國 立 交 通 大 學

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碩 士 論 文

大眾運輸路網結構化分析指標：臺灣主要城市與巴拿馬之比較分析

Structural Indicators for Transit Network Systems: Comparisons among Taiwan Major Cities and Panama

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中 華 民 國 一 〇 七 年 六 月

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摘要

都會區大眾運輸系統主要是提供市民由甲地至乙地之運輸服務，並以降低旅運成本（時間及金錢)，滿足多數人的移動需求為目標。為確保運輸系統能達成這些需要，如何界定及掌握民眾旅運需求至為重要。

基此，本研究乃建立大眾運輸系統路網結構性指標，包括路徑長度、路網效率、旅運時間、空間可及性等四項，用以了解巴拿馬目前大眾運輸系統路網結構之完整性與效率性。此外，由於臺灣 6 個直轄市之大眾運輸系統路網發展差異甚大，部分城市之大眾運輸系統路網發展相當完整，但也有相當發展較為缺乏者，正可作為巴拿馬比較分析之對照基礎，俾供巴拿馬市未來發展大眾運輸之參考。另外，由於指標的計算基礎中，起迄矩陣也是重要資訊之一。而臺灣 6 都都早已有完整之整體運輸規劃，但巴拿馬卻一直未有官方版的起迄矩陣。因此，本研究也透過重力模式進行巴拿馬各交通分區起迄矩陣之建立。

分析結果顯示，相對於臺灣 6 都，巴拿馬的大眾運輸路網需要相當高的旅運時間，而且空間可及性（路網覆蓋率）甚低。但相對而言，路徑長度及路網效率還可以接受，甚至高於臺灣部分直轄市。此一分析架構及與臺灣 6 都之比較結果，可作為未來巴拿馬發展大眾運輸之重要指引。

關鍵詞：路網結構指標、路徑長度、路網效率、旅運時間、空間可及性、重力模式。

Structural Indicators for Transit Network Systems: Comparisons among Taiwan Major Cities and Panama

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Abstract

The main purpose of a transit system is to coordinate the mobility of people from one node to another efficiently. The goal of a transit system is to reduce travel cost, either in terms of money or time and seeks to satisfy the mobility needs of as many people as possible. In order to have a transit system that covers these needs, it is important to measure and understand the mobility needs of the population and how the current transit system satisfies them.

Based on this, this study developed network structural indictors for transit systems, including average shortest path length, network efficiency, total travel time, and spatial accessibility, so as to analyze the completeness and efficiency of Panama. Meanwhile, since the six municipals of Taiwan have rather different levels of transit system development. Some of them have very efficient and effective transit systems; others do not, which provide an excellent roadmap for Panama to learn from. Additionally, since Panama has not yet published her official version of travel demand OD table, which long been developed in six municipals in Taiwan, this study also estimated the OD travel demand table based on a Gravity model.

The comparison results show Panama transit system has a high total travel time and a very low spatial coverage, which need to improve. However, it is also found that shortest path length and network efficiency of Panama transit system are acceptable in comparing with some municipals in Taiwan.

Keywords: Network structural indicators, Shortest path length, Network efficiency, Travel time, Spatial accessibility, Gravity model.

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I would like start by thanking God for accompanying me and guiding me during this journey, for being my strength, and for giving me a life full of opportunities and blessings.

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Glossary of Symbols

Length and Efficiency

L : Average shortest path length of the network

F : Network Efficiency

d_{ij} : Distance between zone ***i*** and zone ***j***

N : Total number of zones in the network

Total Travel Time

T : Total Travel Time

q_{ij} : Number of trip from zone ***i*** to zone ***j***.

$\bar{d}_i$: Average distance from zone ***i*** to the nearest public transport station

$\bar{d}_j$: Average distance from the nearest public transport station to zone ***j***

v_o : Minimum walking time rate

l_a : Length of section ***a***

v_a : Average rate of the line ***a***

$\delta_{a,ij}$: If the section line a is the shortest path from zone ***i*** to zone ***j***, it is 1, otherwise it's 0

Spatial Accessibility

AS : Ratio between the served areas and the administrative area

S : Real surface served by the network

S_u : Reference territory surface

R_i : Range of influence

R_b : Acceptable walking range *(500 m)*

n_{Di} : Number of destinations directly connected by node ***i***

N_D : Average number of destinations directly connected by the network nodes

p_i : Node weight. it is equal to 1 when local degree is 1, or it is a multiple of local degree when this is greater than 1

p_{ri} : Relative node weight

S_i : Circular served surface of each node

ST : Theoretical served surface

Gravity Model

q_{ij} : Number of trip from zone ***i*** to zone ***j***.

G : Gravitational constant

M_i : Population of zone ***i***

M_j : Population of zone ***j***

α, β: Population exponential parameters

λ : Distance exponential parameters

Genetic Algorithm

q_{ij} : Number of trip from zone ***i*** to zone ***j***.

M_i : Population of the zone ***i***

Q : Average number of trips per day per person

k : Power number

1. INTRODUCTION

1.1 Background and Motivation

Public transport plays a critical role in the sustainability of urban settings. The mass mobility and quality of urban lives can be improved by establishing public transport networks that are accessible to pedestrians within a reasonable walking distance [1].

The main purpose of a transit system is to coordinate the mobility of people from one zone to another efficiently. The goal of a transit system is to reduce travel cost, either in terms of money or time and seeks to satisfy the mobility needs of as many people as possible. This main concern is a very important issue around the world, and Panama isn't the exception. In order to solve this problem, first we have to measure and understand the characteristics and different needs of each city, to be able to make the necessary change or upgrades to the transit system.

The structure of the bus network is very significant for the bus system [2]. According to Avishai Ceder (2014) [3] the principal public transportation planning process can be categorized into four aspects, including line or network designs, timetable development, bus or vehicle scheduling and crew scheduling; another important aspect that were consider for many authors is the frequency setting. A lot of index were proposed and used to solve the problem related with these five aspects, such as accessibility, mobility, speed, frequency, reliability, safety, range, productivity, among others.

About 60% of the population in Panama are centered around the Metropolitan Area, which is where the economy and trade of the country is centered. This research developed network structural indictors including average shortest path length, network efficiency, total travel time, and spatial accessibility, so as to analyze the completeness and efficiency of Panama transit system.

1.1.1 History of Panama's Transportation System

The first massive transport mode in Panama was the transcontinental railroad in 1855, which was the only mode of transportation until 1880.

In 1880 the first tram began operations in Panama City. The first tram route was from Panama Canal area to central points of the City. This service had two trains with capacity for 30 persons. The second route was built in 1913. In 1941 the use of the tram was suspended, by orders of government of that period.

In 1941, began the usage of buses and private cars as a primary mode of transportation. In 1974 the first public transport company started to operate, and the first routes of the city were created.

Panama was and remains to be characterized by the Diablo Rojo. The Diablo Rojo, was the yellow scholar buses used in United States, they were brought into Panama in 1970. The Diablo Rojo were painted in different colors according to the area of the city where they traveled, based on the route of each bus.

The Diablo Rojo became famous because a few years later, Panamanians gave their buses a special touch, the owners of each bus, modified the design of the bus, putting label names and painted with drawings of famous people or cartoons in the sides and the back part the bus. Making unique the Diablo Rojo. Until 2010 the Diablo Rojo headed the mode of public transport in the Panama City.

In 2010, A new massive transport system of buses was introduced. This new network is called Metro bus. The Metro bus operates only in 2 of the 6 districts of Panama City, which are, Panama district and San Miguelito districts.

In 2012 was implemented, for the first time in Panama, the e-card (Smart Card) as payment method, and currently could be also use in the metro *(Panama's MRT)*, which began operations of the first line in 2014.

The implementation of the Metro bus in Panama City not only wanted to release the critical situation of public transport in the City, but also wanted to remove from circulation the Diablo Rojo, which, until now, has not been fully achieved.

Even though in 2012, most of the Diablo Rojo were indemnified by the Government to stop their circulation in the city. In 2014 the Diablo Rojo return without being regulated by the government or controlled by any company in particular. Those Diablo Rojo along with minibuses are public transports that work independently. This may be a few step back in term of Panama public transport development.

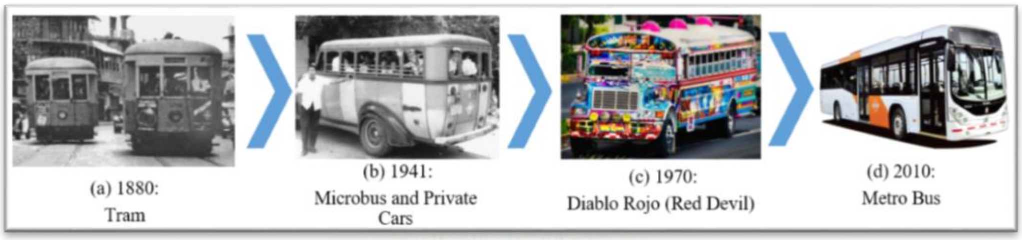

Figure 1: Panama's transport mode evolution

1.2 Research Purpose

In the last seven years, the metropolitan area has presented many changes in its transit infrastructure and systems. The implementation of a new urban public transport systems that work along with the new metro lines is one of the projects developed by the authorities. To obtain a full integration of the systems and reduction of some of the most common transportation problems that Panama City faces.

The purpose of this study aims to analyze and understand the nature and characteristic of the public transportation system of Panama City, underneath different demands, mobility needs, population, and routes to obtain the level of transit system development.

After reviewing the related literature, we determined four important indicators that could help us to understand and make the corresponding conclusions of the characteristics of the public transit system of Panama City. In addition, based on this, we also used Taiwan's public bus system as a benchmark to compare the level of transit system development of Panama City. These indexes are the following: average shortest path length, network efficiency, total travel time and spatial accessibility.

1.3 Research Scope

1.3.1 Current bus network system

The goal of the implementation of a new public transport system is to obtain a full integration of the systems and reduction of some of the most common transportation problems that this city faces. But Panama Metro bus it has not yet been possible to fulfill the mobility needs of the population. The weak structure of the bus network in Panama forced many people to continue choosing private transport as their daily mode of transportation. This situation has translated into highly traffic congestion, noise, air pollution among other issues, such as reduction and deterioration of public spaces, and many other negative aspects.

The Metro bus, has 6 operation centers within Panama City, a bus fleet of 1,200 buses with a capacity of 85 passengers each (38 sitting and 47 standing). The operation area of the Metro bus is only Panama district and San Miguelito district. This network has 330 different routes and 1,000 bus stops. In 2015 was estimated by the Transit and Transportation Authority of Panama that the trip demand is around 824 thousand daily trips, of which 50% are made in the public bus system, 42% by traditional system (private vehicle), 3% by metro (MRT) and 5% by alternative microbuses.

1.3.2 Definition of the Study Area

The Republic of Panama is located in Central America. It has an extension of 75,420 km^2, and a total population of 4.1 million inhabitants.[1] Panama is divided into 10 provinces and 5 indigenous regions, which in turn are distributed in 77 districts and 655 corregimientos[2]. As the concept "corregimineto" is a word only used in a few country of Latin America, for a better understanding of the concept, from this point forward we will call it "zones" instead of corregimientos.

Panama City, capital and largest city of the country, is organized in 6 districts and 54 zones; (1) Panama District, including 23 zones; (2) San Miguelito District, including 9 zones; (3) Balboa

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[1] Source: Institute of Statistic and Census of Panama. (December 2017)

[2] In Panama, the word "corregimiento" is used to describe a population living on a same territory, but that do not constitute a district (municipality). In other word, inside a district (municipality), are a determine number of corregiminetos.

District, including 6 zones; (4) Chepo District, including 8 zones; (5) Chiman District, including 5 zones; (6) Taboga District, including 3 zones.

This research is conducted in Panama district and San Miguelito district. To clarify Panama City has 6 district but only in this research and for better understanding, from this point forward we will be referring to Panama district and San Miguilito district as "Panama City". These two districts are located in the providence of Panama, being the largest districts among Panama City. The total population in this two districts is around 1.5 million inhabitants, which represents 70% of the total population of the city, in an area of 2,081 km^2.

Figure 2: Map of Panama. Panama City is the shaded area.

1.4 Research Process

First we review the background of Panama's bus transit system, to determine the research scope, which was selected according to the coverage of the bus network system. Then were reviewed the relevant literature to select the appropriate indicators that would help us understand the characteristics of Panama's bus network system.

The information used in this research was collected from Mi Bus Company, the Ministry of Economy, National Institute of Statistics and Census and Finance, Panama Municipality, San Miguelito Municipality and the Transit and Transportation Authority of Panama.

After the data was collected we use Google Maps and Microsoft Excel to convert the data into a functional form and perform the calculation of the four index. The last step is summarizing the calculation results of the four indicators for the two districts in Panama and then compare it with 6 cities of Taiwan, to obtain the level of Panama City transit system development.

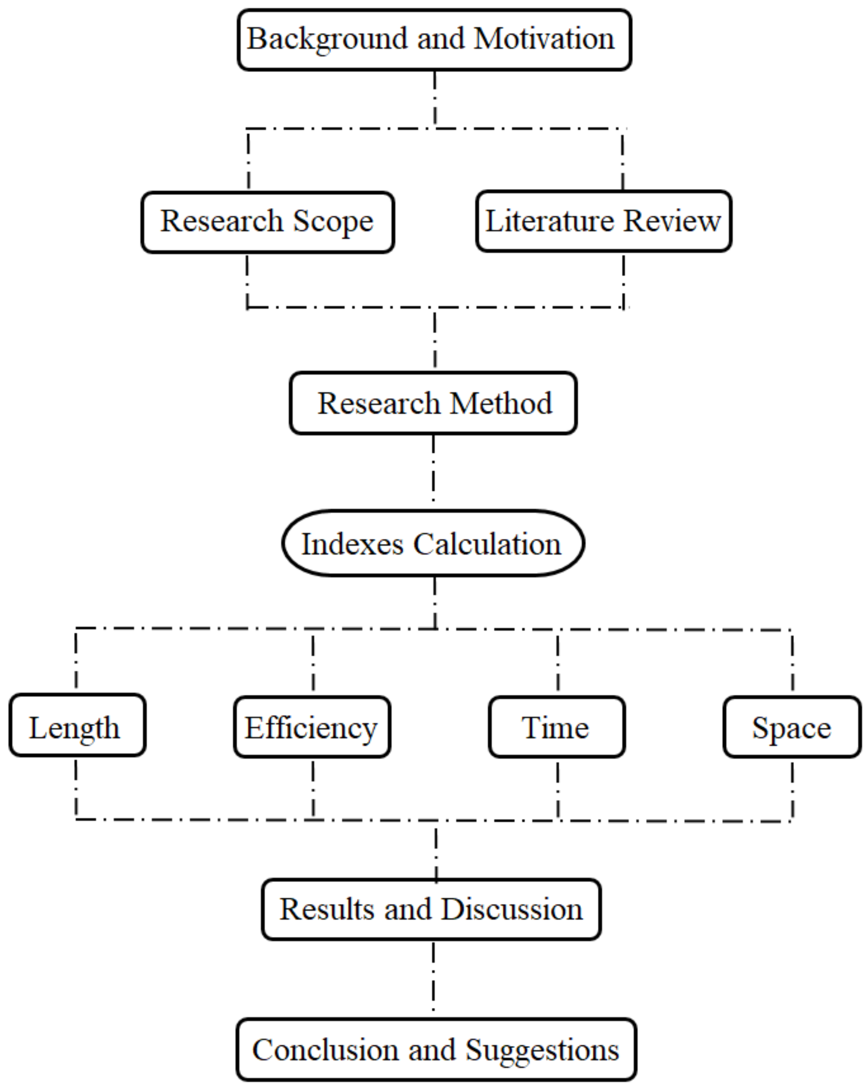

Figure 3: Research flow chart

2. LITERATURE REVIEW

2.1 Transport Network System

In the last decades, Panama has had a great development, in term of economics and trade. This has resulted in a special expansion of the city without real vision on the nature of the extension or the consequence of it. Moreover, the shortcoming of the urban transport and private system, seem to have reached the limit of the manageable. The combination of urban development without control and an inadequate urban transport system increases the effect of congestion, pollution and excessive travel time of the users, tending to reduce the general accessibility of the city and the economic activities [4].

