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Alternative Mass Transport System for Davao City: A Geographic Information System Approach

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Abstract

In highly progressive and populated places such as in Metro Manila, it becomes conventional among people who commute every day on their way to work, school, and home. In the Philippines, there are Metro Rail Transit (MRT) and Light Rail Transit (LRT) found in Metro Manila. As the number of mobile vehicles increase, problems slowly appeared that soon affected the citizens especially the commuters. The situation is also gradually appearing in Davao City, for the city itself has been having a positive progress economically. And to ease the negative effect of a sudden increase in a quantity of the mass transportation in the City, the researchers have conducted a study that was mainly focused on making an alternative mass transport system for Davao City using the FOSS Geo-Spatial Technique. This study was conducted in the city of Davao, in order to make another route with regards to the existing Korean LRT route to ease the traffic congestion on the proposed stations. The study found out that the Population of Davao City is gradually increasing per year and the implementation of LRT is necessary to provide solution to the uprising dilemma. This study developed a mass transport map as alternative route. The highest residential area commercial area in Davao City is Bucana followed by Talomo, Buhangin, and Poblacion area. The alternative Mass Transport System in Davao City are the combination of road networks, 2024 projected population, Traffic Congestions and the Commercial Areas in Davao City.

Keywords: *Geographic Information System, Mass Transport System, Davao City, Geo-Spatial*

1. Introduction

1.1 Background of the Study

Growing congestion and the rising of fuel prices have seen light rail as an international resurgence. A study in Salt Lake City, Utah, found that light rail commuters use their cars less which results to having healthier walking habits as well as lower rates of obesity (Department of Transportation, 2013).

Like Perth, Australia, more and more cities are choosing light rail as part of the solution to growing urban sprawl, traffic congestion, environmental concerns and rising fuel costs. Light rail is proving a game-changer for commuters worldwide, making it easier for people to connect with their city. More modern commuters are turning away from cars for the smooth-running comfort of traffic-beating light rail (Department of Transportation, 2013). In 2011, the Portland light rail system handled 40 percent of weekday transit trips. That meant fewer cars on the roads, reduced vehicle emissions and ultimately, cleaner air, which goes hand in hand with better health.

The Manila Metro Rail Transit (or better known as MRT or Blue Line) has been the main mode of transportation of commuters traveling along Epifanio Delos Santos Avenue (EDSA) in Metro Manila, gaining tremendous popularity since its opening a decade ago. Latest statistics show that there are 10-12 million passengers every month, with around 400,000-500,000 on a daily average (Metro Manila Directions, 2010). Manila's traffic rate situation is getting worse. Metro Manila may become "uninhabitable" within four years, an official of a foreign chamber said due to the annual new car growth increases to 500,000 by 2020. Forbes, senior advisor of the America Chamber of Commerce of the Philippines said that while roads are being improved throughout the country, the National Capital Region urgently needs more limited access roads, especially skyways and rails (Mercurio, 2016).

Davao City is cited as one of the fast growing cities in terms of population, the geographic and economic condition in the country and in Southeast Asia. Based on the 2010 census, Davao City had boomed to a population of 1,449,296 citizens, making it the fourth-most-populous city in the Philippines and the most populous in Mindanao (Census of Population and Housing, 2010). With a total

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land area of 2,444 square kilometers, the city is the largest in the country in terms of land area. The city serves as the main trade, commerce, and industry hub of Mindanao and the regional center of Davao Region.

Davao City had been recognized as one of the safest city in the Philippines and also in the world making it more investors have been investing in the city, like condominiums, housing, shopping malls, IT centers and medium to large business scale establishments and increasing population make it more appealing to businessmen. With this result, traffic congestion is highly expected. Due to rapid urbanization, mobility problems arise. The economic development of Davao City has brought upscale on the vehicle volume, which results in traffic congestion during peak hours along major thoroughfares. If left unabated, it will pose a serious problem in the future and may hinder further development and economic growth of the city (Lirio, 2004).

Lack of transportation due to the swelling of population growth, traffic and road trifling in Davao City were increasingly being seen as a threat to Davao's economic efficiency, time, safety, quality of life to the commuters. The city currently has a total of 15,115 public transport vehicles, of which 13,985 busy city routes while only 1,130 cover regional routes. Of the total number of public utility vehicles in the city, 7,278 are jeepneys, 3,602 are taxi cabs and 2,105 are motorized tricycles (Carillo, 2014).

According to Councilor Leonardo Avila III, chair of the city council's committee on transportation and communication, decongestion of Davao City's heavy traffic is a priority of the city government. Some studies were conducted for this problem. Avila said the city is collating useful data on the transportation situation and reviewing research funded by the Asian Development Bank (ADB) for a sustainable urban transport system in Davao City (Edge Davao, 2013).

Mayor Duterte said that the LRT is a viable option for the city's transportation problem. (Davao Today, 2014).On his end, Mayor Duterte said he will be sending engineers from the city government and the private sector to Korea to study the Korean LRT systems and to familiarize on the construction and operating procedures (Manila Bulletin, 2014).

With the help of the Light Rail Transportation, it can act as a catalyst for significant investment around stations and along routes. As many know, light rails are recognized to improve livability, amenity by attracting investment and also creating traffic congestion on the proposed stations of the proposed Korean LRT.

