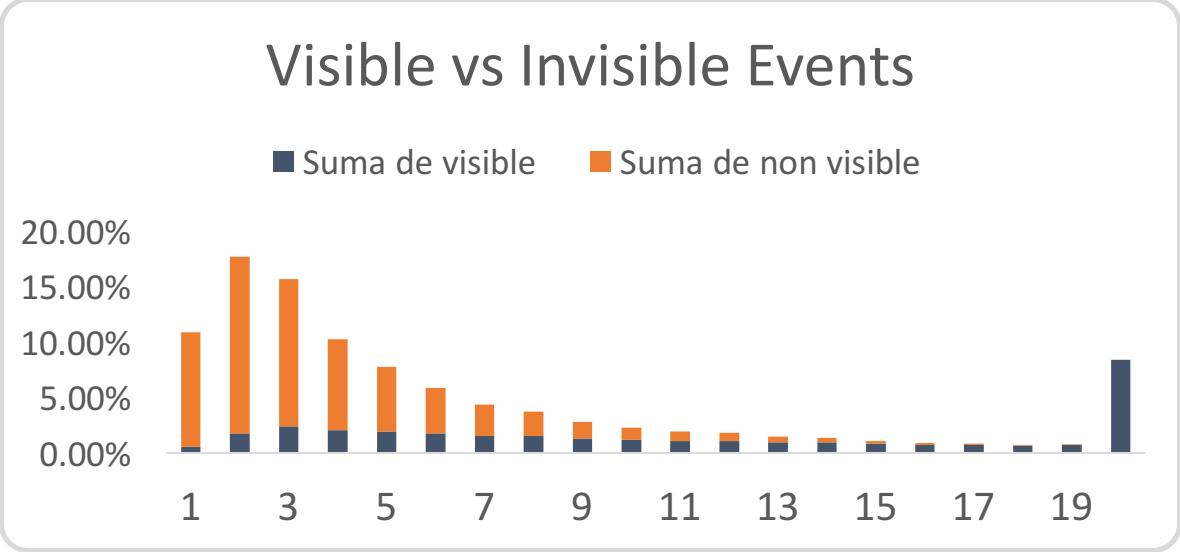
[21]

GRAPH 15: AVERAGE SPEED PER HOUR

From 6:45am to 8:15am there is a clear trend of low speeds. This is exactly the time where the bus encounters heavy traffic. Graph 15 considers considers buses that begin the trip at around 5:15 am.

[21] Source: Elaborated by the author

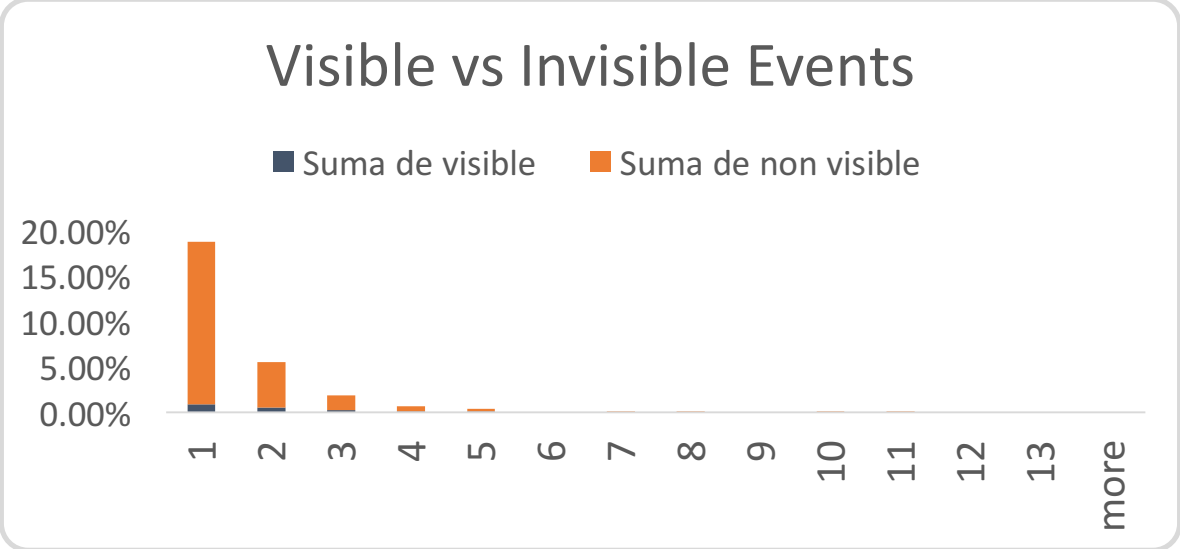
Visible events due to the 1 second's GPS logs:



[22]

GRAPH 16: DISTRIBUTION OF TIME PER EVENTS (1 SEC)

Comparison with readings each 20 seconds:



[23]

GRAPH 17: DISTRIBUTION OF TIME PER EVENTS (EVERY 20 SEC)

[22] Source: Elaborated by the author

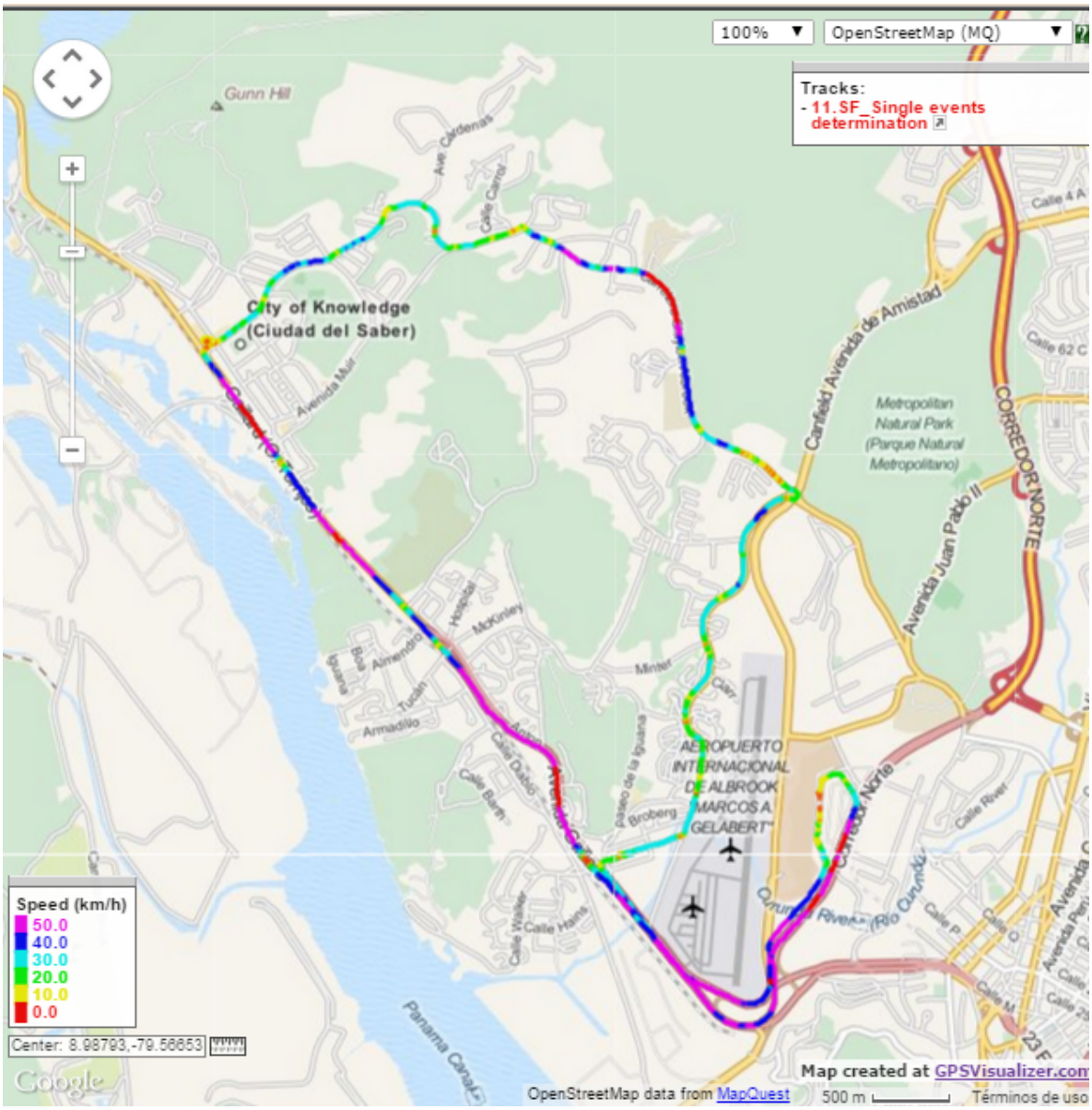
[23] Source: Elaborated by the author

Graph 16 & 17 above, are a comparison of data collection methodologies. For the analysis on this report, the data on every bus trip was collected for every second. In other words, every second GPS devices collected data about speed, location, and time. On the other hand, MetroBus buses have GPS devices on board that collect data about location and time (speed is omitted) every 20 seconds.