The high percentage of passengers with transshipments in the public transport network reflects the limitations of it and the impact of the road structure of Panama City. Around 53% of the trips made on public transport involve one or more transshipments. This, in turn, increases the travel time of the users.

An integrated transport system allows public transport user to board not a single line, but a whole system [3]. In 2015 the Transit and Transportation Authority of Panama, present an evaluation study for the implementation of the joint public transport system for the metropolitan area of Panama City, including the providence of West Panama. The joint system tries to integrate and organize the public transport modes, improve the coverage of the public transport system, integrates the operations and rates, modernize the bus fleet and rationalize the service offer. The adoption of partial projects or measures in recent years has not yet fulfilled the expected results.

The objective of the transportation service is to find the most efficient way to connect our origins and destinations and to achieve that goal, first, we had to be able to measure the transport network. When we talk about public transport network, there are two indicators that plays an important role in term of measurement, the first indicator is the accessibility, which could be defined as the ease with which inhabitants can reach their destinations [5] and the other indicator is urban mobility which also play an essential role in the transport network.

2.2 Network Structure Indexes

There are various indicators that help measure the network structure of the roads. As the transport system evolves, the indexes used to measure it would also vary depending on the research's goals and the conditions of the different research areas, such as travel behaviors, population, the organization of roads, among other characteristics. In order to obtain the more suitable indexes to achieve the objective of this research, we examine the literature related on the road network structure. Shown in (Table 1).

H. Zhang (2017) [1]. Propose in a study of complex network, some indicators, such as degree, average shortest path, cluster coefficient, efficiency, degree correlation, community structure and average transfer time.

The original analysis objectives of the indicators below are all general road network or track network structures. Since, the objective of this study is the bus network system. Therefore, it is necessary to adjust the assumption of the lines and nodes that are not available for public transport.

Furthermore, for the purpose of make the correspondently comparison of the bus public network between Taiwan and Panama, this research use as benchmark the study of Huang, Wei-Jia and Shih, Han-Yang (2018) [6], where they present a comparison of the overall urban public transit network of six municipalities in Taiwan, not only of the bus transport, but also of the MRT, Ferry and Taiwan Railway. However, this research only considers the results of the bus transport network, given that the other mode of transport are outside the scope of this research.

2.2.1 Average Shortest Path Length

Many research used the average shortest path by calculating the total number of nodes, the distance between two zones and then averaged. The length is the performance of two different traffic networks, random and scale-free network in the aspect of different traffic situations, such as the relationship between volume of traffic and optimal topology, in which there is a practical benchmark for the flow balance on traffic systems [7].

In the research was defines the average shortest path length ***L*** as a measure of the typical separation between two zones in the graph, also known as characteristics path length, defined as the mean of the lengths over all Origen-Destination (OD) combinations. In order to estimate the length of Panama City we used the equation proposed by Wu et al. (2008) [7].

2.2.2 Network Efficiency

Based on the research of Latora and Marchiori (2007) [8], the efficiency is a good measure of the performance of parallel systems. The efficiency is always used to measure how efficiently the information is exchange in the Wu et al. (2008) [7]. The estimation the network efficiency of Panama City, is based on the assumption that the information in a network travels along the shortest path length and that the efficiency ***F*** between two zones is equal to the inverse of the average shortest path length.

2.2.3 Total Travel Time

Xie and Lavison (2009) [9] explored the topological evolution of the surface transportation network *(road network)* by a simulation model validated on the data. To determine the total travel time ***T,*** the Four steps model to predict the traffic flow on a given road network was used as one of the metrics for the path selection. The longer the length of the road, the higher the travel time would be.

Chen et al. (2010) [10], described a new approach to road network design, to optimized the travel time consistency that has drawn much attention in recent two decades as one of the goals of the transportation network system.

This index is obtaining by calculating the total walking time, and the travel time in the route from zone ***i*** to zone ***j.***

2.2.4 Spatial Accessibility

Gattuso and Miriello (2011) [11] proposed the spatial accessibility ***S*** indicator, which is used to measure the actual service range of the public transport. The biggest difference from the theoretical service scope is that the actual service area deducts the overlapping part. Therefore, the actual public transport coverage can be presented more effectively. With ***S***, the article also proposes a further indicator - Road Network Coverage ***AS***, which is used to indicate the ratio of public transport service coverage in a given area.

To obtained the actual service range of the public transport network, is necessary to consider the location of each transport node (bus stop), the number of transfer routes and other factors, then can be obtained the net service range of each transport node.

2.2.5 Gravity Model

The name gravity model comes from Newton's law of gravitation, which states that the force of attraction between two bodies is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them [12]. The gravity model is widely accepted and used for transportation applications.

Hong and Jung (2016) [13] applied the gravity model on the urban bus system of five cities in Korea, they focused on the validation and characteristics of the model for urban mobility. The biggest contribution of their research is the range of value to set the parameters on the predictors, as well, proofed that the setting of the predictors population and distance is a correct assumption to measure the gravity population model. The range of value to set the parameter, was obtained from a multiple regression on the linearized equation by taking logarithms and used the R^2 statistic regression to quantify the estimated performance.

The travel demand OD table is obtained by using the Gravity model from Erlander and Stewart (1990) [14], and also the equation proposed by Hong and Jung (2016) [13]. Additionally, a Genetic Algorithm is introduced to determine the parameter settings of the Gravity model equation, by using Evolver Software.

Gen and Choi (1999) [15] mentioned that the Genetic algorithm is a probabilistic algorithm based on the mechanisms of natural selection and natural genetics. GAs start with a set of arbitrary solutions called a population. Each individual in the population is called a chromosome, and represents a solution to the problem.

Genetic representation is a type of data structure that represents the possible solution of the problem. Different problems usually have different data structures or genetic representations.

	Zhang, H. (2017)	Jian-Jun Wu, Zi-You Gao, and Hui-jun Sun (2008)	Latora, V., & Marchiori, M (2007)	Chen, A., Zhou, Z., Chootinan, P., Ryu, S., Yang, C., & Wong, S. C. (2011)	Xie, F., & Levinson, D. (2009)	Gattuso, D., & Miriello, E. (2005)	Hong, I., & Jung, W. S. (2016)	Erlander, S., & Stewart, N. F. (1990)	Huang, Wei-Jia & Shih, Han-Yang (2018)
Average Shortest Path									
Average Transfer Time									
Cluster Coefficient									
Degree									
Degree Correlation									
Efficiency									
Congestion Factor									
Spatial Accesability									
Access Density									
Travel Time									
Gamma Index									
Gini Index									
Network Density									
Traffic Congestion									
Conectivity									
Network Weight									
Network Average Weight									
Gravity Model									

Table 1:Summarize of the Literature Review

3. RESEARCH METHOD

3.1 Average Shortest Path Length

Based on Wu et al. (2008) [7] the average shortest path length L is used as a measure of the typical separation between two zones in the graph. The equation is as follow:

$$L = \frac{1}{N(N-1)} \sum_{i \neq j} d_{ij} \qquad (1)$$

Where d_{ij}, is the bus shortest path distance between zone i and zone j.

The average shortest path length L is only estimated in terms of distance, the bus travel distance, does not change with the time. The L was estimated using Google Maps. Since is one of the most used GPS navigation tools by Panamanian, students and workers, to determine which is the most appropriate route to reach their destinations, thus we think Google Maps it's a realistic option to calculate L.

First, in order to have a consistency in the results, we located the center of each zones to calculate the path from i to j. Once we had located the center of each zones, the next step is to prepare the length OD-Matrix. We calculated the length with the shortest path and with the fewer bus transfer for each OD combination. In order to simplify the calculation, this research assumes that the route from i to j is the same as the route from j to i.

After the overall length OD-matrix was done, we used the equation proposed by Wu et al (2008) to obtain the average shortest path length for Panama district and San Miguelito District. We divide the sum of all the OD lengths d_{ij} by $(N(N-1))$.

3.2 Network Efficiency

According to Latora and Marchiori (2007) [8] the network efficiency measure how efficiently the information is exchanged in the network. This index is based on the assumption that the information in a network travels along the shortest routes and that the efficiency in the communication between zone i and zone j is equal to the inverse of the shortest path length d_{ij}.

The equation proposed is as follow:

$$F = \frac{1}{N(N-1)} \sum_{i \neq j} \frac{1}{d_{ij}} \tag{2}$$

Where d_{ij}, is the bus shortest path distance between zone i and zone j. *S*ame as Equation 1.

To calculate the efficiency F, we used the equation proposed by Latora and Marchiori. In this case d_{ij} is the same as the average shortest path length in part *3.1*. To get the network efficiency of Panama and San Miguelito districts we calculate the inverse of each d_{ij}. Once we had the inverse of each d_{ij} we generate a new OD-Matrix, and the last step is sum up all the d_{ij} and divided by *(N(N-1))*.

3.3 Total Travel Time

For index T, we referred to the study of Xie and Levinson (2009) [9] who used the Four steps model to determine the total travel time between zone i and zone j. We calculate the walking time and the bus travel time using Google maps. The equation is as follow:

$$T = \sum_{i,j} q_{ij} \left\{ \left(\frac{\overline{d_i}}{v_o}\right) + \sum_a \frac{l_a}{v_a} \delta_{a,ij} + \left(\frac{\overline{d_j}}{v_o}\right) \right\} \tag{3}$$

Where q_{ij}, is the number of trips from zone i to zone j, which is determined by the Gravity model.

As Xie and Levinson (2009) [9] mentioned in their research the total travel time enhances three parts: the first part calculates the average walking time from zone i to the nearest bus network. The variable $\overline{d_i}$ is the average distance from the zone i to the nearest node of the bus network, while v_o is a specified minimum speed , for accessing the nearest node of the network from zone i. Similarly, the third part calculates the average walking time from the last bus stop to zone j. The second part is the travel time spent on the links along the shortest path, where $\delta_{a,ij}$ is a dummy variable equal to 1 if link a belongs to this shortest path and 0 otherwise. The variable l_a indicates the length of link a, and v_a indicates its average speed.

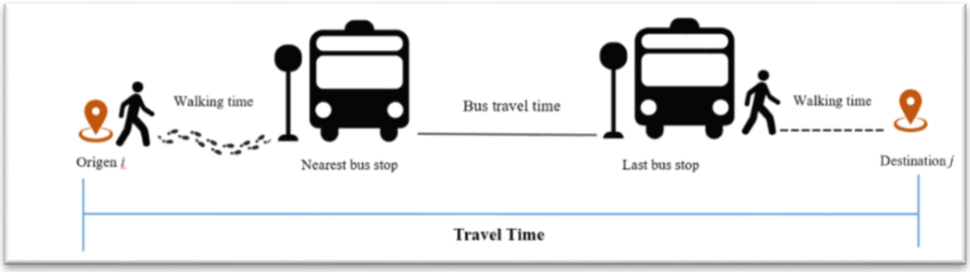

*Figure 4: Travel time from zone **i** to zone **j**.*

Since in Panama more than the 50% of the trips made on public bus implicate one or more transshipments hence, it's difficult to estimate the real travel time. Thus, this research also recorded the number of transfer times that a user has to make from any origin to any destination, and made a sensitivity analysis to compare the transfer time in 5, 10, 15, 30 and 60 minutes.

3.3.1 Gravity Model Application

To calculate the number of trip q_{ij} of equation 3, we used basic Gravity Model equation from Erlander and Stewart (1990) [14], and then applying it to a functional form, for the purpose of this study in this step we used as guideline the equation presented by Hong and Jung (2016) [13]. The functional form of Gravity model is given as follow:

$$q_{ij} = G\frac{M_i^{\alpha} \cdot M_j^{\beta}}{d_{ij}^{\gamma}} \quad (4)$$

Where, G is the gravitational constant; M_i and M_j represent the population of zone i and zone j, respectively; d_{ij} is the distance between zones; α, β, and λ are the exponential parameter to be set.

Additionally, in order to determine the optimal parameter settings of the Gravity Model, we introduced a Genetic Algorithms. The equation is given as follow:

$$Min\ \sum_i \left(\frac{\sum_j q_{ij}}{M_i} - Q\right)^k \quad (5)$$

Where, q_{ij} is number of trips from zone i to zone j, which is determined by the gravity model; M_i is the population of zone i; Q is average number of trips per day per person; and k is a power number. Q and k are given.

3.4 Spatial Accessibility

The spatial accessibility is the ratio between the served surface and the reference territory surface. For the last index S, we used the method provided by Gattuso and Miriello (2005) [11]. The equation is as follow:

$$A_s = \frac{S}{S_u} \, x \, 100\% \tag{6}$$

Where S, is the area served by the network, and S_u is the reference territory surface. As defined by Gattuso and Miriello the served surface S does not often correspond to the administrative borders and when the transport network extends outside of the administrative borders, the reference territory surface is larger than town extension.

In order to determine the spatial accessibility, the method is divided into two approaches the first approach is the node's range of influence and the second approach is the network's coverage.

3.4.1 Node's Range of Influence

The proposed equation 7 to equation 11 are to calculate the range of influence R_i of each node.

$$R_i = R_b \cdot a_1 (0.65 \cdot \frac{n_{Di}}{N_D} + 0.35 \cdot p_{ri}) \tag{7}$$

$$N_D = \frac{1}{N} \sum_i n_{Di} \tag{8}$$

$$p_{ri} = \frac{p_i}{\left({}^1/_N \sum_i p_i\right)} \tag{9}$$

$$p_i = \begin{cases} \delta_i & for\ \delta_1 = 1 \\ 2\delta_i & for\ \delta_1 > 1 \end{cases} \tag{10}$$

Where R_b, standard range, represent the average walking distance average accepted by the users (R_b =500 m); n_{Di}, is the number of destinations directly connected by node i; N_D, is the average number of destinations directly connected by node i; p_{ri}, represent the average node weight; and a_1: would depend of the node location; the variables ***0.65*** and ***0.35*** are two coefficient used to weight the contributions of the ratio between (n_{Di} / N_D) and p_{ri}, obtained from the Gattuso and Miriello (2005) [11].

According to the Transit and Transportation Authority of Panama, the land use is classified into two categories, "center areas" or "suburbs areas". In equation 7, a_1 can be defined as 0.5 if the node is located in the "center" (urban planning areas) or 1.0 if the node is located in the "suburbs" (non-urban planning areas). In addition, the information of all the public bus stops location, were obtained by Mi Bus company, as well as the route information of each node.

After collecting the all data mention above is possible to calculate the node weight p_i, and n_{Di}, the number of destinations directly connected by node i. We use Microsoft Excel pivot table to make the analysis the tables.

3.4.2 Network's Coverage

To determine the surface served by the network S, we used the following equations.

$$S_i = \pi \cdot R_i^2 \tag{11}$$

$$ST = \sum_{i \in N_2} (\pi \cdot R_i^2) \tag{12}$$

$$S = ST - [(S_1 \cap S_2) \cup (S_2 \cap S_3) \dots] \tag{13}$$

And for the last step, after calculated the range of influence Ri and inputting the data into QGIS, we obtained the surface served by the network S of Equation 14. Finally, through the buffer analysis, we can find the proportion of the net service range of the public transport network A_s of equation 6.

4. INDEXES CALCULATION: Examples

In this section, we would use examples to explain the calculation method of each of the indexes used in this research.

4.1 Average Shortest Path Length

To generate the Length OD-Matrix, we took the center of each zones and determine the shortest path of all OD combination among the 32 zones of Panama and San Miguelito districts.