The purpose of the comparison is to expose the amount of "events" that each type of data collection is able to record. For instance, the data from the buses will only see certain events in which the duration meets the point in which the bus records data. Also, the buses will not record the whole event duration if the event takes longer or less than the amount of time the buses need to see the event.

From the graphs above, the results show the difference from what the recordings of this report show and what the MetroBus is able to see. The x-axis is the duration time for an event. An event can be 'X' amounts of seconds long. Each bar is the amount of events that our recordings show. The blue segments of each bar represents the amount of events from the data that a bus would be able to see. For example, 18% of all the events were of duration '2 seconds'. Yet, only 16% of those 2 second events would be seen by a bus GPS reading.

9.2 Circular Route: Ciudad del Saber- Albrook



24

FIGURE 12: AVERAGE SPEED OF THE WHOLE TRIP

This circular route, "Ciudad del Saber-Albrook", covers City of Knowledge (is a government-sponsored cluster of academic organizations, technology companies and non-governmental organizations), national airport, university, schools, the US Embassy and the

[24] Source: Elaborated by the author in www.gpsvisualizer.com

national bus Terminal (Albrook) which represents 53.66% among the destinations Metrobus buses travel.

The congestion on this route is almost negligible. As it can be appreciated in the image above the red and yellow which represent 0-3.3km/h and 3.3-10km/h respectively, barely appear. One of the reasons this route does not present heavy congestion is due to the lack of direct connection to any main road as this is basically an isolated system.

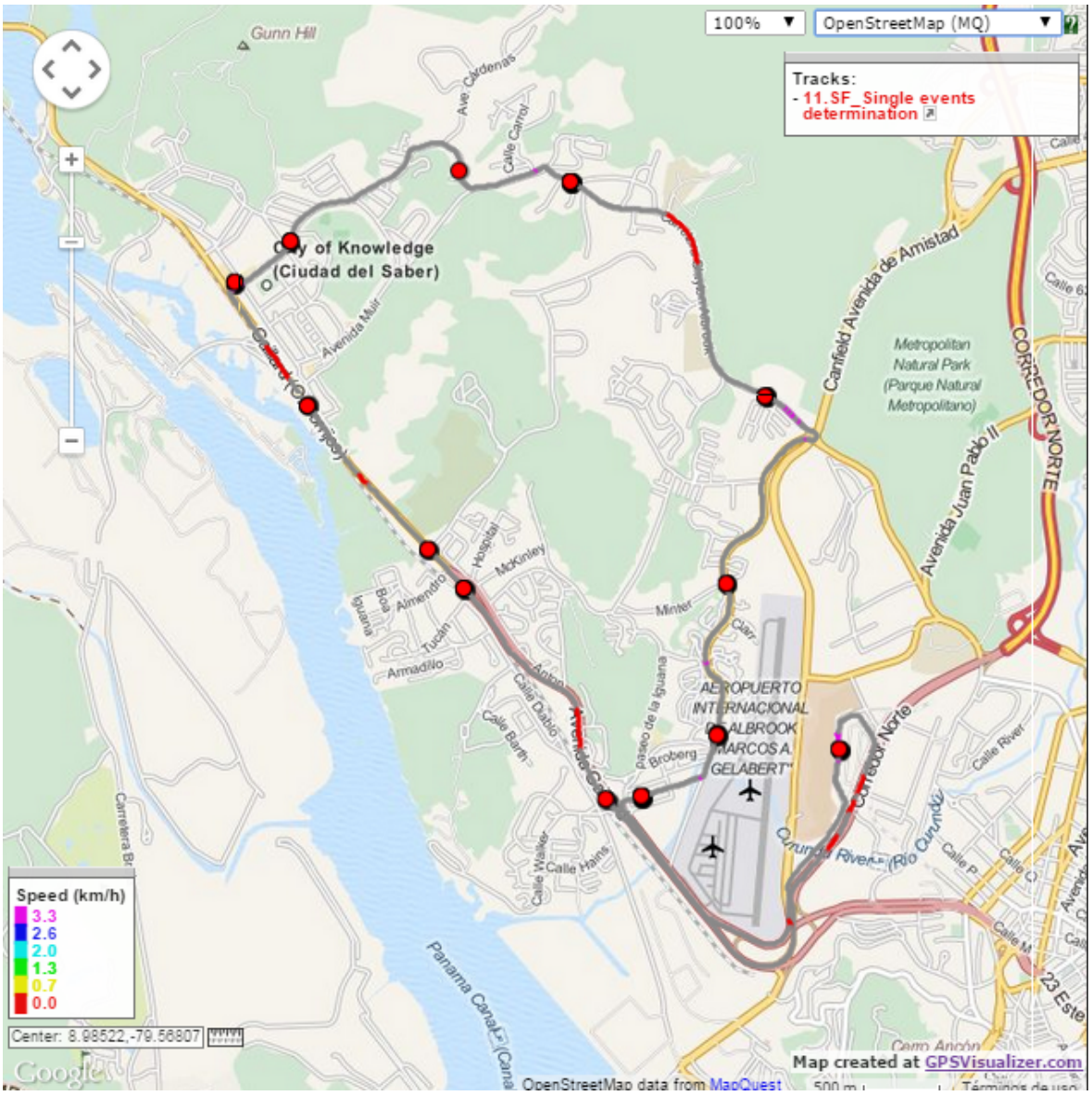
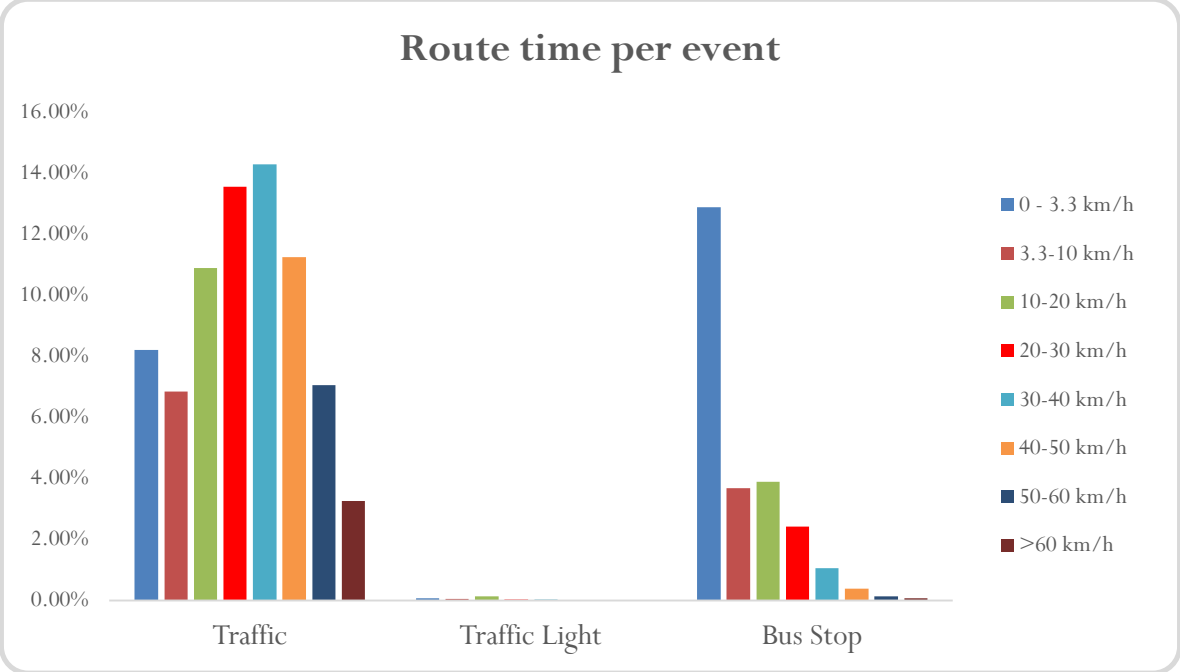


FIGURE 13: CONGESTION VISUALIZATION (RED DOTS ARE BUS STOPS)

As shown in figure 14, the red lines are almost scarce which means that traffic does not seem to be a problem in this route. Nevertheless, they are not exactly near bus stops. The areas that mark red lines are conformed by: North Highway, a roundabout, a school (Colegio Javier). Therefore, we can infer that bus stops are not an issue regarding route congestion.