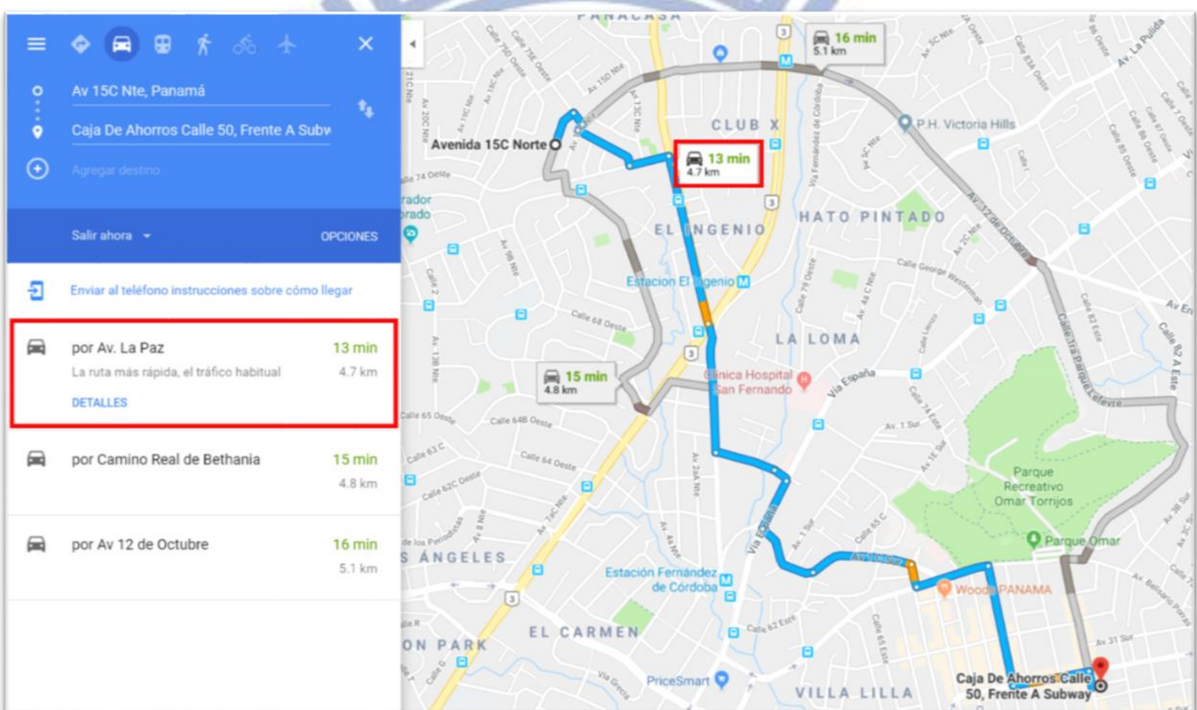

Figure 5: The shortest path length from Bethania to San Francisco
Source: Google Maps.

To illustrate the collection of the shortest path length from zone ***i*** to zone ***j***, we used as an example Bethania as zone ***i*** and San Francisco as zone ***j***.

4.1.1 ***Length Results***

Km		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
San Felipe	1		1.4	1.0	2.9	4.2	9.1	5.3	9.2	7.1	12.4	14.2	21.1	25.5	19.9	32.3	22.7	40.6	33.7	27.5	28.7	31.5	26.9	21.6	13.6	20.1	19.5	17.4	18.1	12.4	16.7	25.0	11.3
El Chorrillo	2	1.4		1.5	3.7	5.9	8.7	6.0	9.2	8.4	13.9	12.8	21.8	26.7	19.9	32.2	21.4	41.5	33.9	26.6	29.8	36.9	24.9	21.1	13.8	20.3	19.7	17.6	19.0	12.6	16.9	25.2	11.5
Santa Ana	3	1.0	1.5		2.6	3.8	8.1	5.7	8.9	8.1	12.8	12.5	21.5	26.0	19.6	31.8	22.4	41.0	35.1	27.9	28.2	31.3	26.6	21.3	18.0	19.1	19.2	17.8	18.5	15.1	17.1	24.6	11.0
Calidonia	4	2.9	3.7	2.6		1.6	6.1	3.2	6.9	5.0	8.8	11.1	19.8	24.3	19.7	28.8	18.1	39.3	31.3	24.1	26.6	29.6	23.5	17.2	10.7	14.6	15.0	15.1	14.0	10.0	14.3	21.6	8.9
Curundu	5	4.2	5.9	3.8	1.6		4.4	2.5	5.1	4.6	8.1	9.4	18.8	22.5	21.8	29.0	16.4	38.3	29.6	22.3	25.5	28.6	20.6	16.8	9.0	15.3	14.7	13.3	11.9	8.3	11.1	21.8	7.2
Bethania	6	8.5	8.7	8.1	6.1	4.4		4.7	1.9	4.7	8.0	6.9	14.1	18.6	24.2	23.5	13.2	37.0	27.5	20.3	26.5	23.7	18.3	12.3	5.8	9.7	10.1	7.9	9.1	5.1	7.9	14.1	4.0
Bella Vista	7	7.0	6.0	5.7	3.2	2.5	4.7		4.8	3.0	7.3	9.0	17.1	21.6	22.2	28.8	18.4	36.6	30.8	23.5	25.5	26.9	23.5	17.3	9.5	15.8	15.2	14.8	14.2	10.2	13.1	18.7	7.7
Pueblo Nuevo	8	9.2	9.2	8.9	6.9	5.1	1.9	4.8		3.9	3.9	4.2	11.7	17.0	27.1	24.2	12.3	31.0	25.1	17.9	18.4	21.3	16.5	11.4	5.0	8.6	9.3	7.1	7.4	4.2	7.0	14.8	3.2
San Francisco	9	7.1	8.4	8.1	5.0	4.6	4.7	3.0	3.9		4.7	6.4	14.3	18.8	25.8	30.3	17.7	33.8	27.9	20.3	21.1	24.1	21.9	16.8	7.9	10.9	12.2	10.1	9.9	6.9	12.4	14.1	6.1
Parque Lefrevre	10	12.4	13.9	12.8	8.8	8.1	8.0	7.3	3.9	4.7		3.4	9.6	16.5	29.9	28.3	14.3	30.3	25.6	17.2	18.7	21.8	19.0	11.6	7.5	7.9	9.1	7.1	6.8	4.0	9.3	11.1	5.6
Rio Abajo	11	14.2	12.8	12.5	11.1	9.4	6.9	9.0	4.2	6.4	3.4		8.0	14.3	31.5	27.4	13.1	28.8	23.0	15.7	16.3	19.1	17.5	9.9	5.8	6.2	7.6	5.6	5.3	2.5	7.3	9.6	4.1
Juan Diaz	12	21.1	21.8	21.5	19.8	18.8	14.1	17.1	11.7	14.3	9.6	8.0		5.9	35.3	38.0	21.5	22.7	18.4	9.6	9.9	14.6	25.6	15.3	12.5	12.7	15.9	12.4	8.5	9.3	16.1	7.6	10.8
Pedregal	13	25.5	26.7	26.0	24.3	22.5	18.6	21.6	17.0	18.8	16.5	14.3	5.9		31.2	32.5	17.3	19.9	14.4	10.6	6.6	10.8	21.5	11.0	13.9	15.5	14.5	13.7	11.7	11.2	12.0	7.6	15.4
Ancon	14	19.9	19.9	19.6	19.7	21.8	24.2	22.2	27.1	25.8	29.9	31.5	35.3	31.2		12.4	23.0	50.5	44.5	36.4	39.5	41.4	16.2	24.7	22.8	24.5	23.9	22.5	25.9	21.9	21.8	29.4	22.6
Chilibre	15	32.3	32.2	31.8	28.8	29.0	23.5	28.8	24.2	30.3	28.3	27.4	38.0	32.5	12.4		18.7	52.5	47.0	46.7	40.8	42.4	11.9	20.4	23.5	25.7	23.0	23.2	29.8	25.3	23.1	30.6	26.8
Las Cumbres	16	22.7	21.4	22.4	18.1	16.4	13.2	18.4	12.3	17.7	14.3	13.1	21.5	17.3	23.0	18.7		35.9	30.0	27.4	25.4	26.7	8.1	8.9	8.7	9.4	8.2	8.4	15.0	10.5	7.4	15.9	10.1
Pacora	17	40.6	41.5	41.0	39.3	38.3	37.0	36.6	31.0	33.8	30.3	28.8	22.7	19.9	50.5	52.5	35.9		8.1	17.2	16.2	10.5	39.4	28.9	31.6	31.7	32.4	31.0	27.6	28.8	29.9	25.5	29.9
San Martin	18	33.7	33.9	35.1	31.3	29.6	27.5	30.8	25.1	27.9	25.6	23.0	18.4	14.4	44.5	47.0	30.0	8.1		11.1	10.3	5.2	33.5	23.0	25.5	26.8	26.5	21.5	23.8	27.5	24.0	19.6	27.4
Tocumen	19	27.5	26.6	27.9	24.1	22.3	20.3	23.5	17.9	20.3	17.2	15.7	9.6	10.6	36.4	46.7	27.4	17.2	11.1		4.0	3.4	30.2	18.5	18.4	18.6	22.0	17.8	14.4	15.6	19.5	13.8	16.7
Las Mañanitas	20	28.7	29.8	28.2	26.6	25.5	26.5	25.5	18.4	21.1	18.7	16.3	9.9	6.6	39.5	40.8	25.4	16.2	10.3	4.0		7.3	30.7	17.6	17.7	17.9	20.1	17.1	13.3	14.1	17.7	11.2	16.0
24 de Diciembre	21	31.5	36.9	31.3	29.6	28.6	23.7	26.9	21.3	24.1	21.8	19.1	14.6	10.8	41.4	42.4	26.7	10.5	5.2	3.4	7.3		30.4	19.9	21.6	24.3	23.4	21.1	17.7	18.9	20.9	16.5	20.0
Alcalde Diaz	22	26.9	24.9	26.6	23.5	20.6	18.3	23.5	16.5	21.9	19.0	17.5	25.6	21.5	16.2	11.9	8.1	39.4	33.5	30.2	30.7	30.4		9.8	12.8	13.5	12.1	12.6	19.1	14.7	11.6	16.5	14.3
Ernesto Cordoba Campos	23	21.6	21.1	21.3	17.2	16.8	12.3	17.3	11.4	16.8	11.6	9.9	15.3	11.0	24.7	20.4	8.9	28.9	23.0	18.5	17.6	19.9	9.8		8.1	4.0	2.2	5.3	13.0	8.4	5.2	8.4	9.6
Amelia Denis de Icaza	24	13.6	13.8	18.0	10.7	9.0	5.8	9.5	5.0	7.9	7.5	5.8	12.5	13.9	22.8	23.5	8.7	31.6	25.5	18.4	17.7	21.6	12.8	8.1		5.8	5.6	3.4	9.5	3.1	3.4	11.1	2.6
Arnulfo Arias	25	20.1	20.3	19.1	14.6	15.3	9.7	15.8	8.6	10.9	7.9	6.2	12.7	15.5	24.5	25.7	9.4	31.7	26.8	18.6	17.9	24.3	13.5	4.0	5.8		1.7	2.8	13.1	4.6	4.4	14.1	6.3
Belisario Frias	26	19.5	19.7	19.2	15.0	14.7	10.1	15.2	9.3	12.2	9.1	7.6	15.9	14.5	23.9	23.0	8.2	32.4	26.5	22.0	20.1	23.4	12.1	2.2	5.6	1.7		2.9	12.3	6.0	3.5	13.2	7.5
Belisario Porras	27	17.4	17.6	17.8	15.1	13.3	7.9	14.8	7.1	10.1	7.1	5.6	12.4	13.7	22.5	23.2	8.4	31.0	21.5	17.8	17.1	21.1	12.6	5.3	3.4	2.8	2.9		9.9	3.1	3.0	10.8	4.5
Jose Domingo Espinar	28	18.1	19.0	18.5	14.0	11.9	9.1	14.2	7.4	9.9	6.8	5.3	8.5	11.7	25.9	29.8	15.0	27.6	23.8	14.4	13.3	17.7	19.1	13.0	9.5	13.1	12.3	9.9		4.0	9.3	8.3	5.6
Mateo Iturrale	29	12.4	12.6	15.1	10.0	8.3	5.1	10.2	4.2	6.9	4.0	2.5	9.3	11.2	21.9	25.3	10.5	28.8	27.5	15.6	14.1	18.9	14.7	8.4	3.1	4.6	6.0	3.1	4.0		5.2	13.0	2.1
Omar Torrijos	30	16.7	16.9	17.1	14.3	11.1	7.9	13.1	7.0	12.4	9.3	7.3	16.1	12.0	21.8	23.1	7.4	29.9	24.0	19.5	17.7	20.9	11.6	5.2	3.4	4.4	3.5	3.0	9.3	5.2		11.1	5.4
Rufina Alfaro	31	25.0	25.2	24.6	21.6	21.8	14.1	18.7	14.8	14.1	11.1	9.6	7.6	7.6	29.4	30.6	15.9	25.5	19.6	13.8	11.2	16.5	16.5	8.4	11.1	14.1	13.2	10.8	8.3	13.0	11.1		9.9
Victoriano Lorenzo	32	11.3	11.5	11.0	8.9	7.2	4.0	7.7	3.2	6.1	5.6	4.1	10.8	15.4	22.6	26.8	10.1	29.9	27.4	16.7	16.0	20.0	14.3	9.6	2.6	6.3	7.5	4.5	5.6	2.1	5.4	9.9	

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16.7832

Table 2: Length OD-Matrix (walking distance + bus travel distance).

Following the example above, we can perceive the input of the distance from Bethania to San Francisco is 4.7 km (red square), determined in the previous step. By summing up the whole matrix and divide by *N(N-1)*, Which is [32(32-1)] = [32x31], we can obtain the average shortest path length of Panama and San Miguelito districts

4.2 Network Efficiency

Km		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
San Felipe	1		0.7143	1.0000	0.3448	0.2381	0.1099	0.1887	0.1087	0.1408	0.0806	0.0704	0.0474	0.0392	0.0503	0.0310	0.0441	0.0246	0.0297	0.0364	0.0348	0.0317	0.0372	0.0463	0.0735	0.0498	0.0513	0.0575	0.0552	0.0806	0.0599	0.0400	0.0885
El Chorrillo	2	0.7143		0.6667	0.2703	0.1695	0.1149	0.1667	0.1087	0.1190	0.0719	0.0781	0.0459	0.0375	0.0503	0.0311	0.0467	0.0241	0.0295	0.0376	0.0336	0.0271	0.0402	0.0474	0.0725	0.0493	0.0508	0.0568	0.0526	0.0794	0.0592	0.0397	0.0870
Santa Ana	3	1.0000	0.6667		0.3846	0.2632	0.1235	0.1754	0.1124	0.1235	0.0781	0.0800	0.0465	0.0385	0.0510	0.0314	0.0446	0.0244	0.0285	0.0358	0.0355	0.0319	0.0376	0.0469	0.0556	0.0524	0.0521	0.0562	0.0541	0.0662	0.0585	0.0407	0.0909
Calidonia	4	0.3448	0.2703	0.3846		0.6250	0.1639	0.3125	0.1449	0.2000	0.1136	0.0901	0.0505	0.0412	0.0508	0.0347	0.0552	0.0254	0.0319	0.0415	0.0376	0.0338	0.0426	0.0581	0.0935	0.0685	0.0667	0.0662	0.0714	0.1000	0.0699	0.0463	0.1124
Curundu	5	0.2381	0.1695	0.2632	0.6250		0.2273	0.4000	0.1961	0.2174	0.1235	0.1064	0.0532	0.0444	0.0459	0.0345	0.0610	0.0261	0.0338	0.0448	0.0392	0.0350	0.0485	0.0595	0.1111	0.0654	0.0680	0.0752	0.0840	0.1205	0.0901	0.0459	0.1389
Bethania	6	0.1176	0.1149	0.1235	0.1639	0.2273		0.2128	0.5263	0.2128	0.1250	0.1449	0.0709	0.0538	0.0413	0.0426	0.0758	0.0270	0.0364	0.0493	0.0377	0.0422	0.0546	0.0813	0.1724	0.1031	0.0990	0.1266	0.1099	0.1961	0.1266	0.0709	0.2500
Bella Vista	7	0.1429	0.1667	0.1754	0.3125	0.4000	0.2128		0.2083	0.3333	0.1370	0.1111	0.0585	0.0463	0.0450	0.0347	0.0543	0.0273	0.0325	0.0426	0.0392	0.0372	0.0426	0.0578	0.1053	0.0633	0.0658	0.0676	0.0704	0.0980	0.0763	0.0535	0.1299
Pueblo Nuevo	8	0.1087	0.1087	0.1124	0.1449	0.1961	0.5263	0.2083		0.2564	0.2564	0.2381	0.0855	0.0588	0.0369	0.0413	0.0813	0.0323	0.0398	0.0559	0.0543	0.0469	0.0606	0.0877	0.2000	0.1163	0.1075	0.1408	0.1351	0.2381	0.1429	0.0676	0.3125
San Francisco	9	0.1408	0.1190	0.1235	0.2000	0.2174	0.2128	0.3333	0.2564		0.2128	0.1563	0.0699	0.0532	0.0388	0.0330	0.0565	0.0296	0.0358	0.0493	0.0474	0.0415	0.0457	0.0595	0.1266	0.0917	0.0820	0.0990	0.1010	0.1449	0.0806	0.0709	0.1639
Parque Lefrevre	10	0.0806	0.0719	0.0781	0.1136	0.1235	0.1250	0.1370	0.2564	0.2128		0.2941	0.1042	0.0606	0.0334	0.0353	0.0699	0.0330	0.0391	0.0581	0.0535	0.0459	0.0526	0.0862	0.1333	0.1266	0.1099	0.1408	0.1471	0.2500	0.1075	0.0901	0.1786
Rio Abajo	11	0.0704	0.0781	0.0800	0.0901	0.1064	0.1449	0.1111	0.2381	0.1563	0.2941		0.1250	0.0699	0.0317	0.0365	0.0763	0.0347	0.0435	0.0637	0.0613	0.0524	0.0571	0.1010	0.1724	0.1613	0.1316	0.1786	0.1887	0.4000	0.1370	0.1042	0.2439
Juan Diaz	12	0.0474	0.0459	0.0465	0.0505	0.0532	0.0709	0.0585	0.0855	0.0699	0.1042	0.1250		0.1695	0.0283	0.0263	0.0465	0.0441	0.0543	0.1042	0.1010	0.0685	0.0391	0.0654	0.0800	0.0787	0.0629	0.0806	0.1176	0.1075	0.0621	0.1316	0.0926
Pedregal	13	0.0392	0.0375	0.0385	0.0412	0.0444	0.0538	0.0463	0.0588	0.0532	0.0606	0.0699	0.1695		0.0321	0.0308	0.0578	0.0503	0.0694	0.0943	0.1515	0.0926	0.0465	0.0909	0.0719	0.0645	0.0690	0.0730	0.0855	0.0893	0.0833	0.1316	0.0649
Ancon	14	0.0503	0.0503	0.0510	0.0508	0.0459	0.0413	0.0450	0.0369	0.0388	0.0334	0.0317	0.0283	0.0321		0.0806	0.0435	0.0198	0.0225	0.0275	0.0253	0.0242	0.0617	0.0405	0.0439	0.0408	0.0418	0.0444	0.0386	0.0457	0.0459	0.0340	0.0442
Chilibre	15	0.0310	0.0311	0.0314	0.0347	0.0345	0.0426	0.0347	0.0413	0.0330	0.0353	0.0365	0.0263	0.0308	0.0806		0.0535	0.0190	0.0213	0.0214	0.0245	0.0236	0.0840	0.0490	0.0426	0.0389	0.0435	0.0431	0.0336	0.0395	0.0433	0.0327	0.0373
Las Cumbres	16	0.0441	0.0467	0.0446	0.0552	0.0610	0.0758	0.0543	0.0813	0.0565	0.0699	0.0763	0.0465	0.0578	0.0435	0.0535		0.0279	0.0333	0.0365	0.0394	0.0375	0.1235	0.1124	0.1149	0.1064	0.1220	0.1190	0.0667	0.0952	0.1351	0.0629	0.0990
Pacora	17	0.0246	0.0241	0.0244	0.0254	0.0261	0.0270	0.0273	0.0323	0.0296	0.0330	0.0347	0.0441	0.0503	0.0198	0.0190	0.0279		0.1235	0.0581	0.0617	0.0952	0.0254	0.0346	0.0316	0.0315	0.0309	0.0323	0.0362	0.0347	0.0334	0.0392	0.0334
San Martin	18	0.0297	0.0295	0.0285	0.0319	0.0338	0.0364	0.0325	0.0398	0.0358	0.0391	0.0435	0.0543	0.0694	0.0225	0.0213	0.0333	0.1235		0.0901	0.0971	0.1923	0.0299	0.0435	0.0392	0.0373	0.0377	0.0465	0.0420	0.0364	0.0417	0.0510	0.0365
Tocumen	19	0.0364	0.0376	0.0358	0.0415	0.0448	0.0493	0.0426	0.0559	0.0493	0.0581	0.0637	0.1042	0.0943	0.0275	0.0214	0.0365	0.0581	0.0901		0.2500	0.2941	0.0331	0.0541	0.0543	0.0538	0.0455	0.0562	0.0694	0.0641	0.0513	0.0725	0.0599
Las Mañanitas	20	0.0348	0.0336	0.0355	0.0376	0.0392	0.0377	0.0392	0.0543	0.0474	0.0535	0.0613	0.1010	0.1515	0.0253	0.0245	0.0394	0.0617	0.0971	0.2500		0.1370	0.0326	0.0568	0.0565	0.0559	0.0498	0.0585	0.0752	0.0709	0.0565	0.0893	0.0625
24 de Diciembre	21	0.0317	0.0271	0.0319	0.0338	0.0350	0.0422	0.0372	0.0469	0.0415	0.0459	0.0524	0.0685	0.0926	0.0242	0.0236	0.0375	0.0952	0.1923	0.2941	0.1370		0.0329	0.0503	0.0463	0.0412	0.0427	0.0474	0.0565	0.0529	0.0478	0.0606	0.0500
Alcalde Diaz	22	0.0372	0.0402	0.0376	0.0426	0.0485	0.0546	0.0426	0.0606	0.0457	0.0526	0.0571	0.0391	0.0465	0.0617	0.0840	0.1235	0.0254	0.0299	0.0331	0.0326	0.0329		0.1020	0.0781	0.0741	0.0826	0.0794	0.0524	0.0680	0.0862	0.0606	0.0699
Ernesto Cordoba Campos	23	0.0463	0.0474	0.0469	0.0581	0.0595	0.0813	0.0578	0.0877	0.0595	0.0862	0.1010	0.0654	0.0909	0.0405	0.0490	0.1124	0.0346	0.0435	0.0541	0.0568	0.0503	0.1020		0.1235	0.2500	0.4545	0.1887	0.0769	0.1190	0.1923	0.1190	0.1042
Amelia Denis de Icaza	24	0.0735	0.0725	0.0556	0.0935	0.1111	0.1724	0.1053	0.2000	0.1266	0.1333	0.1724	0.0800	0.0719	0.0439	0.0426	0.1149	0.0316	0.0392	0.0543	0.0565	0.0463	0.0781	0.1235		0.1724	0.1786	0.2941	0.1053	0.3226	0.2941	0.0901	0.3846
Arnulfo Arias	25	0.0498	0.0493	0.0524	0.0685	0.0654	0.1031	0.0633	0.1163	0.0917	0.1266	0.1613	0.0787	0.0645	0.0408	0.0389	0.1064	0.0315	0.0373	0.0538	0.0559	0.0412	0.0741	0.2500	0.1724		0.5882	0.3571	0.0763	0.2174	0.2273	0.0709	0.1587
Belisario Frias	26	0.0513	0.0508	0.0521	0.0667	0.0680	0.0990	0.0658	0.1075	0.0820	0.1099	0.1316	0.0629	0.0690	0.0418	0.0435	0.1220	0.0309	0.0377	0.0455	0.0498	0.0427	0.0826	0.4545	0.1786	0.5882		0.3448	0.0813	0.1667	0.2857	0.0758	0.1333
Belisario Porras	27	0.0575	0.0568	0.0562	0.0662	0.0752	0.1266	0.0676	0.1408	0.0990	0.1408	0.1786	0.0806	0.0730	0.0444	0.0431	0.1190	0.0323	0.0465	0.0562	0.0585	0.0474	0.0794	0.1887	0.2941	0.3571	0.3448		0.1010	0.3226	0.3333	0.0926	0.2222
Jose Domingo Espinar	28	0.0552	0.0526	0.0541	0.0714	0.0840	0.1099	0.0704	0.1351	0.1010	0.1471	0.1887	0.1176	0.0855	0.0386	0.0336	0.0667	0.0362	0.0420	0.0694	0.0752	0.0565	0.0524	0.0769	0.1053	0.0763	0.0813	0.1010		0.2500	0.1075	0.1205	0.1786
Mateo Iturrale	29	0.0806	0.0794	0.0662	0.1000	0.1205	0.1961	0.0980	0.2381	0.1449	0.2500	0.4000	0.1075	0.0893	0.0457	0.0395	0.0952	0.0347	0.0364	0.0641	0.0709	0.0529	0.0680	0.1190	0.3226	0.2174	0.1667	0.3226	0.2500		0.1923	0.0769	0.4762
Omar Torrijos	30	0.0599	0.0592	0.0585	0.0699	0.0901	0.1266	0.0763	0.1429	0.0806	0.1075	0.1370	0.0621	0.0833	0.0459	0.0433	0.1351	0.0334	0.0417	0.0513	0.0565	0.0478	0.0862	0.1923	0.2941	0.2273	0.2857	0.3333	0.1075	0.1923		0.0901	0.1852
Rufina Alfaro	31	0.0400	0.0397	0.0407	0.0463	0.0459	0.0709	0.0535	0.0676	0.0709	0.0901	0.1042	0.1316	0.1316	0.0340	0.0327	0.0629	0.0392	0.0510	0.0725	0.0893	0.0606	0.0606	0.1190	0.0901	0.0709	0.0758	0.0926	0.1205	0.0769	0.0901		0.1010
Victoriano Lorenzo	32	0.0885	0.0870	0.0909	0.1124	0.1389	0.2500	0.1299	0.3125	0.1639	0.1786	0.2439	0.0926	0.0649	0.0442	0.0373	0.0990	0.0334	0.0365	0.0599	0.0625	0.0500	0.0699	0.1042	0.3846	0.1587	0.1333	0.2222	0.1786	0.4762	0.1852	0.1010	

F
0.092292

Table 3: Efficiency OD-Matrix

To the calculation of the average shortest path length, to calculate the network efficiency, we first create an efficiency OD table by taking the average shortest path length table, obtained in the previous part, and calculate the inverse of the distance $\boldsymbol{d_{ij}}$, of each OD pair, then by summing up the efficiency OD table and divided by the number of zones *N(N-1)*, we obtained the network efficiency of Panama City, which is 0.092 km

4.3 Total Travel Time

To prepare the Time OD-Matrix and be able to calculate the index ***T***, we used the four-step model proposed by Xie and Levinson [9].

To illustrate how we prepare the Time OD-Matrix we used as an example, Parque Lefevre as zone ***i*** and Las Cumbres as zone ***j***. Having said this, to go from Parque Lefevre to Las Cumbres, the total travel time would be 1 hour 16 minutes. Shown in Fig 8 to Fig 12.

Step 1: The first step is determining the best route, including the walking time and bus travel time. For this step, we used the result of the Length OD-Matrix, since both meet the same characteristics.

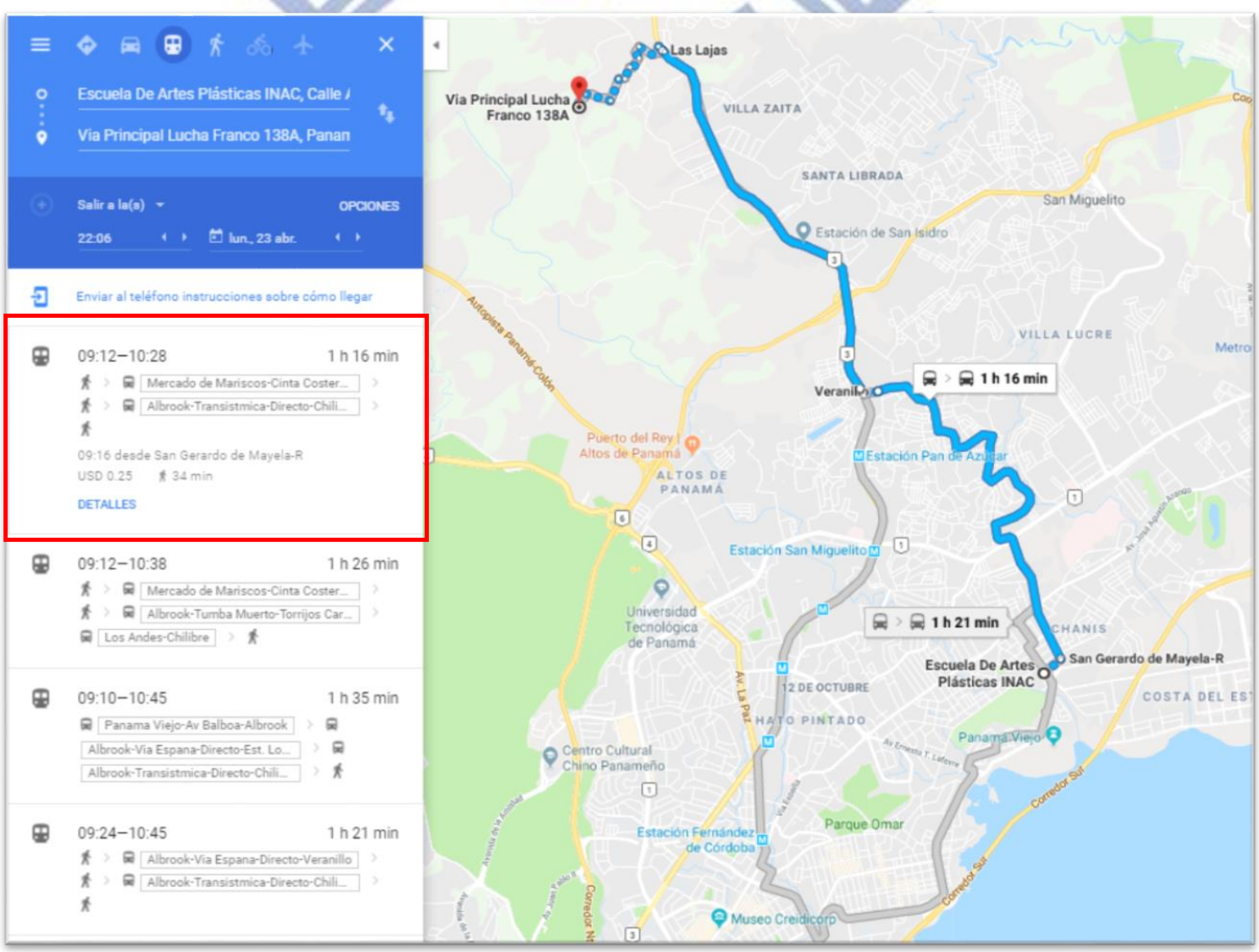

Figure 6: Best route from Parque Lefevre to Las Cumbres.

Step 2: Estimate the total walking time from the zone ***i*** to the nearest bus stop, change bus stops, and from the last bus stop to zone ***j***. In this example after the first bus trip, the user must change bus stop to take the next trip that will take him/her to their destination. Shown in Fig 9 to Fig 11.