Route time per event representation:



25

GRAPH 18: PERCENTAGE OF TIME SPENT BY EVENT AND SPEED

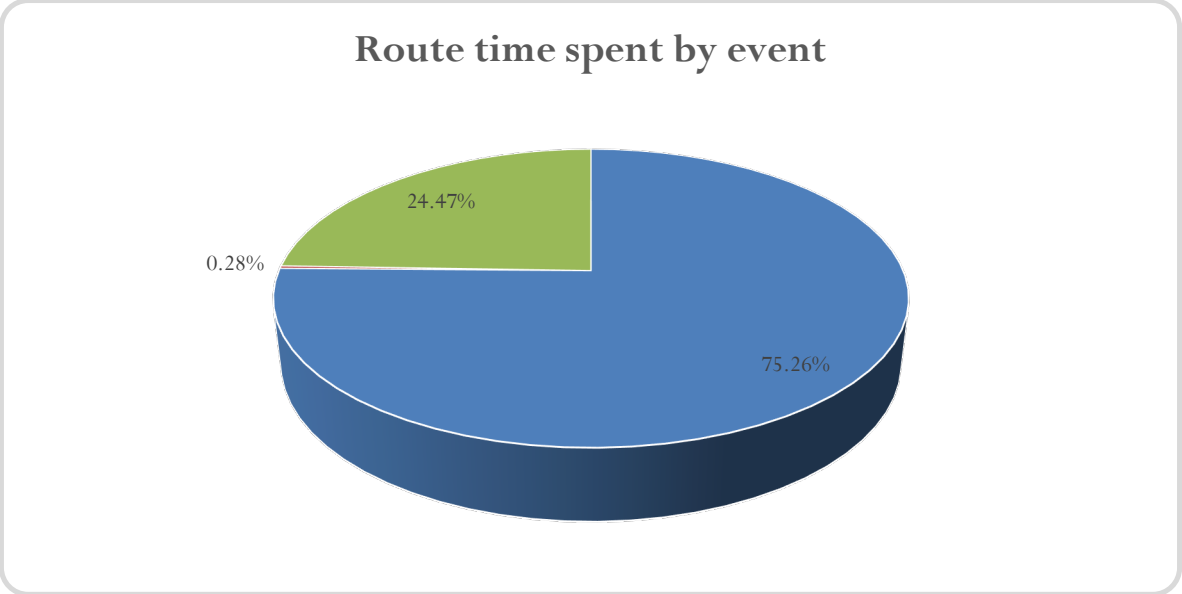
According to graph 18, we can observe that most of the time the bus was static 21% of the total trip time, 13% was due to a bus stop waiting for users to get in and out. In addition, there were also times that the bus skipped completely the bus stop since there is some occurrence of speeds above 10 km/h meaning he didn't stop at certain locations.

In the other hand, the graph above shows that about 8% of the total trip time the bus was completely stopped in traffic, which is a very good indicator. The highest percentage of

[25] Source: Elaborated by the author

speeds in this section are from 20-40 km/h which means that the bus usually has a constant fluent speed in the street.

Percentage of time spent per event:



[26]

GRAPH 19: PERCENTAGE OF TOTAL TRIP TIME PER EVENT

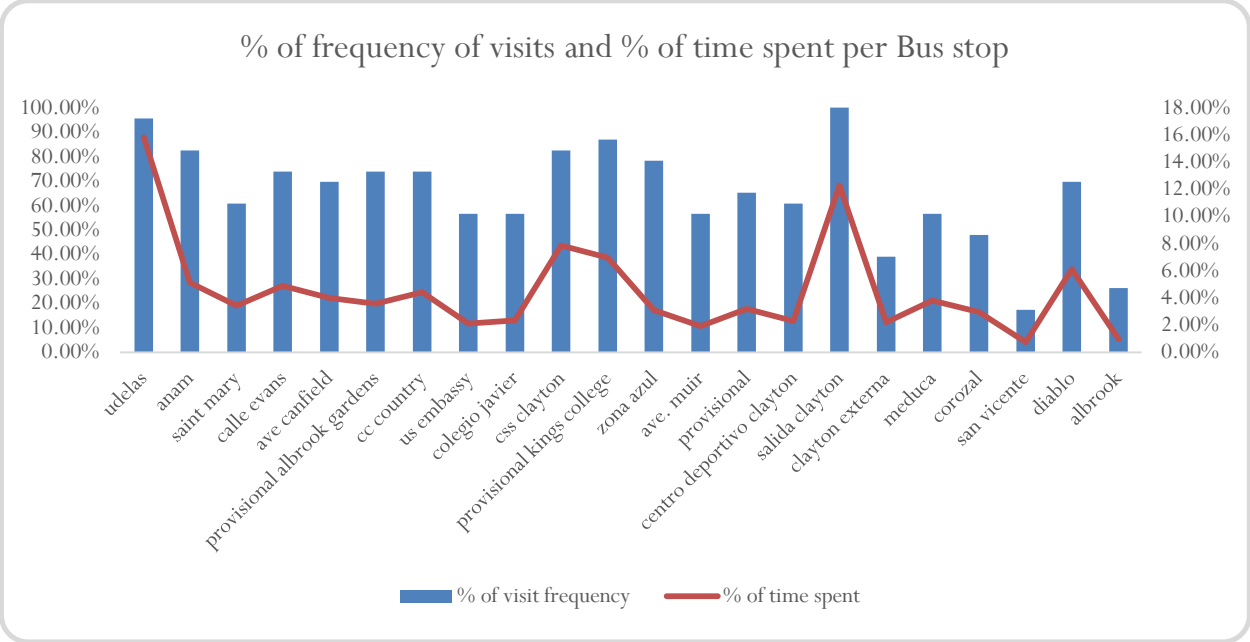
According to graph 19, 2/3 of the average percentage of time per trip is at traffic(blue). Nevertheless, as previously pointed out in graph N°18, the majority is light traffic.

Bus stops make a 24% but as previously mentioned in graph N°18, half of this time percentage belongs to skipped bus stops.

Traffic lights in this graph and the previous one confirm that traffic lights do not affect the system in this case.

[26] Elaborated by the author

Relevance of bus stops:



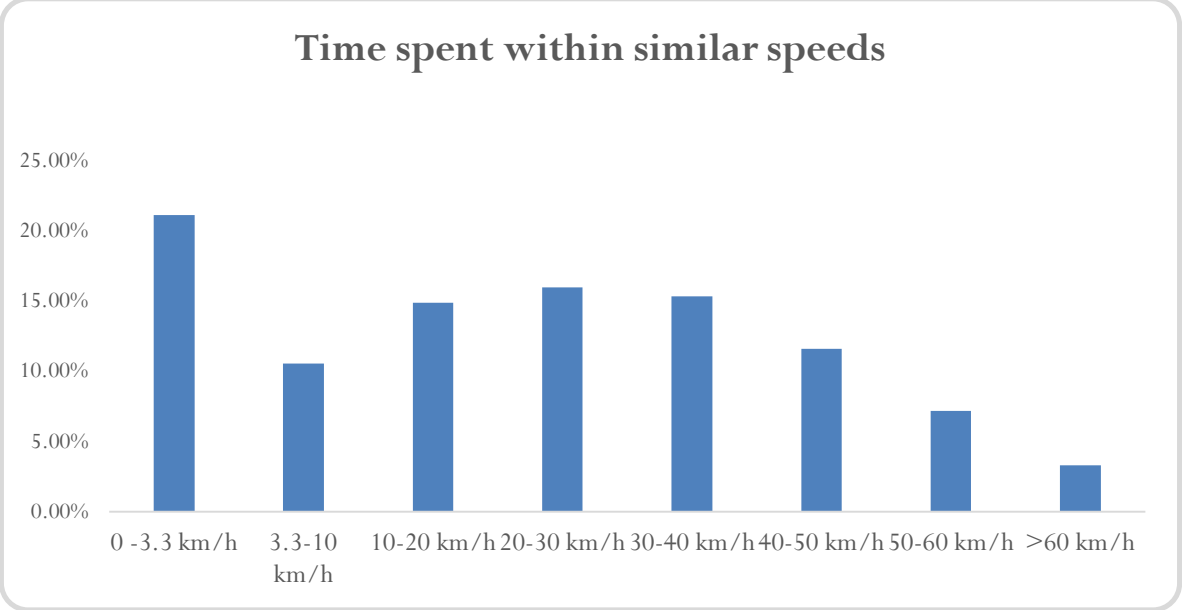
27

GRAPH 20: RELEVANCE OF STOPS

As previously mentioned, bus stops are frequently skipped. Graph 20 shows which bus stops can be considered as irrelevant for this route taking into consideration two criteria: Percentage of visit frequency per bus stop and percentage of total time spent per bus stop. In this case, "Udelas" and "Salida Clayton" are considered as the most relevant since they have been visited always in every trip and have the highest duration of the trip compared to the other bus stops. On the contrary, "San Vicente", is almost invisible since the bus visits it only 3% of the time.

[27] Source: Elaborated by the author

Percentage of time spent per trip within similar speeds:



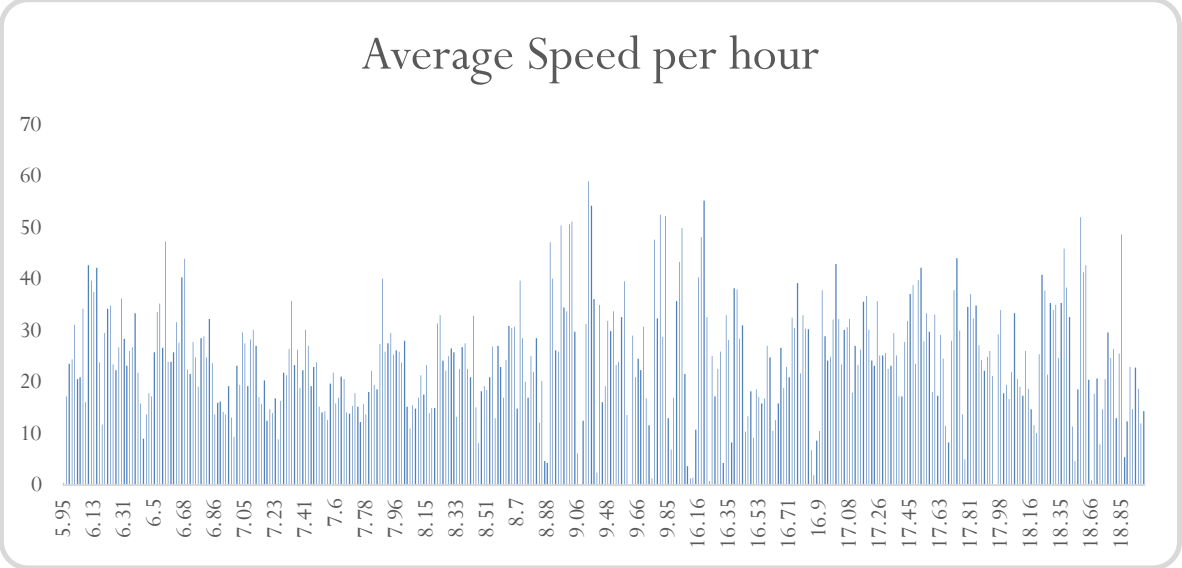
[28]

GRAPH 21: TOTAL TRIP TIME DIVIDED BY SPEEDS

After compiling all the information, we can see in graph 21 that about 21% of the total trip time is spent static, not moving anywhere due to bus stops and traffic. After seeing the previous analyses, we can infer that most of that time, the bus is spent in transit.

[28] Source: Elaborated by the author

Peak hour identification:



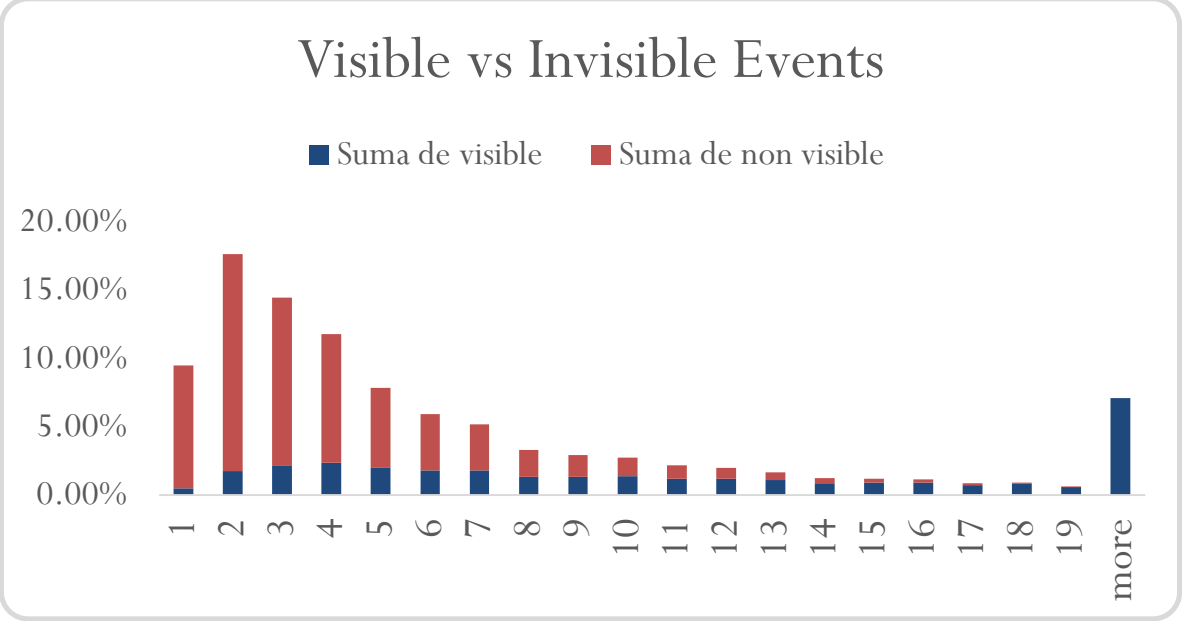
[29]

GRAPH 22: AVERAGE SPEED PER HOUR

The Graph 22 shows that the route presents no clear pattern of a peak hour, the distribution of average speeds is mostly random. In the morning, despite long lines in the terminal, once buses start riding, they usually stay moving along the road. In a similar fashion, in the afternoon, the bus remains at speeds above 10 km/h. The main reason of this behavior is because this route has almost no convergence with any main road (except for North Highway) and the majority of enterprises located there are private which means that they do not follow a fixed departure time.

[29] Source: Elaborated by the author

Visible events due to the 1 second's GPS logs:



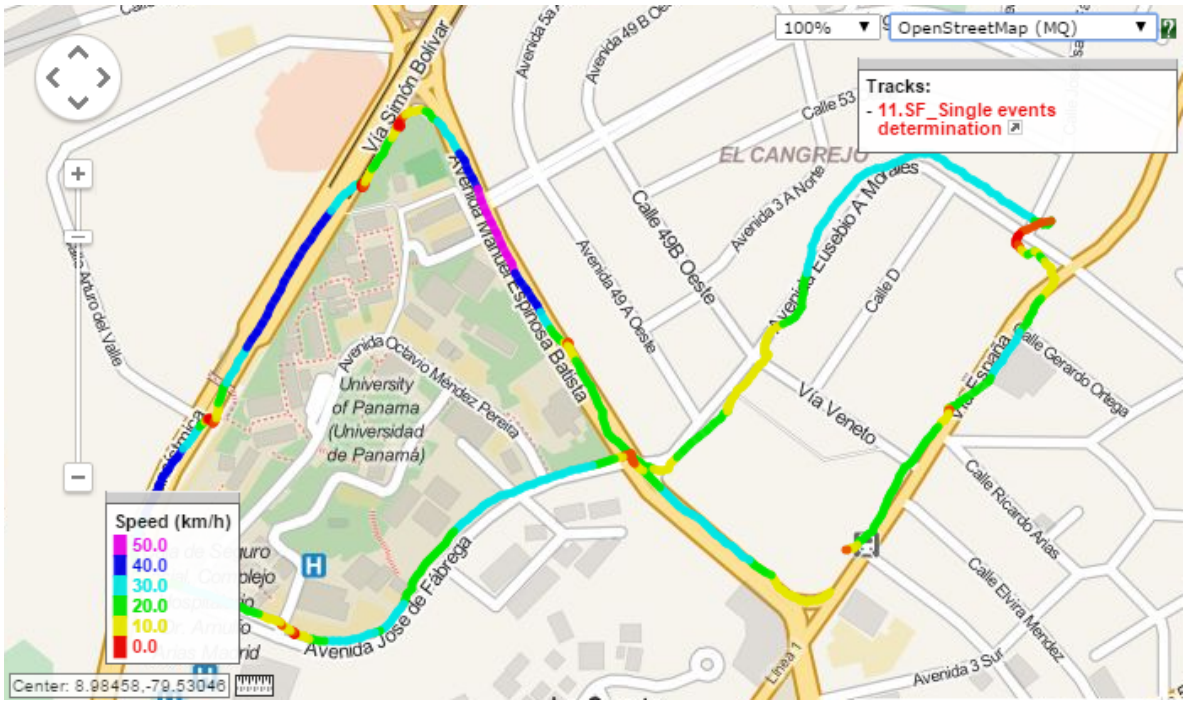
[30]