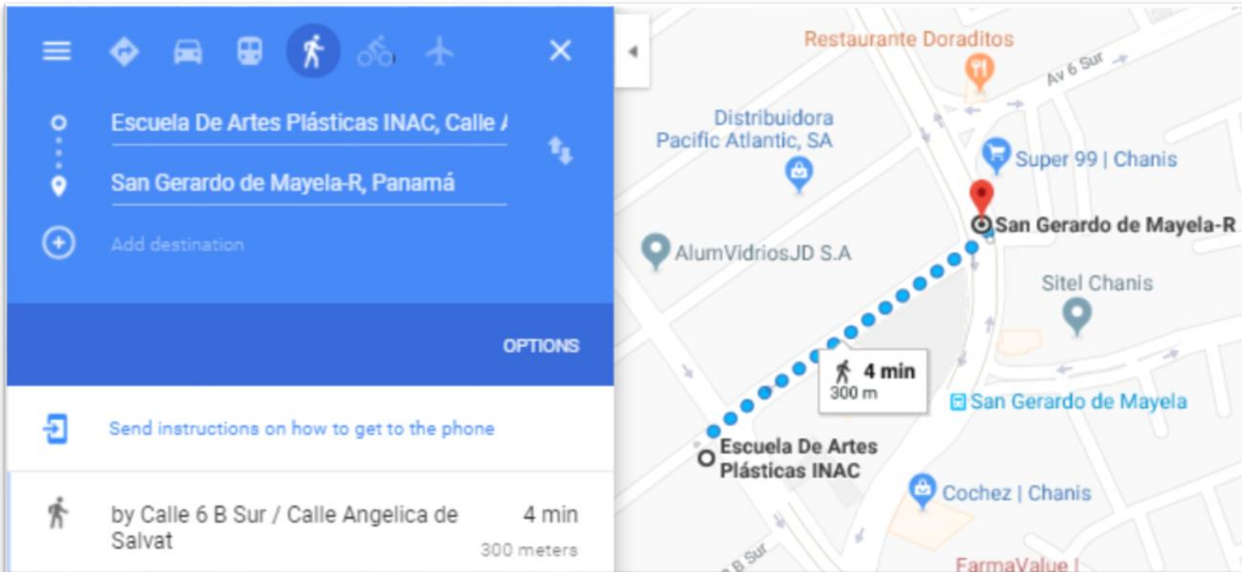

Figure 7: Walking time from the zone ***i*** *to the nearest bus stops.*

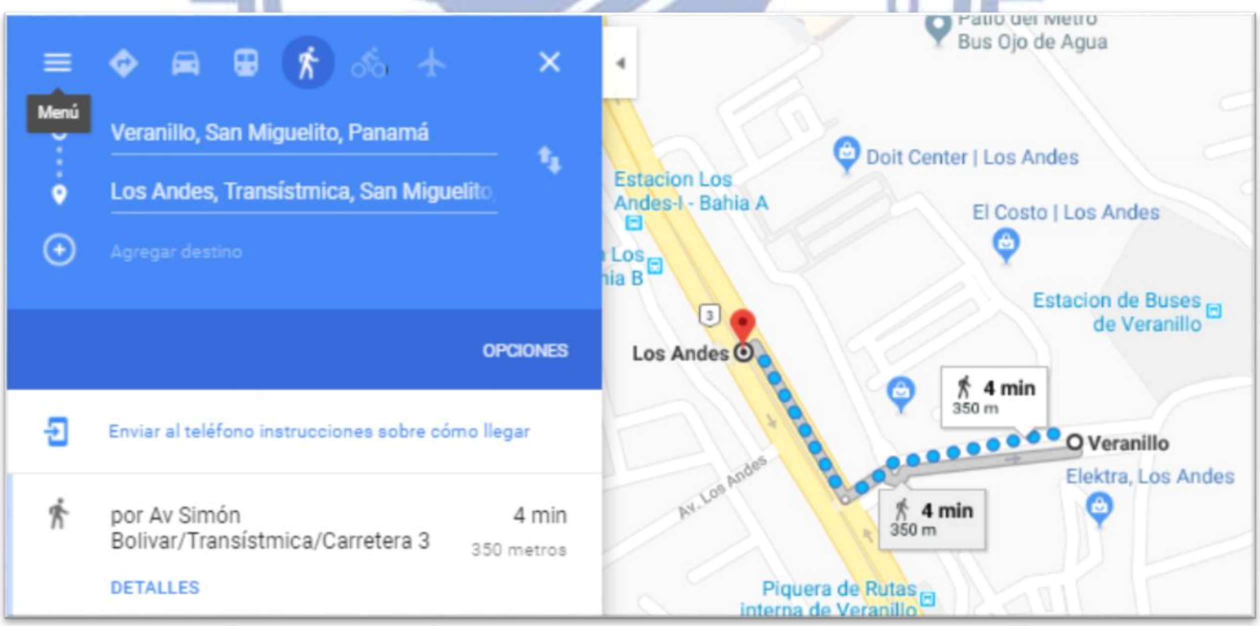

Figure 8: Walking time to change bus stops.

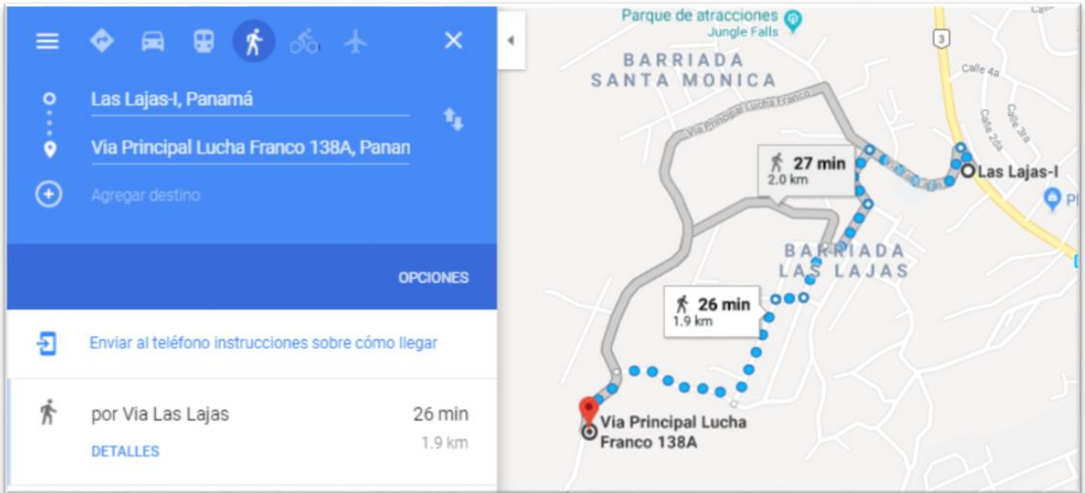

*Figure 9: Walking time from the last stop to zone **j**.*

Step 3: Calculate the total travel time, adding the total walking time with the bus travel time.

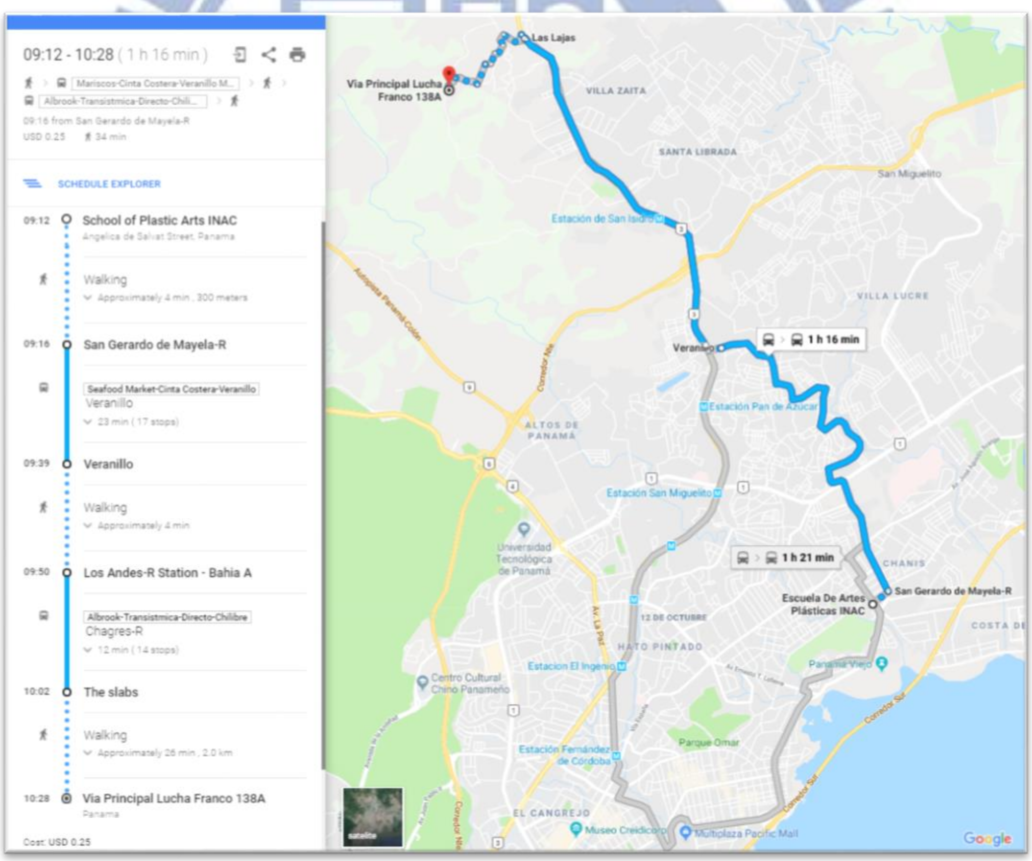

Figure 10: Total travel time from Parque Lefevre to Las Cumbres

The total travel time including walking time and bus travel time is 1 hour 16 minutes (or 76 minutes).

Step 4: Prepare the Initial Travel Time matrix, with all the OD combinations.

Min		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*
San Felipe	*1*		16	12	25	29	59	31	67	43	57	64	57	76	64	81	116	84	119	52	84	71	84	84	56	63	56	64	79	53	51	72	48
El Chorrillo	*2*	16		16	28	33	59	38	74	49	63	64	64	93	68	84	119	88	127	88	125	75	83	90	68	70	65	73	83	57	57	102	50
Santa Ana	*3*	12	16		19	21	50	23	43	40	57	53	57	91	61	99	83	90	113	52	78	72	71	78	51	67	60	66	80	57	38	61	48
Calidonia	*4*	25	28	19		5	34	18	32	30	35	40	52	67	49	76	67	84	125	69	72	67	52	66	33	61	57	55	68	39	27	48	35
Curundu	*5*	29	33	21	5		25	18	28	28	37	34	61	69	70	60	62	93	119	56	83	78	51	68	28	51	35	46	51	27	31	45	22
Bethania	*6*	59	59	50	34	25		30	21	54	53	43	71	81	79	89	73	110	123	60	86	85	57	73	40	55	47	54	65	39	35	56	27
Bella Vista	*7*	31	38	23	18	18	30		28	19	32	36	69	77	72	71	78	98	117	54	91	77	58	77	43	59	54	53	67	46	26	67	35
Pueblo Nuevo	*8*	67	74	43	32	28	21	28		29	33	30	75	65	71	80	73	104	122	58	81	76	52	65	31	46	45	43	55	29	29	58	33
San Francisco	*9*	43	49	40	30	28	54	19	29		20	27	63	77	90	101	92	91	114	56	74	78	66	92	47	67	55	52	75	41	45	72	46
Parque Lefrevre	*10*	57	63	57	35	37	53	32	33	20		18	45	62	96	103	76	81	117	51	68	78	83	74	41	70	48	38	56	22	37	68	31
Rio Abajo	*11*	64	64	53	40	34	43	36	30	27	18		45	66	95	100	75	91	110	52	65	79	77	85	35	57	42	32	50	16	31	63	26
Juan Diaz	*12*	65	64	57	52	61	71	69	75	63	45	45		38	104	122	115	83	106	40	49	65	106	108	71	86	72	66	69	51	71	46	53
Pedregal	*13*	81	93	91	67	69	81	77	65	77	62	66	38		129	130	116	82	93	39	46	65	115	120	67	90	74	70	65	56	62	50	58
Ancon	*14*	64	68	61	49	70	79	72	71	90	96	95	104	129		34	91	132	150	116	114	112	48	103	96	101	87	95	115	101	100	117	74
Chilibre	*15*	81	84	99	76	60	89	71	80	101	103	100	122	130	34		68	109	123	104	106	94	42	96	62	68	64	66	95	67	38	105	58
Las Cumbres	*16*	116	90	83	67	62	73	78	73	92	76	75	115	116	91	68		106	140	99	94	87	43	77	59	63	53	54	88	63	31	85	47
Pacora	*17*	84	88	90	84	93	110	98	104	91	81	91	83	82	132	109	106		52	44	46	32	95	102	84	99	84	86	92	89	58	78	84
San Martin	*18*	112	127	113	125	119	123	117	122	114	117	110	106	93	150	123	140	52		68	67	53	107	120	96	107	114	100	101	103	87	98	111
Tocumen	*19*	55	88	52	69	56	60	54	58	56	51	52	40	39	116	104	99	44	68		26	23	107	91	65	80	72	66	60	50	53	46	49
Las Mañanitas	*20*	84	125	78	72	83	86	91	81	74	68	65	49	46	114	106	94	46	67	26		56	86	114	72	96	95	85	75	65	68	60	68
24 de Diciembre	*21*	71	75	72	67	78	85	77	76	78	78	79	65	65	112	94	87	32	53	23	56		75	94	90	89	75	83	83	75	57	81	70
Alcalde Diaz	*22*	84	83	71	52	51	57	58	52	66	83	77	106	115	48	42	43	95	107	107	86	75		82	45	55	49	48	84	57	24	84	46
Ernesto Cordoba Campos	*23*	84	90	78	66	68	73	77	65	92	74	85	108	120	103	96	77	102	120	91	114	94	82		57	44	28	49	99	78	48	102	59
Amelia Denis de Icaza	*24*	56	68	51	33	28	40	43	31	47	41	35	71	67	96	62	59	84	96	65	72	90	45	57		41	28	33	54	34	17	63	15
Arnulfo Arias	*25*	63	70	67	61	51	55	59	46	67	70	57	86	90	101	68	63	99	107	80	96	89	55	44	41		18	31	86	56	28	91	49
Belisario Frias	*26*	56	65	60	57	35	47	54	45	55	48	42	72	74	87	64	53	84	114	72	95	75	49	28	28	18		20	72	49	20	75	33
Belisario Porras	*27*	64	73	66	55	46	54	53	43	52	38	32	66	70	95	66	54	86	100	66	85	83	48	49	33	31	20		69	29	23	63	28
Jose Domingo Espinar	*28*	79	83	80	68	51	65	67	55	75	56	50	69	65	115	95	88	92	101	60	75	83	84	99	54	86	72	69		42	46	59	35
Mateo Iturrale	*29*	53	57	57	39	27	39	46	29	41	22	16	51	56	101	67	63	89	103	50	65	75	57	78	34	56	49	29	42		28	56	24
Omar Torrijos	*30*	51	57	38	27	31	35	26	29	45	37	31	71	62	100	38	31	58	87	53	68	57	24	48	17	28	20	23	46	28		63	18
Rufina Alfaro	*31*	72	102	61	48	45	56	67	58	72	68	63	46	50	117	105	85	78	98	46	60	81	84	102	63	91	75	63	59	56	63		36
Victoriano Lorenzo	*32*	48	50	48	35	22	27	35	33	46	31	26	53	58	74	58	47	84	111	49	68	70	46	59	15	49	33	28	35	24	18	36	

Table 4: Initial Travel Time OD-Matrix (total walking time + travel time).

Following the example above, in the red square we can observe the input of total travel time from Parque Lefevre to Las Cumbres is 76 minutes (or 1 hour 16 minutes).

4.3.1 Transfer Times

In order to explain the calculation of the times the user has to make a transshipment to reach their final destination. Continuing with the previous example we used Parque Lefevre as zone ***i***. Thus, to illustrate this example, to go from Parque Lefevre to Las Cumbres the user needs to transfer one time.

Therefore, based on the Time OD-Matrix above, we already know the initial travel time, and so to obtain the outcomes we multiply the number of transfer times (1) by the transfer time minutes (5, 10, 15, 30, and 60) and then we add it to the initial time (which is 76). In other words, if the user has to wait the 5 minutes to make a transshipment, the total travel time now would be 81 minutes, instead of 76 minutes, if the user has to wait 10 minutes then the total travel time would be 86 minutes, and so on. As we can observe in Table 4. In the case we have 2 or more transshipments, the procedure is the same, we multiply the number of transfer times by the transfer times minutes (5, 10, 15, 30 and 60 minutes) and then adding up to the initial travel time.