GRAPH 23: DISTRIBUTION OF TIME PER EVENTS

According to graph 23, if each GPS reading were to be taken every 20 seconds, it would only guarantee to see about 10% of the events, but the other 90% of events could potentially not be visible at all.

[30] Source: Elaborated by the author

9.3 Circular Route: Estacion del Carmen-Caja de Seguro Social



31

FIGURE 14: AVERAGE SPEED OF THE WHOLE TRIP

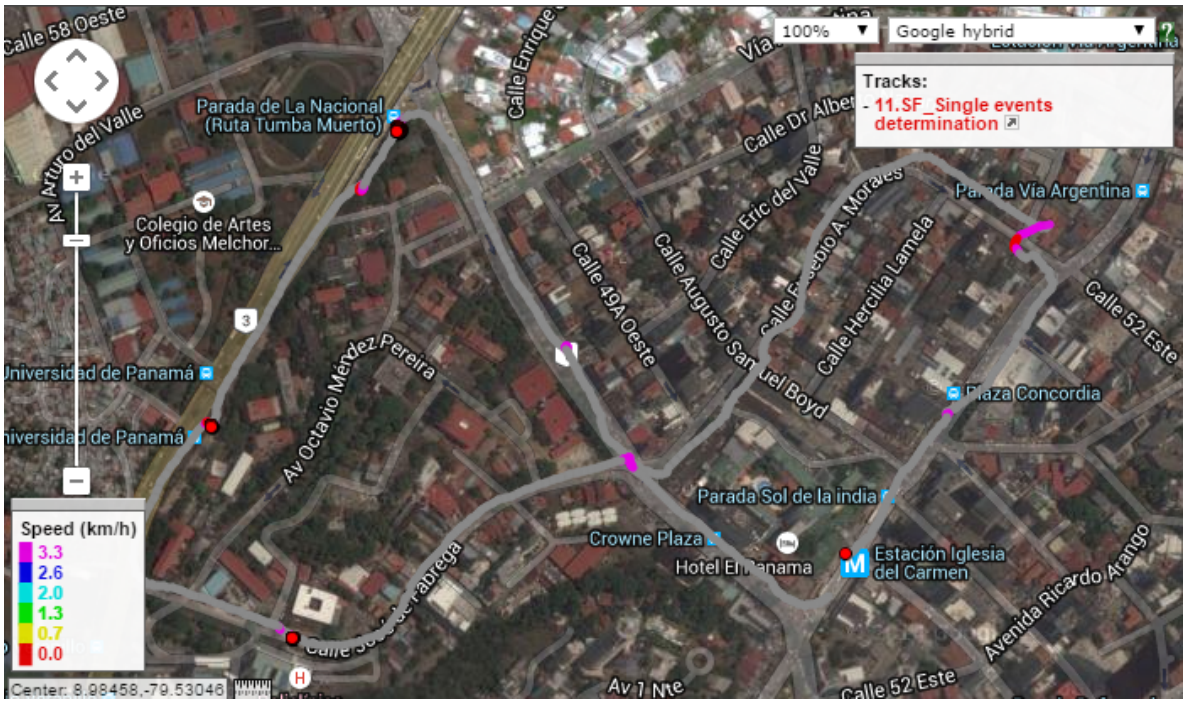
This circular route traverses the "Via España" main road and goes inside the zones and neighborhoods that are close by. This circular route gives service to the National University of Panama, a hospital, another minor university, 2 schools, several hotels and one of the main commercial zones of the city.

The congestion in this route has been reduced dramatically after the construction of the subway.

There was basically no heavy congestion on the whole trip duration on the samples; this can be due to the existence of alternative routes connecting to the main roads.

A point worth noting is that this route is connected to a main subway station, so the buses have to wait a fixed amount of time before departing to allow the passengers to do transshipments to their final destinations.

[31] Source: Elaborated by the author in www.gpsvisualizer.com



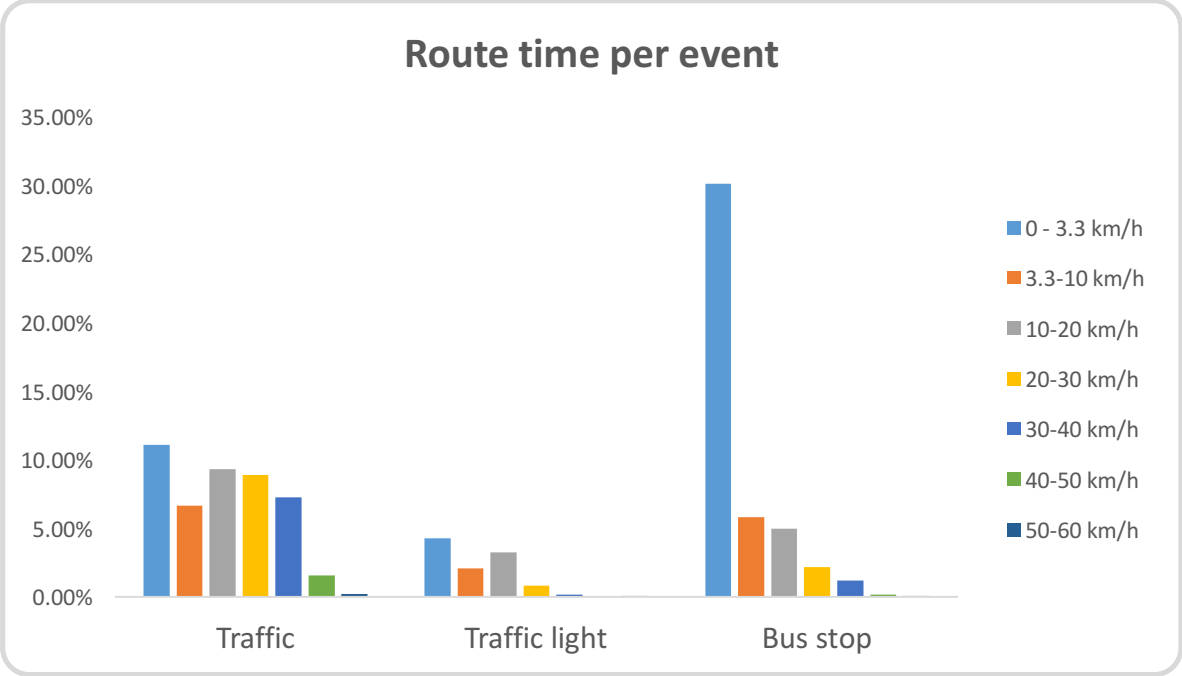
32

FIGURE 15: EXAMPLE OF CONGESTION VISUALIZATION (RED DOTS ARE BUS STOPS)

According to figure 16, from the previous image we can conclude that the route for the duration of the analysis didn't shown remarkable congestions. The amount and distance of the congested zones are minimal, and each one is either close to a bus stop, traffic light or a main intersection, meaning it's a natural road behavior.

[32] Source: Elaborated by the author in www.gpsvisualizer.com

Route time per event representation:



[33]

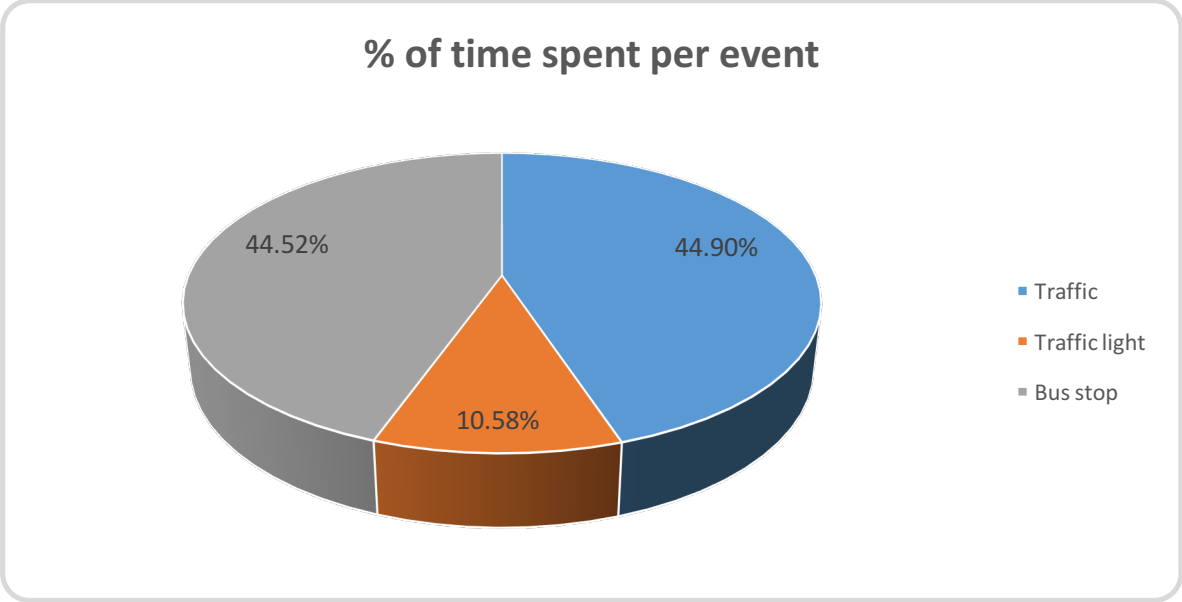
GRAPH 24: PERCENTAGE OF TIME SPENT BY EVENT AND SPEED

After seeing the graph 24, we can observe that most of the time the bus was at a bus stop it was static waiting for users to get in and out, there were also times that the bus skipped completely the bus stop since there is some occurrence of speeds above 10 km/h meaning he didn't stop at certain locations.

The behavior in traffic shows that about 10% of the trip time the bus was completely stopped and exceeding 40 km/h on this route is quite rare.

[33] Source: Elaborated by the author

Percentage of time spent per event:



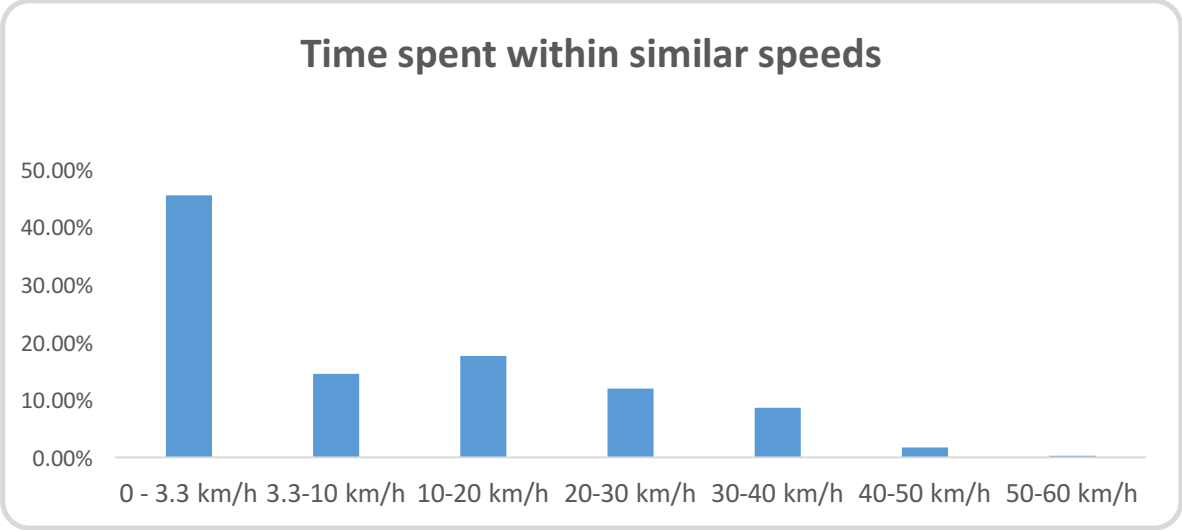
[34]

GRAPH 25: PERCENTAGE OF TOTAL TRIP TIME PER EVENTS

According to the graph 25, the average percentage of time per trip at traffic and at a bus stop was basically the same. This can be due to the buses needing to wait for the passengers to arrive at the metro station, making the time spent at that terminal very long.

[34] Source: Elaborated by the author

Percentage of time spent per trip within similar speeds:



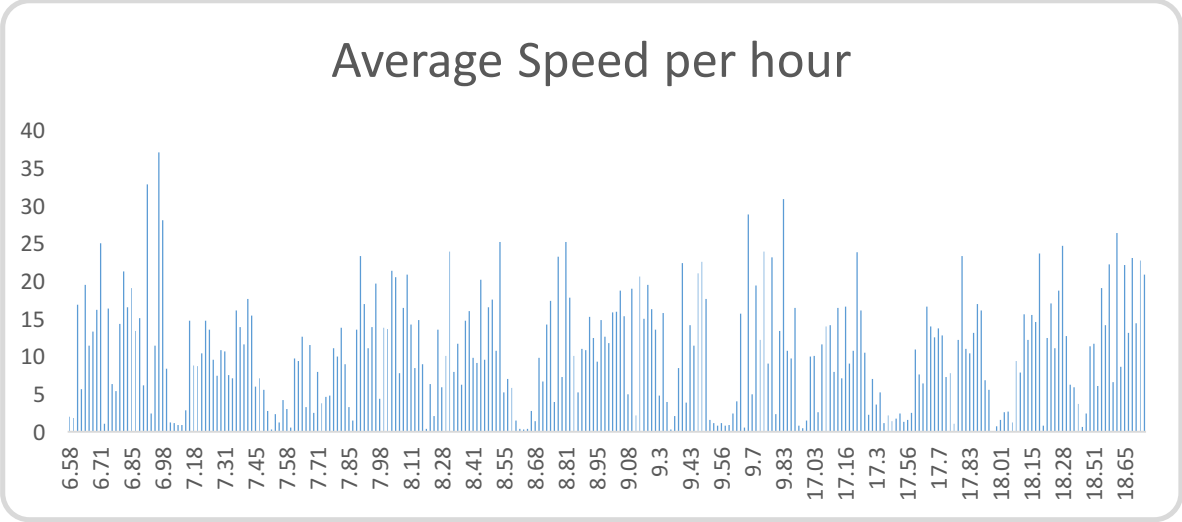
[35]

GRAPH 26: TOTAL TRIP TIME DIVIDED BY SPEEDS

After compiling all the information, we can see in graph 26 that about 45% of the total trip time is spent static, not moving anywhere. After seeing the previous analyses, we can infer that most of that time is spent at the metro terminal waiting for passengers to arrive and depart.