Finally, to obtain the overall Time OD-Matrix (after the sensitivity analysis) we recorded the number of transshipment for each OD combination, then multiply by the transfer times minutes (5, 10, 15, 30 and 60 minutes) and then adding up to the respectively initial travel time.

Corregiminetos		Initial Travel Time	Transfer Times	Sensitivity Analysis (min)				
i	*j*			5	10	15	30	60
Parque Lefevre	Rio Abajo	18	0	18	18	18	18	18
	Juan Diaz	45	0	45	45	45	45	45
	Pedregal	62	0	62	62	62	62	62
	Ancon	96	1	101	106	111	126	156
	Chilibre	103	1	108	113	118	133	163
	Las Cumbres	76	1	81	86	91	106	136
	Pacora	81	1	86	91	96	111	141
	San Martin	117	1	122	127	132	147	177
	Tocumen	51	0	51	51	51	51	51
	Las Mañanitas	68	0	68	68	68	68	68
	24 de Diciembre	78	0	78	78	78	78	78
	Alcalde Diaz	83	2	93	103	113	143	203
	Ernesto Cordoba Campos	74	1	79	84	89	104	134
	Amelia Denis de Icaza	41	0	41	41	41	41	41
	Arnulfo Arias	70	1	75	80	85	100	130
	Belisario Frias	48	1	53	58	63	78	108
	Belisario Porras	38	0	38	38	38	38	38
	Jose Domingo Espinar	56	1	61	66	71	86	116
	Mateo Iturrale	22	0	22	22	22	22	22
	Omar Torrijos	37	1	42	47	52	67	97
	Rufina Alfaro	68	1	73	78	83	98	128
	Victoriano Lorenzo	31	1	36	41	46	61	91

Table 5: Transfer Times -Sensitivity Analysis.

4.3.2 Gravity Model

In order to calculate the travel demand OD-Matrix, first we had to determine the parameter settings of the Equation 4, and to do so, we introduced a Genetic Algorithm where the average number of trips per day per person $\boldsymbol{T}$ and the power number $\boldsymbol{k}$, are given. By using the Evolver software, we obtained the optimal parameter, given as follow: $\boldsymbol{G}$ = 9.809E-07; $\boldsymbol{\alpha}$ = 1.021; $\boldsymbol{\beta}$ = 1.031; $\boldsymbol{\lambda}$ = 0. After the parameter are all set, we were able to prepare the travel demand OD-Matrix. As we can see in Table 7.

4.3.3 Total Travel Time Results

To illustrate the results of this part we selected as an example the transfer times table (*10 minutes)* from the sensitivity analysis. Once we calculated the Transfer Times OD-Matrix, can obtain the total travel time $\boldsymbol{T}$ of Panama City, by multiplying the Transfer Time OD-Matrix with the Travel Demand OD-Matrix, estimated by Gravity Model, as shown in Tables 6 to Table 8.

Transfer time: (10 min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
San Felipe	1		16	12	25	29	59	31	67	43	57	64	65	81	74	81	100	84	112	55	84	71	94	84	56	63	56	64	79	53	51	82	48
El Chorrillo	2	16		16	38	43	69	48	84	49	73	74	64	103	88	94	90	98	137	98	135	95	93	110	78	80	75	83	93	67	67	112	60
Santa Ana	3	12	16		19	21	50	23	53	40	57	53	57	91	71	99	83	90	113	52	78	82	71	78	51	67	60	66	80	57	38	61	48
Calidonia	4	25	38	19		5	34	18	32	30	35	40	52	67	59	76	67	84	125	79	82	77	62	66	33	61	57	55	68	39	27	58	61
Curundu	5	29	43	21	5		25	18	28	38	47	44	71	69	80	70	62	103	129	56	83	88	61	68	28	51	35	46	51	27	31	55	22
Bethania	6	59	69	50	34	25		30	21	64	63	53	71	81	89	89	73	120	133	60	96	95	67	73	40	55	47	54	65	39	35	66	27
Bella Vista	7	31	48	23	18	18	30		28	19	32	36	69	87	82	81	88	108	117	54	91	77	68	87	43	69	64	63	77	46	36	87	35
Pueblo Nuevo	8	67	84	53	32	28	21	28		29	33	30	75	65	81	80	73	114	122	58	81	76	52	75	31	56	55	43	55	29	29	68	33
San Francisco	9	43	49	40	30	38	64	19	29		20	27	73	97	100	111	102	101	124	66	84	88	76	102	47	77	65	52	85	51	55	92	46
Parque Lefrevre	10	57	73	57	35	47	63	32	33	20		18	45	62	106	113	86	91	127	51	68	78	103	84	41	80	58	38	66	22	47	78	41
Rio Abajo	11	64	74	53	40	44	53	36	30	27	18		45	66	105	110	85	101	110	52	65	79	97	95	35	67	52	32	50	16	41	73	36
Juan Diaz	12	65	64	57	52	71	71	69	75	73	45	45		38	124	132	135	93	106	40	49	65	126	128	81	96	92	76	69	61	91	56	53
Pedregal	13	81	103	91	67	69	81	87	65	97	62	66	38		139	140	126	92	103	39	46	75	125	130	77	100	84	80	65	56	72	60	58
Ancon	14	74	88	71	59	80	89	82	81	100	106	105	124	139		44	101	142	160	126	124	122	68	113	106	111	97	105	125	111	110	137	84
Chilibre	15	81	94	99	76	70	89	81	80	111	113	110	132	140	44		68	119	133	114	116	104	52	106	62	78	74	66	105	77	38	125	68
Las Cumbres	16	100	90	83	67	62	73	88	73	102	86	85	135	126	101	68		126	160	109	104	97	43	87	59	73	63	54	98	63	31	105	57
Pacora	17	84	98	90	84	103	120	108	114	101	91	101	93	92	142	119	126		52	54	56	32	105	122	104	99	84	86	102	99	68	98	94
San Martin	18	112	137	113	125	129	133	117	122	124	127	110	106	103	160	133	160	52		78	67	53	127	140	116	127	134	120	111	113	97	118	121
Tocumen	19	55	98	52	79	56	60	54	58	66	51	52	40	39	126	114	109	54	78		26	23	117	101	75	90	82	76	60	50	63	56	59
Las Mañanitas	20	84	135	78	82	83	96	91	81	84	68	65	49	46	124	116	104	56	67	26		66	96	124	82	106	105	95	75	65	78	70	68
24 de Diciembre	21	71	95	82	77	88	95	77	76	88	78	79	65	75	122	104	97	32	53	23	66		85	104	100	99	85	93	83	75	67	91	80
Alcalde Diaz	22	94	93	71	62	61	67	68	52	76	103	97	126	125	68	52	43	105	127	117	96	85		92	82	65	59	48	94	57	24	104	56
Ernesto Cordoba Campos	23	84	110	78	66	68	73	87	75	102	84	95	128	130	113	106	87	122	140	101	124	104	92		57	44	28	49	109	88	48	122	59
Amelia Denis de Icaza	24	56	78	51	33	28	40	43	31	47	41	35	81	77	106	62	59	104	116	75	82	100	82	57		41	28	33	54	34	17	73	15
Arnulfo Arias	25	63	80	67	61	51	55	69	56	77	80	67	96	100	111	78	73	99	127	90	106	99	65	44	41		18	31	96	66	28	101	59
Belisario Frias	26	56	75	60	57	35	47	64	55	65	58	52	92	84	97	74	63	84	134	82	105	85	59	28	28	18		20	82	59	20	85	33
Belisario Porras	27	64	83	66	55	46	54	63	43	52	38	32	76	80	105	66	54	86	120	76	95	93	48	49	33	31	20		69	29	23	83	28
Jose Domingo Espinar	28	79	93	80	68	51	65	77	55	85	66	50	69	65	125	105	98	102	111	60	75	83	94	109	54	96	82	69		42	56	69	35
Mateo Iturrale	29	53	67	57	39	27	39	46	29	51	22	16	61	56	111	77	63	99	113	50	65	75	57	88	34	66	59	29	42		28	76	24
Omar Torrijos	30	51	67	38	27	31	35	36	29	55	47	41	91	72	110	38	31	68	97	63	78	67	24	48	17	28	20	23	56	28		83	18
Rufina Alfaro	31	82	112	61	58	55	66	87	68	92	78	73	56	60	137	125	105	98	118	56	70	91	104	122	73	101	85	83	69	76	83		46
Victoriano Lorenzo	32	48	60	48	61	22	27	35	33	46	41	36	53	58	84	68	57	94	121	59	68	80	56	59	15	59	33	28	35	24	18	46	

Table 6: Transfer Time OD-Matrix (minutes).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
San Felipe	1		101	101	108	90	276	178	109	268	218	153	619	307	254	419	253	371	32	631	327	545	323	436	225	189	265	297	289	66	218	302	91
El Chorrillo	2	101		624	663	552	1701	1098	674	1654	1342	943	3815	1892	1568	2583	1560	2289	195	3891	2012	3360	1991	2685	1387	1164	1633	1832	1780	405	1343	1862	562
Santa Ana	3	101	624		664	553	1702	1099	675	1656	1343	944	3819	1894	1570	2585	1562	2291	195	3894	2014	3363	1993	2688	1388	1165	1635	1834	1782	405	1344	1863	562
Calidonia	4	108	663	664		588	1809	1168	717	1759	1427	1003	4058	2013	1668	2747	1659	2435	208	4138	2140	3573	2118	2856	1475	1238	1737	1949	1893	430	1428	1980	597
Curundu	5	90	552	553	588		1510	975	599	1469	1191	837	3388	1680	1393	2294	1385	2033	173	3455	1787	2983	1768	2385	1231	1034	1450	1627	1581	359	1192	1653	499
Bethania	6	276	1701	1702	1809	1510		2969	1822	4471	3626	2549	10313	5115	4239	6982	4217	6187	528	10517	5439	9081	5382	7259	3749	3147	4415	4953	4812	3749	3630	5032	1518
Bella Vista	7	178	1098	1099	1168	975	2969		1182	2900	2352	1653	6689	3318	2749	4529	2735	4013	342	6821	3528	5890	3491	4708	2431	2041	2864	3213	3121	709	2354	3264	985
Pueblo Nuevo	8	109	674	675	717	599	1822	1182		1789	1451	1020	4126	2047	1696	2794	1687	2475	211	4208	2176	3634	2153	2904	1500	1259	1767	1982	1925	438	1452	2014	607
San Francisco	9	268	1654	1656	1759	1469	4471	2900	1789		3528	2480	10034	4976	4124	6793	4103	6019	514	10232	5292	8835	5236	7062	3647	3062	4296	4819	4681	1064	3531	4896	1477
Parque Lefrevre	10	218	1342	1343	1427	1191	3626	2352	1451	3528		2015	8154	4044	3352	5521	3334	4892	417	8315	4301	7180	4255	5739	2964	2488	3491	3916	3804	865	2870	3979	1200
Rio Abajo	11	153	943	944	1003	837	2549	1653	1020	2480	2015		5752	2853	2364	3894	2352	3451	294	5866	3034	5065	3002	4048	2091	1755	2463	2763	2684	610	2024	2807	847
Juan Diaz	12	619	3815	3819	4058	3388	10313	6689	4126	10034	5752	5752		11383	9434	15539	9386	13769	1175	23405	12105	20211	11978	16154	8342	7004	9826	11023	10708	2434	8078	11200	3378
Pedregal	13	307	1892	1894	2013	1680	5115	3318	2047	4976	4044	2853	11383		4712	7761	4688	6877	587	11689	6046	10094	5982	8068	4166	3498	4908	5505	5348	1216	4034	5594	1687
Ancon	14	254	1568	1570	1668	1393	4239	2749	1696	4124	3352	2364	9434	4712		6444	3892	5710	487	9706	5020	8381	4967	6699	3459	2904	4075	4571	4440	1010	3350	4644	1401
Chilibre	15	419	2583	2585	2747	2294	6982	4529	2794	6793	5521	3894	15539	7761	6444		6379	9358	798	15908	8228	13736	8141	10979	5670	4760	6679	7492	7278	1655	5490	7612	2296
Las Cumbres	16	253	1560	1562	1659	1385	4217	2735	1687	4103	3334	2352	9386	4688	3892	6379		5681	485	9656	4994	8338	4942	6665	3442	2889	4054	4548	4418	1004	3333	4621	1394
Pacora	17	371	2289	2291	2435	2033	6187	4013	2475	6019	4892	3451	13769	6877	5710	9358	5681		708	14113	7299	12187	7222	9740	5030	4223	5925	6647	6457	1468	4871	6753	2037
San Martin	18	32	195	195	208	173	528	342	211	514	417	294	1175	587	487	798	485	708		1234	638	1065	631	852	440	369	518	581	564	128	426	590	178
Tocumen	19	631	3891	3894	4138	3455	10517	6821	4208	10232	8315	5866	23405	11689	9706	15908	9656	14113	1234		12342	20606	12212	16470	8506	7141	10019	11239	10917	2482	8236	11419	3444
Las Mañanitas	20	327	2012	2014	2140	1787	5439	3528	2176	5292	4301	3034	12105	6046	5020	8228	4994	7299	638	12342		10727	6357	8574	4428	3717	5216	5851	5684	1292	4288	5945	1793
24 de Diciembre	21	545	3360	3363	3573	2983	9081	5890	3634	8835	7180	5065	20211	10094	8381	13736	8338	12187	1065	20606	10727		10560	14243	7355	6175	8664	9719	9441	2146	7122	9875	2979
Alcalde Diaz	22	323	1991	1993	2118	1768	5382	3491	2153	5236	4255	3002	11978	5982	4967	8141	4942	7222	631	12212	6357	10560		8485	4382	3679	5161	5790	5624	1279	4243	5883	1774
Ernesto Cordoba Campos	23	436	2685	2688	2856	2385	7259	4708	2904	7062	5739	4048	16154	8068	6699	10979	6665	9740	852	16470	8574	14243	8485		5892	4946	6940	7785	7563	1719	5705	7910	2386
Amelia Denis de Icaza	24	225	1387	1388	1475	1231	3749	2431	1500	3647	2964	2091	8342	4166	3459	5670	3442	5030	440	8506	4428	7355	4382	5892		2571	3608	4047	3931	894	2966	4112	1240
Arnulfo Arias	25	189	1164	1165	1238	1034	3147	2041	1259	3062	2488	1755	7004	3498	2904	4760	2889	4223	369	7141	3717	6175	3679	4946	2571		3034	3404	3306	752	2494	3458	1043
Belisario Frias	26	265	1633	1635	1737	1450	4415	2864	1767	4296	3491	2463	9826	4908	4075	6679	4054	5925	518	10019	5216	8664	5161	6940	3608	3034		4759	4623	1051	3488	4836	1459
Belisario Porras	27	297	1832	1834	1949	1627	4953	3213	1982	4819	3916	2763	11023	5505	4571	7492	4548	6647	581	11239	5851	9719	5790	7785	4047	3404	4759		5180	1178	3908	5418	1634
Jose Domingo Espinar	28	289	1780	1782	1893	1581	4812	3121	1925	4681	3804	2684	10708	5348	4440	7278	4418	6457	564	10917	5684	9441	5624	7563	3931	3306	4623	5180		1144	3797	5265	1588
Mateo Iturrale	29	66	405	405	430	359	1094	709	438	1064	865	610	2434	1216	1010	1655	1004	1468	128	2482	1292	2146	1279	1719	894	752	1051	1178	1144		876	1215	366
Omar Torrijos	30	218	1343	1344	1428	1192	3630	2354	1452	3531	2870	2024	8078	4034	3350	5490	3333	4871	426	8236	4288	7122	4243	5705	2966	2494	3488	3908	3797	876		3983	1201
Rufina Alfaro	31	302	1862	1863	1980	1653	5032	3264	2014	4896	3979	2807	11200	5594	4644	7612	4621	6753	590	11419	5945	9875	5883	7910	4112	3458	4836	5418	5265	1215	3983		1660
Victoriano Lorenzo	32	91	562	562	597	499	1518	985	607	1477	1200	847	3378	1687	1401	2296	1394	2037	178	3444	1793	2979	1774	2386	1240	1043	1459	1634	1588	366	1201	1660	