[35] Source: Elaborated by the author

Peak hour identification:



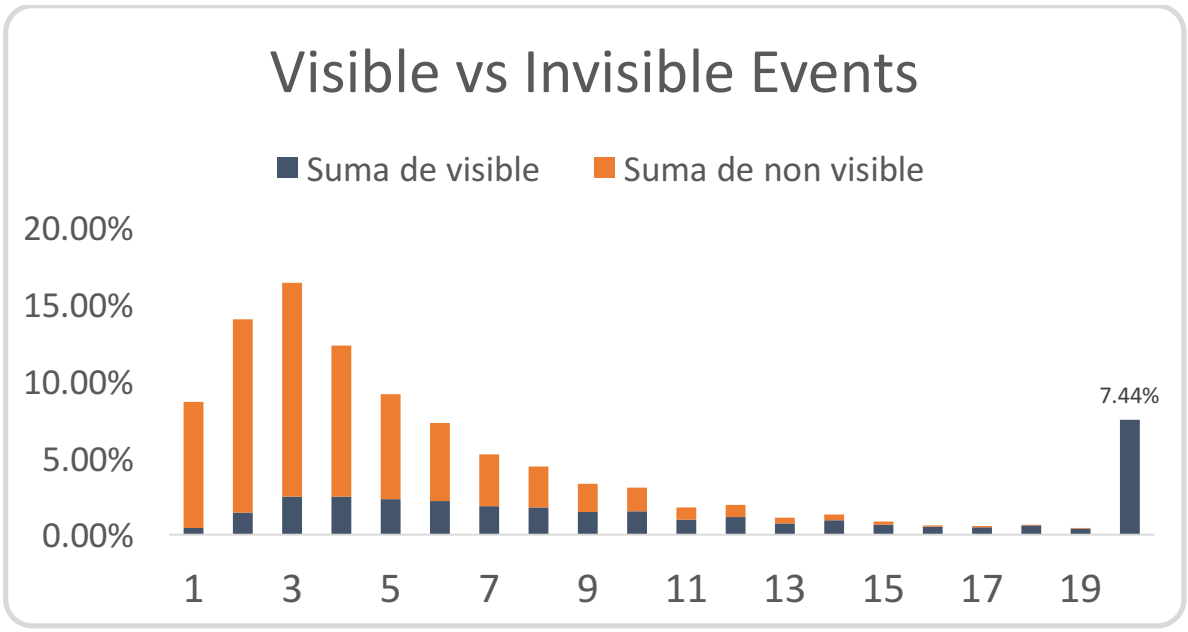
[36]

GRAPH 27: AVERAGE SPEED PER HOUR

The route presents no clear pattern of a peak hour after seeing graph 27, the distribution of average speeds is mostly random and could very well give a hint of the bus schedules. The reason why it this could be inferred is because the only moment that the bus spent a relevant amount of time static was when it was waiting passengers to board from the subway station. According to the previously mentioned, it seems that there is a bus waiting for passengers to arrive at the subway station every 30 minutes, and it stays there waiting for 5 minutes.

[36] Source: Elaborated by the author

Visible events due to the 1 second's GPS logs:



[37]

GRAPH 28: DISTRIBUTION OF TIME PER EVENTS

If each GPS reading were to be taken every 20 seconds, as shown on the blue columns in graph 28, it would only guarantee to see about 10% of the events, but the other 90% of events could potentially not be visible at all.

Note: For more detailed information, please refer to the python file and the dashboard. These tools will allow the user(s) to filter each possible field and customize the visualization accordingly.

[37] Source: Elaborated by the author

10. Conclusions

- With the actual 20 second measurement frequency, almost 70% of events are not visible in every route studied.

- According to the survey, users show a great interest and need more information about routes. Also, users want to know where the bus is located.

- Heavy traffic slows buses on some routes so that they are mostly idle.

- Traffic is reducing return on investment, damaging service and annoying the people Mibus is to serve.

- Since it is very difficult for buses to keep up with a schedule due to heavy traffic, at least visibility would allow users to schedule and relieve their frustration.

11. Ideas to study

- **Offer visibility to users by enabling a mobile app to watch where is the bus.**

  Eliminating heavy traffic is more than challenging. Series of actions would have to take place, maybe taking years. Even there are plans that seem very complex to achieve in order to eliminate this phenomenon. Also, it is necessary to keep in mind the possibility that heavy traffic will never disappear. At this moment and in the future, visibility of buses' location may mean the only way to dramatically improve user experience.

- **Join the Google Transit Partner Program**

  The Google Transit Partner Program is a public transportation planning tool that combines the latest agency data with the power of Google Maps. It integrates transit stop, route, schedule, and fare information to make trip planning quick and easy for everyone. For agencies around the world, Google Maps is a cost-effective solution targeted at transit novices and seasoned travelers alike (maps.google.com). The government or the company in charge of the public transport in Panama are the only capable of joining the program, and more importantly, it is free. It would allow users a better experience and access to information they should have access to and today they don't have access.

<u>Other ideas that may improve the overall user experience:</u>

Improve the Albrook National Transport Terminal and "paid zones" to avoid disorder and user confusion.

- Implement line separators and floor/hanging signs:

  At present time, it is very difficult for new users and even for regular users to understand where should they wait for their selected route. It seems the only way to get to the desired place in the departure and arrival area is by asking someone. Floor or/and hanging signs may prove useful for users to know where should they wait for their bus. Another problem observed at peak hours is line skipping. For example, most users make long lines for the Ciudad del Saber route. The moment the bus arrives, there is

no system that denotes a line or prevents other users to push in the bus, making users on the line wait for the next bus. Some kind of line separators, along with security officers would improve the order on the terminal. Also, line separators could help separate two kinds of lines: one of users willing to get on the bus either seated or standing and another one with users willing to wait more for a seat on the bus.

- Install a user interface where users can check routes, operating times and bus stops: The implementation of a public information system would improve the user experience. There is not a single source of information about the system in the terminal, besides some old hanging signs that prove little help. A machine displaying a dashboard with all the routes and bus stops on each route, together with operating times would decrease uncertainty of users. Adding signboards of routes and bus stops in that route alongside with maps in the arrival/departure area could be an alternative or another improvement.

Implement a user claim system and add the bus driver's names to the LED displays inside buses.

Many users claim that many bus driver's behavior is far from the best. Many of them don't allow people to get on the bus, even if there is space for them and even skip bus stops if no one in the bus needs to get off at it. It is unclear what are the reasons for this kind of conduct, and there is no system for users to report these events. Setting a phone hotline for users to report anomalies and adding the driver's name on the existing LED displays inside the bus would force drivers to be better at their jobs.

12. Further Research

After the results from the data analyzed in this project, we have identified key points and ideas for further research.

- Implement a bus dedicated lane by inverting a lane on peak hours on the zones identified in the report with heaviest traffic.

- Eliminate or lower frequency of routes that go over the subway (Linea 1) lane.

- Replace long trunk routes with shorter routes using consolidation points e.g. (El Parador, Fernandez de Cordoba)

- Re-evaluate the number of bus stops, their names, their locations and the concept of every bus stopping at every bus stop on its way.

- Unifying all public transport companies and unions (CANATRA, SICOTRAC, METROBUS) into one or interconnect their systems.

- Dedication and semi-dedication of buses to certain routes at certain times.

13. References

ACAN-EFE. La Prensa Web. 15 March 2013. <http://www.prensa.com/locales/Panama-despide-diablos-rojos-servicios_0_3616138365.html>.

Holleywell, Ryan. Top Reasons People Stop Using Public Transit. <http://www.governing.com/blogs/view/gov-reasons-riders-abandon-public-transit.html>.

maps.google.com. google.com. <https://maps.google.com/help/maps/mapcontent/transit/>.

profesionalespanama.net/nacionales/medidas-anti-tranque-no-surten-efectos-conductores-se-quejan/. <http://profesionalespanama.net/nacionales/medidas-anti-tranque-no-surten-efectos-conductores-se-quejan/>.

Superintendencia de Bancos de Panamá. "Informe de coyuntura del sector automotriz." n.d.

www.elnuevoherald.com/noticias/article1915255.html. El Nuevo Herald. <http://www.elnuevoherald.com/noticias/article1915255.html>.

14. Annex

User manual for the python codes with prefix "Real"

DATA FORMATS

The python works currently with 2 extra files: MASTER BusStops.csv and MASTER Lights.csv. Those 2 files must be present on all routes to analyze with those exact same names. The previously mentioned files must have the following column format:

	A	B	C	D	E	F	G
1	DATETIME	LATITUDE	LONGITUD	desc	color	label_scal	symbol
2	udelas	8.971728	-79.5627	udelas	yellow	2	pin
3	anam	8.975208	-79.5585	anam	yellow	2	pin
4	saint mary	8.979103	-79.559	saint mary	yellow	2	pin
5	calle evan	8.98337	-79.558	calle evan	yellow	2	pin
6	ave canfie	8.988425	-79.556	ave canfie	yellow	2	pin
7	provisiona	8.99362	-79.5558	provisiona	yellow	2	pin
8	cc country	8.99505	-79.5584	cc country	yellow	2	pin

[38]

FIGURE 16: FORMAT OF THE MASTER FILES.

These files contain the information regarding the exact latitude, longitude and name of the point of interest.

In red are the columns that the python uses, all the other columns can be different and won't affect the outcome of the python code.