Table 7: Travel Demand OD-Matrix

Transfer time: (10 min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	∑
San Felipe	1	0	1617	1214	2689	2600	16282	5525	7330	11542	12408	9793	40243	24872	18832	33953	25318	31200	3549	34724	27429	38708	30371	36603	12602	11902	14844	19030	22819	3480	11113	24773	4374	541740
El Chorrillo	2	1617	0	9976	25193	23757	117349	52718	56636	81054	97930	69782	244188	194910	138011	242819	140421	224318	26752	381299	271666	319177	185172	295392	108171	93140	122512	152094	165547	27115	89971	208525	33696	4200909
Santa Ana	3	1214	9976	0	12608	11613	85111	25283	35767	66226	76534	50024	217673	172356	111449	255963	129615	206190	22085	202502	157102	275745	141494	209646	70790	78074	98097	121050	142533	23088	51074	113673	26981	3201535
Calidonia	4	2689	25193	12608	0	2938	61501	21026	22948	52781	49939	40119	211020	134849	98414	208806	111184	204500	25961	326921	175506	275153	131299	188506	48675	75535	99030	107195	128742	16787	38563	114853	36436	3049675
Curundu	5	2600	23757	11613	2938	0	37754	17554	16764	55816	55987	36843	240545	115942	111407	160564	85897	209348	22368	193474	148311	262533	107849	162147	34480	52724	50767	74849	80612	9703	36965	90928	10971	2524010
Bethania	6	16282	117349	85111	61501	37754	0	89060	38272	286156	228442	135093	732227	414310	377280	621424	307862	742442	70199	631007	522175	862729	360588	529873	149940	173081	207520	267468	312748	146192	127040	332144	40986	9024256
Bella Vista	7	5525	52718	25283	21026	17554	89060	0	33097	55100	75259	59516	461541	288625	225456	366823	240708	433390	40053	368342	321041	453540	237367	409583	104545	140835	183280	202392	240295	32636	84752	283972	34460	5587775
Pueblo Nuevo	8	7330	56636	35767	22948	16764	38272	33097	0	51880	47877	30595	309475	133024	137384	223493	123178	282204	25764	244055	176282	276148	111974	217815	46494	70510	97163	85217	105882	12692	42116	136921	20043	3218998
San Francisco	9	11542	81054	66226	52781	55816	286156	55100	51880	0	70556	66956	732455	482707	412424	754036	418509	607958	63676	675302	444524	777507	397943	720311	171407	235749	279219	250584	397897	54277	194225	450445	67936	9387156
Parque Lefrevre	10	12408	97930	76534	49939	55987	228442	75259	47877	70556	0	36276	366933	250738	355276	623826	286760	445154	52999	424073	292443	560057	438289	482076	121515	199051	202477	148816	251080	19027	134883	310359	49209	6766249
Rio Abajo	11	9793	69782	50024	40119	36843	135093	59516	30595	66956	36276	0	258838	188283	248251	428369	199931	348522	32382	305010	197190	400134	291163	384592	73174	117595	128054	88401	134177	9762	83001	204896	30479	4687199
Juan Diaz	12	40243	244188	217673	211020	240545	732227	461541	309475	732455	258838	258838	0	432568	1169838	2051175	1267063	1280546	124513	936211	593160	1313696	1509169	2067709	675732	672341	904024	837766	738857	148502	735097	627193	179051	21971255
Pedregal	13	24872	194910	172356	134849	115942	414310	288625	133024	482707	250738	188283	432568	0	654932	1086511	590626	632670	60426	455886	278106	757042	747747	1048818	320817	349781	412239	440430	347618	68088	290478	335616	97860	11808875
Ancon	14	18832	138011	111449	98414	111407	377280	225456	137384	412424	355276	248251	1169838	654932	0	283532	393103	810813	77938	1222939	622469	1022496	337751	756969	366704	322375	395261	479975	555062	112059	368482	636289	117679	12940851
Chilibre	15	33953	242819	255963	208806	160564	621424	366823	223493	754036	623826	428369	2051175	1086511	283532	0	433777	1113658	106183	1813475	954392	1428590	423315	1163800	351539	371284	494216	494477	764176	127405	208631	951516	156136	18697863
Las Cumbres	16	25318	140421	129615	111184	85897	307862	240708	123178	418509	286760	199931	1267063	590626	393103	433777	0	715790	77541	1052551	519412	808828	212490	579831	203069	210933	255409	245587	432952	63277	103316	485183	79447	10799568
Pacora	17	31200	224318	206190	204500	209348	742442	433390	282204	607958	445154	348522	1280546	632670	810813	1113658	715790	0	36831	762089	408754	389968	758323	1188330	523143	418072	497702	571617	658581	145323	331215	661816	191481	15831952
San Martin	18	3549	26752	22085	25961	22368	70199	40053	25764	63676	52999	32382	124513	60426	77938	106183	77541	36831	0	96232	42753	56464	80183	119212	51010	46885	69408	69727	62654	14501	41303	69664	21547	1710763
Tocumen	19	34724	381299	202502	326921	193474	631007	368342	244055	675302	424073	305010	936211	455886	1222939	1813475	1052551	762089	96232	0	320893	473937	1428778	1663460	637914	642647	821519	854150	655049	124103	518866	639460	203219	19110090
Las Mañanitas	20	27429	271666	157102	175506	148311	522175	321041	176282	444524	292443	197190	593160	278106	622469	954392	519412	408754	42753	320893	0	708015	610317	1063207	363095	394041	547644	555840	426274	83991	334437	416129	121934	12098532
24 de Diciembre	21	38708	319177	275745	275153	262533	862729	453540	276148	777507	560057	400134	1313696	757042	1022496	1428590	808828	389968	56464	473937	708015	0	897632	1481238	735532	611316	736416	903866	783613	160981	477189	898601	238288	19385138
Alcalde Diaz	22	30371	185172	141494	131299	107849	360588	237367	111974	397943	438289	291163	1509169	747747	337751	423315	212490	758323	80183	1428778	610317	897632	0	780587	359300	239103	304508	277910	528680	72884	101828	611788	99367	12815172
Ernesto Cordoba Campos	23	36603	295392	209646	188506	162147	529873	409583	217815	720311	482076	384592	2067709	1048818	756969	1163800	579831	1188330	119212	1663460	1063207	1481238	780587	0	335846	217644	194324	381489	824354	151308	273855	965049	140776	19034351
Amelia Denis de Icaza	24	12602	108171	70790	48675	34480	149940	104545	46494	171407	121515	73174	675732	320817	366704	351539	203069	523143	51010	637914	363095	735532	359300	335846	0	105424	101015	133555	212296	30389	50418	300174	18605	6817372
Arnulfo Arias	25	11902	93140	78074	75535	52724	173081	140835	70510	235749	199051	117595	672341	349781	322375	371284	210933	418072	46885	642647	394041	611316	239103	217644	105424	0	54611	105509	317396	49610	69836	349264	61542	6857809
Belisario Frias	26	14844	122512	98097	99030	50767	207520	183280	97163	279219	202477	128054	904024	412239	395261	494216	255409	497702	69408	821519	547644	736416	304508	194324	101015	54611	0	95186	379103	62014	69753	411022	48133	8336468
Belisario Porras	27	19030	152094	121050	107195	74849	267468	202392	85217	250584	148816	88401	837766	440430	479975	494477	245587	571617	69727	854150	555840	903866	277910	381489	133555	105509	95186	0	357449	34155	89885	449724	45763	8941155
Jose Domingo Espinar	28	22819	165547	142533	128742	80612	312748	240295	105882	397897	251080	134177	738857	347618	555062	764176	432952	658581	62654	655049	426274	783613	528680	824354	212296	317396	379103	357449	0	48065	212653	363282	55584	10706031
Mateo Iturrale	29	3480	27115	23088	16787	9703	42662	32636	12692	54277	19027	9762	148502	68088	112059	127405	63277	145323	14501	124103	83991	160981	72884	151308	30389	49610	62014	34155	48065	0	24531	92318	8794	1873526
Omar Torrijos	30	11113	89971	51074	38563	36965	127040	84752	42116	194225	134883	83001	735097	290478	368482	208631	103316	331215	41303	518866	334437	477189	101828	273855	50418	69836	69753	89885	212653	24531	0	330583	21625	5547687
Rufina Alfaro	31	24773	208525	113673	114853	90928	332144	283972	136921	450445	310359	204896	627193	335616	636289	951516	485183	661816	69664	639460	416129	898601	611788	965049	300174	349264	411022	449724	363282	92318	330583	0	76374	11942534
Victoriano Lorenzo	32	4374	33696	26981	36436	10971	40986	34460	20043	67936	49209	30479	179051	97860	117679	156136	79447	191481	21547	203219	121934	238288	99367	140776	18605	61542	48133	45763	55584	8794	21625	76374	0	2338774

291,755,270

Table 8: Total Travel Time OD-Matrix (Transfer time: 10 min)

4.4 Spatial Accessibility

4.4.1 *Calculation of the Node Weight (Pi)*

To explain the calculation of ***Pi*** we used as an example the route from Albrook to Amandor, as we can see in Figure 11. From Albrook to Calle Van Hook-R we set the direction = 0; and in the opposite direction, from Calle Van Hook-R to Albrook we set the direction = 1. This is to say, When the direction = 0, the value of the bus stop would be either 1 or 2, where, when the value = 1 means, that the bus stop is the starting node or the last node on the route; and when the value = 2, represent that particular bus stops has one bus stops behind and one bus stop ahead. In other words, the bus stops with the value = 2 has 2 adjacent bus stops.

Figure 11: Route from Albrook to Amandor.

For example, in Table 9 we can observe that the value of bus stop *Museo Frank Gehry* is 2, because has 2 adjacent bus stops *Smithsonian* and *Figali-R*. In the case of *Calle Van Hook-R* since is the last stop on the route, the value is equal to 1, because only have 1 adjacent bus stop, *Figali-R*.

In order to avoid double counting when the direction = 1, the value of the bus stops would be 0.

Route ID	SubRoute Name	Direction	Stop ID	Value
Albrook	Albrook - Amador	0	Smithsonian	2
Albrook	Albrook - Amador	0	Museo Frank Gehry	2
Albrook	Albrook - Amador	0	Figali-R	2
Albrook	Albrook - Amador	0	Calle Van Hook-R	1
Albrook	Albrook - Amador	1	Calle Van Hook-R	0
Albrook	Albrook - Amador	1	Figali-R	0
Albrook	Albrook - Amador	1	Museo Frank Gehry	0
Albrook	Albrook - Amador	1	Smithsonian	0

Table 9: Routes and bus stops of Panama and San Miguelito districts. (part of the table)

Then through the Excel pivot analysis table, where the vertical axis represent the bus stops and the horizontal axis is the bus route, we can obtain the sum of the corresponding values of all bus stops out of all the bus routes, which is $\boldsymbol{\delta_i}$ from equation 10. And then we be able to calculate the bus station ***Pi***, as shown in Table 10.

BusStop Names / RouteName	Albrook - Autopista - Chilibre	Albrook - Autopista - Corredor Norte - Chilibre	Albrook - Autopista - Estacion - La Cabima	Albrook - Av Omar Torrijos - Ciudad de Saber	Albrook - Corredor Norte - Ciudad Bolivar	Albrook - Corredor Norte - El Valle	Grand Total	Pi
Abarroteria Griselda							16	32
Abastos-I							2	4
Abastos-R	2	2	2		2	2	98	196
Academia De Policia-I							4	8
Aeropuerto-I							30	60
Aeropuerto-R							36	72
Agua Bendita Abajo-I							10	20
Agua Bendita Interna-I							10	20
Agua Bendita Interna-R		2					10	20
Agua Bendita-I							12	24
Agua Buena-I							8	16
Agua Buena-R							12	24
Alajuela-I							12	24
Alajuela-R	2	2					14	28
Albrook	1	1	1	1	1	1	22	44
Alcalde Diaz-I							2	4

*Table 10: **Pi** pivot table analysis of the routes and bus stops of Panama and San Miguelito districts (part of the table)*

4.4.2 *Calculation of the number of destinations directly connected by node i (nDi)*

Through the pivot analysis table, where the vertical axis represent the bus stops and the horizontal axis the bus route, we can obtain the number of bus stops on each route and ***nDi*** (number of destinations directly connected by node ***i***). Taking as an example the bus stop *Ana*, we can observe in Table 11 that five route pass through the bus stop *Ana*. Consequently, ***nDi*** is the sum of the number of bus stops of the five routes (ex: 43 + 39 + 11 + 39 + 31 = 163).

BusStop Names / RouteName	24 de Dic - La Doña	Albrook - Av Omar Torrijos - Ciudad de Saber	Albrook - Corredor Sur - Pacor	Albrook - Tumba Muerto - Los And	Estacion Marañon - Tumba Muerto - Los An	Los Andes	Los Andes - Tumba Muerto - Albrook	Los Andes - Tumba Muerto - Cerveceria Nacional	Pacora - Corredor Sur - Albrook	nDi
Altos De 24 De Dic	1									14
Altos De Tatare-I									1	36
Altos De Tatare-R			1							35
Ana				1	1	1	1	1		163
Anam		1								19
Total Number of Bus Stops on each Route	14	19	35	43	39	11	39	31	36	

*Table 11: **nDi** pivot table analysis (part of table)*

4.4.3 ***Calculation of the Node Position (a_1)***

As mention in the previous chapter, the land use of Panama City is classified into two categories, "center area" or "suburbs areas". Thus, a_1 can be defined as 0.5 if the bus stops is located in the "center" or 1.0 if the bus stop are located in the "suburbs". Mi Bus Company provide which stop is located in the center or in the suburbs. And with that information we determine the value of a_1 of each stop. As shown in Table 12.

Bus Stop Name	Location	a1
12 De Octubre-I	Center	0.5
12 De Octubre-R	Center	0.5
24 De Dic Interna	Surburb	1
24 De Diciembre-R	Surburb	1
4 De Julio	Center	0.5
Abarroteria Griselda	Surburb	1
Abastos-I	Center	0.5
Abastos-R	Center	0.5
Academia De Policia-I	Center	0.5
Aeropuerto-I	Surburb	1
Aeropuerto-R	Surburb	1
Agua Bendita Abajo-I	Surburb	1
Agua Bendita Interna-I	Surburb	1
Agua Bendita Interna-R	Surburb	1
Agua Bendita-I	Surburb	1

Table 12: a_1 Bus Stop Position (part of the table)

In the Figure 12 we can observe the scope of the land use, the part shaded in yellow the "center area" and the part shaded in blue and orange are the suburbs area. The suburbs are separated in two different colors, because the blue part is the northern area of Panama City and the orange part is the Eastern side, but both are non-urban areas.

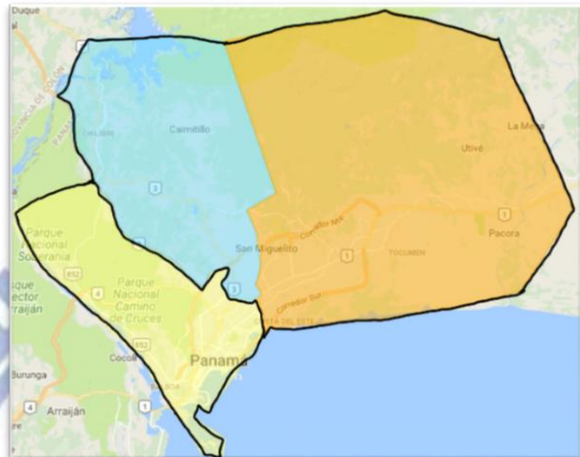

Figure 12: Scope of Panama and San Miguelito district Land Use.
Source: Mi Bus Company – Google Maps.

4.4.4 *Calculation of Range of Influence (R_i)*

After all the information above is collected the results shown in Table 13 can be obtained.

Bus Stop Name	Pi	Pri	nDi	ND	a1	Rb	Ri	Latitude	Longitude
4 De Julio	8	0.16	27	583.17	0.5	500	21.8642194	8.959818	-79.54268
Agua Bendita Abajo-I	20	0.41	216	583.17	1	500	192.079416	9.1661919	-79.6197493
Altos De Tatare-R	4	0.08	35	583.17	1	500	33.8460636	9.097597	-79.291793
Antigua Pepsi-R	100	2.05	1424	583.17	0.5	500	576.053294	9.00507312	-79.5109935
Atlapa-R	16	0.33	103	583.17	0.5	500	57.3821683	8.98795562	-79.501896
Ave De Los Martires	4	0.08	11	583.17	0.5	500	10.2354909	8.957703	-79.543844
Brisas Del Golf-I	108	2.21	1479	583.17	1	500	1211.43929	9.04878611	-79.460676
Buenos Aires Interna-R	12	0.25	147	583.17	1	500	124.944584	9.16955187	-79.6116557
Calle 23	4	0.08	26	583.17	0.5	500	14.415204	9.02330663	-79.505425
Calle 39 Este	96	1.97	610	583.17	0.5	500	342.06383	8.97105248	-79.5303216
Cancha Paraiso-R	4	0.08	23	583.17	0.5	500	13.5792613	9.02856378	-79.6219504
Clayton Externa	8	0.16	34	583.17	0.5	500	23.8147522	8.993128	-79.581267
El Grandioso-R	24	0.49	263	583.17	1	500	232.613021	9.123289	-79.605722
El Valle-I	10	0.20	112	583.17	1	500	98.2688885	9.074993	-79.51426

Table 13: Spatial Accessibility Indicators for Panama Bus Stops. (part of the table).

Finally, we input the table including R_i and the location of all the bus stops into QGIS for the ring analysis as shown in Figure 13.

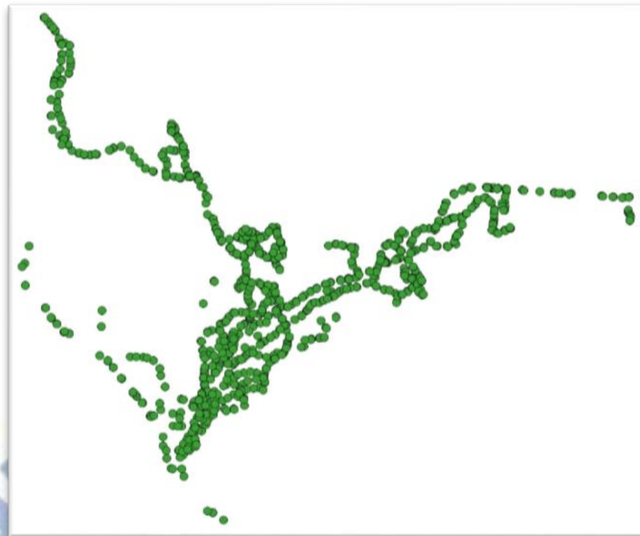

Figure 13: Bus Stops Layers of Panama and San Miguelito districts.

4.4.5 ***Spatial Accessibility Results***

After calculated the range of influence through QGIS and built the geographic operation areas, we can obtain the buffer analysis, that is the surface served by network ***S.*** Finally, we can obtain the special accessibility AS trough the equation 6.

Figure 14: Buffer Analysis by QGIS

5. RESULTS AND DISCUSSION

In this chapter we present the results of the previous chapter and discuss the comparison between Panama and Taiwan. Moreover, we also introduce the results of six municipalities of Taiwan, provided by undergraduate classmates to make the comparison of the transport network between Taiwan and Panama.

5.1 Average Shortest Path Length

The results of the length of public transit network obtained by Huang, Wei-Jia and Shih, Han-Yang (2018) [6] are shown in Table 14. The shaded row would be the length of Panama City obtained in Chapter 4, section 4.1

Average Shortes Path Length	
Panama	**16.7832**
Taipei	9.5805
New Taipei	39.2436
Taoyuan	19.7733
Taichung	23.9985
Tainan	32.3837
Kaohsiung	43.3940

Table 14: Results of the Average Shortest Path Length (Taiwan and Panama).

The best route is the low value because means that the city has the smaller transport path to get from zone ***i*** to zone ***j***. In Table 14, we can observe that the position of Panama City is in between of Taipei City and Taoyuan City. As results, ranking it in the second shortest transport path length. These results are due to Panama City has more zones than Taipei City or Taoyuan City.

Comparing the average shortest path length from Panama with Taoyuan seems more rational, since the results and surface area characteristics are more similar than if we compare it with Taipei City. We can point a few comments, first of all, we need to mention that Taoyuan surface area is 1,221km^2 and have 13 administrative divisions, on the other hand, Panama City surface area is 2,081.2km^2 and include 32 administrative divisions (zones), which means that the area of Panama

City is just 800km^2 bigger than Taoyuan, but in term of quantity of administrative divisions, Panama has a few little more than twice than Taoyuan, not to mention that Panama City us a metropolitan area and Taoyuan does not. Thus, is very notable that the distance between any two administrative divisions in Panama City is smaller than Taoyuan City.

Moreover, if Panama and Taoyuan had the same surface area and a similar numbers of zones division, the length of Taoyuan would be lower.

5.2 Network Efficiency

The results of the network efficiency obtained by Huang, Wei-Jia and Shih, Han-Yang (2018) [6] are shown in Table 15. As well, the last row would be the network efficiency of Panama City obtained in Chapter 4, section 4.2 from this research

The more efficiency network would be the one with the higher the index value. Particularly, the calculation of the network efficiency index strictly depends on the calculation of the average shortest path length, the calculation of this two indexes are highly overlapped. As result, in Table 15, we can see that Taipei is the most efficient city, followed by Panama City.

Network Efficiency	
Panama	**0.0923**
Taipei	0.1410
New Taipei	0.0449
Taoyuan	0.0409
Taichung	0.0659
Tainan	0.0648
Kaohsiung	0.0463

Table 15: Results of the Network Efficiency (Taiwan and Panama).

5.3 Total Travel Time

The results of the total travel time of public transit network obtained by Huang, Wei-Jia and Shih, Han-Yang (2018) [6] are shown in Table 16 and Figure 15. The shaded row in the table would be the total travel time of Panama City obtained in Chapter 4, section 4.3.

The results show that even though Panama is a metropolitan area, with the exception of Kaohsiung, Panama has the higher total travel time among the 7 cities compared.

As Wei-Jia and Shih, Han-Yang (2018) [6] mentioned, Kaohsiung City has a high total travel time because of the large total surface and plus a large number of working population.

	5min	*10 min*	*15 min*	*30 min*	*60 min*
Panama	278249195	291755270	304128148	345779567	426816012
Taipei	1468271	1698926	1929581	2621546	4005476
New Taipei	4210812	4449672	4688532	5405112	6838272
Taoyuan	136646120	142524085	148602050	166835945	203303735
Taichung	61887158	67324801	72762444	89075373	121701230
Tainan	44076285	47158316	50240348	59486444	77978635
Kaohsiung	491631788	535085847	578539906	708902083	969626436

Table 16: Results of the Total Travel Times for Different Transfer Times

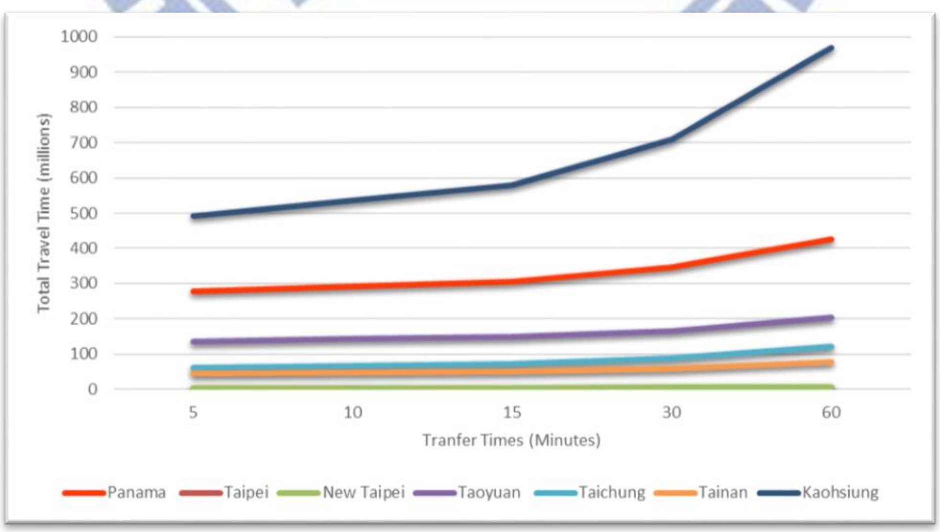

Figure 15: Total Travel Times for Different Transfer Times.

5.4 Spatial Accessibility

The results of the spatial accessibility obtained by Huang, Wei-Jia and Shih, Han-Yang (2018) [6] are shown in Table 17. After all the data processing and calculations in Chapter 4, section 4.4, the parameter required for the spatial analysis are obtained and are shown in the shaded row of the table below.

Since New Taipei and Panama City had approximately the same surface area, you would expect that the coverage of the bus network should be higher. However, is ranked in the position before the last one. Which means that the coverage of Panama City bus network is quit poor to be a metropolitan city.

	Su (Km2)	*S (Km2)*	*AS*
Panama	**271.8**	**191.60**	**9.21%**
Taipei	2053.0	238.86	87.88%
New Taipei	1221.0	1409.19	68.64%
Taoyuan	2215.0	846.36	69.32%
Taichung	2192.0	256.52	11.58%
Tainan	2952.0	392.51	17.91%
Kaohsiung	2081.2	262.08	8.88%

Table 17: Results of the Spatial Accessibility.

5.5 Summary

To summarize, we made a comparison between six major cities in Taiwan and Panama City to obtain the level of the transit network development of Panama City according the four indexes. The rank range is from 1 to 7, where 7 is the best and 1 is the worst. The result in Figure 16 show that Taipei City has the best performance in all the four indexes. The results, also show that the performance of Panama City bus network in terms of time and coverage is very poor to be a metropolitan city. The indexes of length and efficiency are reasonable in comparing with the municipals in Taiwan.

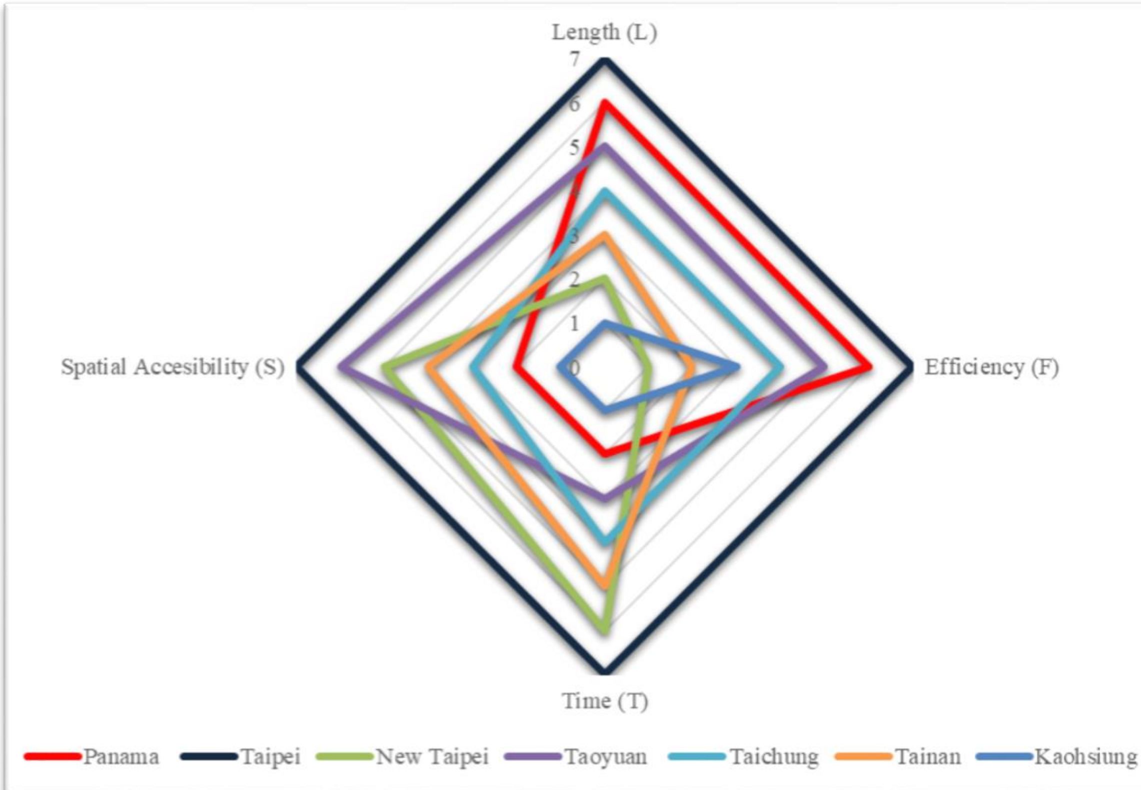

Figure 16: Level Comparison Chart.

6. CONCLUSION AND SUGGESTUONS

In order to understand Panama transit system and to be able to compare it with six municipals of Taiwan, this research selected four main indicators such as average shortest path length, network efficiency, total travel time and spatial accessibility from several literatures on transportation networks. It is hope that these indicators will be help us to analyze the completeness and efficiency of Panama City. Meanwhile, since the six municipals of Taiwan have rather different levels of transit system development. Some of them have very efficient and effective transit systems; others do not, which provide an excellent roadmap for Panama to learn from.

After the calculations and analysis of the four indicators, the research found that in terms of shortest path, Panama City has an acceptable length of the bus public transport routes compared with the cities in Taiwan. However, this indicator is vulnerable to the density of the zones. Means, that if there are more zones division in each district with the same area, the length of the public transportation route will be lower. Nevertheless, the layout density of zones is affected by many factors, then we cannot say that one is better or worse than another.

In terms of efficiency, the results show that Panama City has ranked in the second position, among all the cities compared. Since, is overlapped with the path length, Panama City has a good efficiency.

In terms the time segment, Panama City has a significantly high total travel time. This might be because of the number of transshipments the user has to make to reach their destination, more than the 50% of the trips implicates 2 or more transshipments, causing a high total travel time. Even though, for the simplicity of this research, we do not consider the traffic flow to calculate the travel time, we want to go a little deeper and mention that if we had considered the density of traffic flow, we can assure that the total travel time in Panama City would be higher than the results show.

In term of the index space, the coverage rate of Panama City's public bus network is 9%, a very low coverage for a metropolitan city. We consider that this problem is mainly due to newly of Panama transportation system as we know today. The company managing the current transportation system in Panama is quit new, and since the development of the infrastructure and road on Panama were not planned in a coordinated way, the re-arrange of the road structure and is quit complicated task.

6.1 Suggestions

According to the results of this research, we can suggest that it's important that Panama City consider the users that need to travel long distances, and examine whether the public transit system coverage meet the needs of those people. Since most of Panama traveling people prefer to use the particular automobile, translated into a low demand of public bus transport, because of the higher travel time and low coverage service, its suggested the idea of developing a stronger transportation, system, re-structuring the route line planning to be able to reduce the number of transshipments, and considering the expansion of the public network service scope as well.

This research mainly focuses on the analysis and comparison of the bus transit system of Panama City and six municipals in Taiwan such as, Taipei, New Taipei, Taoyuan, Taichung, Tainan, and Kaohsiung. However, the comparison between Panama and Taiwan may be a little unfair, Panama will always be evaluated at a lower level, due to the difference in resources, investments and especially the development of these two countries. But we hope that this research gave an idea of how is in general the transit system development level in Panama City.

6.2 Limitations

In the process of the development of our research, we came across a series of limitations. One of the main problems was the collection of the information.

Panama government lacks of an institution that provides public details information about transportation and other topics. Consequently, finding the current and correct data to develop this research was difficult. Related studies about Panama transportation problems, was limited and not useful due to the time in which those researches were conducted. Mi Bus company, who is in charge of managing the transportation system in Panama City, were helpful in provide some information regarding the demand, routes, location of the nodes, among other information, that were helpful to compare with the information available online.

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