The GPS logs that needs to feed the python code must have a specific format in order for the algorithms to come up with feasible data. The format is as follows:

1. Each trip file can have any name, but the format of it must be .csv (comma separated value).

[38] Source: Elaborated by the author

2. The column order inside each trip file must be as follows:

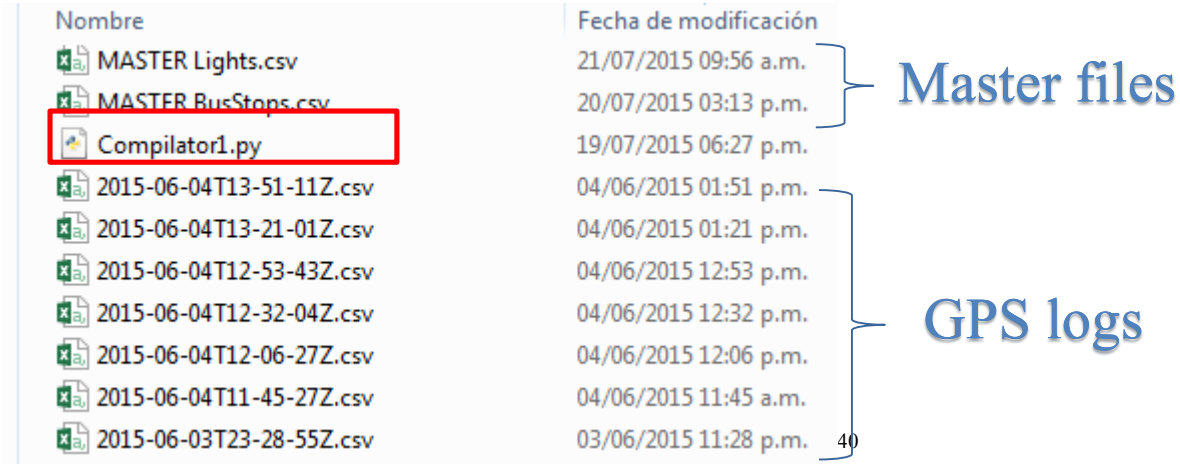
	A	B	C	D	E	F
1	DATETIME	LATITUDE	LONGITUDE	SPEED_KMH	ALTITUDE_M	BARO_ALTITUDE_M
2	2015-05-27T11:07:04Z	8.976221	-79.550366	9.1	23.3	2.2
3	2015-05-27T11:07:05Z	8.976163	-79.55036	12.4	23.9	2.2
4	2015-05-27T11:07:06Z	8.976121	-79.550345	14.2	24.4	1.9
5	2015-05-27T11:07:07Z	8.976078	-79.550328	16.3	24.9	1.9
6	2015-05-27T11:07:08Z	8.976035	-79.550313	16.1	25.7	2
7	2015-05-27T11:07:09Z	8.975985	-79.55029	17.6	26.5	2

[39]

FIGURE 17: FORMAT OF THE GPS TRIP LOG FILES

FOLDER IMAGE

1. After all the previous requirements have been made, the folder containing the information of a specific route should look like this:



[40]

FIGURE 18: EXAMPLE OF FOLDER WITH INFORMATION

2. Double click the Python code named "Real2", and wait for the results. The outcome should be a general analysis like this:

[39] Source: Elaborated by the author

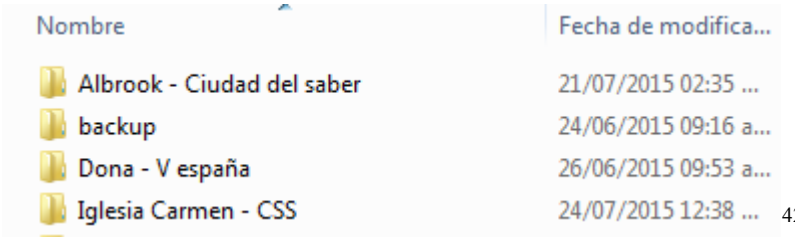
[40] Source: Elaborated by the author

```
Data regarding busstops
-----------------------
1. Porcentage of time spent at bus stops vs total trip time is:  0.691582106617
2. Porcentage of time completely stopped at bus stops vs total trip time is:  0.368920013339
3. Porcentage of time spent at bus stops just moving from and into traffic, not picking passe


Data regarding general congestion
---------------------
1. Porcentage of time spent completely stopped vs total trip time:  0.454956886285
2. Porcentage of time spent at heavy traffic vs total trip time:  0.14515744843
3. Porcentage of time spent at light traffic vs total trip time:  0.17521795055
4. Porcentage of time spent at no traffic vs total trip time:  0.224667714735
5. Porcentage of time spent at overspeed vs total trip time:  0.0


Data regarding traffic lights
---------------------
Total number of traffic light on this route is:  6
Average time spent around a traffic light in minutes is:  1
Total minutes in traffic light:  43.4833333333
Average time spent at a traffic light with speed < 3.3 km/h in minutes is:  0
Porcentage of time spent at traffic light vs total trip time:  0.124291362965
Porcentage of time spent at traffic light at < 3.3 km/h vs total trip time:  0.0150064313277
```

[41]

FIGURE 19: EXAMPLE OF DATA'S SUMMARY ON PYTHON SCREEN

3. Each trip must be located on a separate, dedicated folder containing exclusively the Data logs and Master files for that specific route:



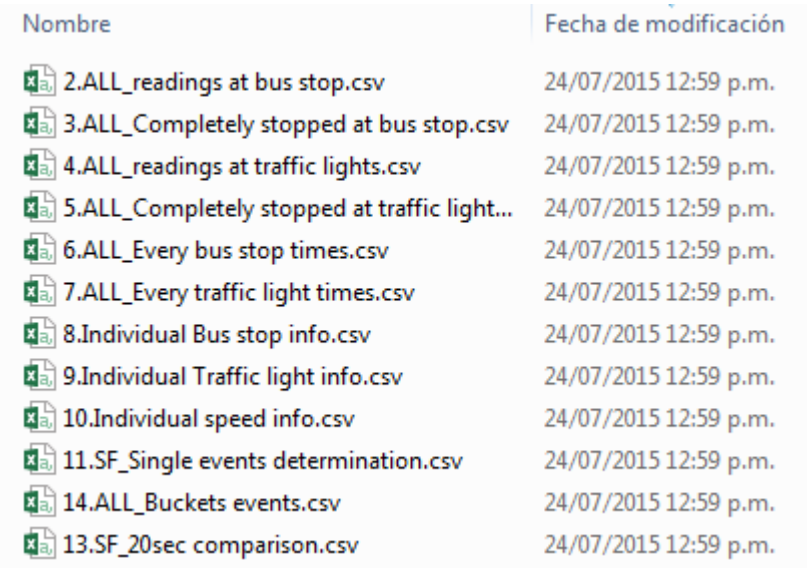
[42]

FIGURE 20: EXAMPLE OF HOW TO SEPARATE TRIP FILES

4. After you run the program, there should be new files inside the folder of the route:

[41] Source: Elaborated by the author

[42] Source: Elaborated by the author



[43]

FIGURE 21: DATA FILES DERIVATE FROM THE CODE

Each file has a different use:

- Files 2.ALL_readings at bus stop.csv: Shows every GPS reading that happened inside the route's bus stops zones.
- File 3.ALL_Completely stopped at bus stop.csv: Shows only the GPS readings that have a speed of 0-3.3 km/h inside a bus stop zone.
- File 4.ALL_readings at traffic light.csv: Shows every GPS reading that happened inside traffic light's zones.
- File 5.ALL_Completely stopped at traffic light.csv: Shows only the GPS readings that have a speed of 0-3.3 km/h inside a traffic light zone.
- File 6.ALL_Every Bus stop times.csv: Shows the means time all the analyzed trips spent at each bus stop.
- File 7.ALL_Every traffic light.csv: Shows the mean time all the analyzed trips spent at each traffic light.
- File 8.Individual Bus stop info.csv: Shows the time spent per data file at each bus stop next to the total trip time.

[43] Source: Elaborated by the author

- File 9.Individual Traffic light info.csv: Shows the time spent per data file at each traffic light next to the total trip time.
- File 10.Individual speed info.csv: Shows the time spent per trip at each range of speed.
- File 11.SF_Single events determination.csv: Shows each point of a GPS log and how the event's parameters change.
- File 13.SF_20sec comparison.csv: Shows the data logs converted into a "each 20 seconds log".

File 14.ALL_Buckets events.csv: Shows a summary with the number of events per file and their duration