Because of this, the researchers conducted a study by creating an alternative mass transport system to ease the traffic congestion in Davao City that will be created in accordance to the proposed stations of the Korean LRT route.

By the help of FOSS geospatial, it will be easier to locate the areas in which the establishment of the alternative mass transport system should be situated. Hence, this study will be a big help to make the alternative transportation route more accurate and accessible.

1.2 Objectives of the Study

The main purpose of this study is to create a map of an alternative mass transport system for Davao City. The following are the specific objectives of the study:

1) To determine the projected population density in Davao City.
2) To determine the commercial areas in Davao City.
3) To Identify the Road Networks in Davao City.
4) To determine the traffic congestion in the proposed LRT route.
5) To create a GIS-based map showing the alternative mass transport system in Davao City.

1.3 Scope and Delimitations

This research is focused on the alternative mass transport system using the Light Rail Transit (LRT) as the mass transportation model for Davao City. It contains data concerning the LRT which is the model being presented, the projected population count, traffic congestion and as well as the commercial areas of the city. The research limited its range from announcing the official date of building the LRT. Thus, it will not also include the identification of LRT model to be used. The research generated a map that contains the alternative mass transport system of the Korean proposed LRT route using the data gathered and it was conducted from November 2015 to February 2016.

1.4 Theoretical Framework

Transportation

Theory and Application. This Theory is presented by Richter Dresden (2007) the negative consequences of private cars use are increasingly being recognized, in particular, the link between polluting emissions and global warming. Given the increasing number of cars in the last decades, there are also other concerns including noise, congestion, traffic accidents, and encroachment on land, in addition, the reduction in the number of rail and bus passengers leads to worse public transport services.

Network Design for Public Transport Success-Theory and Examples

This theory is presented by Gustav Nielsen states that a large number of factors are important to bear in mind when designing systems and networks for public transport at the local and regional level (Nielsen, Lange et al. 2005). Organization and transport policy, long-term

stability, robust and simple structure for major market segments, serving all citizens, a two-tier public travel network similar to the road network, Properties of a successful public travel network, the importance of service frequency, the network factor, Squaresville – the ideal case, regional size, density and urban structure, a real-world confirmation, the key role of transfers and interchange points, Optimum frequency, three classes of service level, the standard urban service level, the challenge of congestion and network structure, extending the areas of high quality service outside city centres, the importance of network simplicity, properties of lines that support network development and design, choosing between direct and feeder lines, common trunk line sections in small cities, "Think tram, use bus", Integrated pulse scheduling, Integrated regional network combining pulse scheduling and demand responsive services.

Transport infrastructure and new economic Growth Theory

This theory is presented by Achauer (2000) that the transport infrastructure affects options to interact inside and between regions, and in the way, it influences economic efficiency. This is to measure transport infrastructure in terms of its "physical" attributes, the approach primarily is applied to regional cross-sectional or panel data from a set of regions. With this approach transport infrastructure may be represented by a variable like a highway density or degree of agglomeration.

Geographic Information System

According to Escobar, who proposed this theory, like the field of geography, the term Geographic Information System (GIS) is hard to define. According to him, it represents the integration of many subject areas. Accordingly there was no absolutely agreed definition of a GIS. A broadly accepted definition of GIS is the one provided by the National Centre for Geographic Information and Analysis: a GIS is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modelling, representation and display of geo-referenced data to solve complex problems regarding planning and management of resources (NCGIA, 1990) Geographic information systems had emerged in the last decade as an essential tool for urban and resource planning and management. Their capacity is to store, retrieve, analyze, model and map large areas with huge volumes of spatial data has led to an extraordinary proliferation of applications. Geographic information systems are now used for land planning, utility management, ecosystems modeling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications.

1.5 Conceptual Framework

Figure 1 shows the connection between the helpful factors in order to come up with an information that will be used to create a map for the mass transportation model for Davao City. This study aimed to develop the mass transportation model for Davao City. The demand for the development of mass transportation model is very crucial for the growth and success of the city for it holds a huge role in the economy. Therefore, the researchers created a map using the FOSS Geospatial Technique which allows creating, illustrating and organizing information for deeper understanding of the solution to the problem.

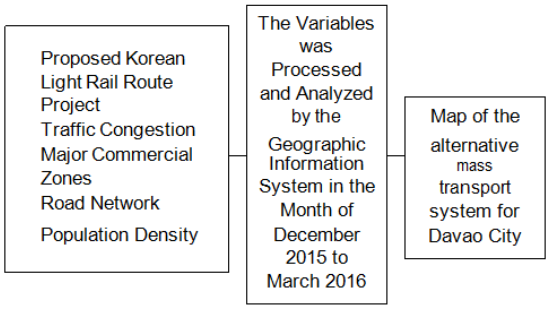

Figure 1 Conceptual Model of the Study

2. Methodology

2.1 Research Design

Descriptive research design was used in this study. Descriptive is usually the best method for collecting information that demonstrates relationships and describes the world as it exists (Aquino, 2014). The true meaning of the data collected should be reported from the point of view of the objectives and the basic assumption of the meaning of descriptive research (Joy, 2015).

This research also used a GIS-based type technique or the FOSS Geo-Spatial technique in developing the alternative transportation system in Davao City. According to Vahed (2012), this Geospatial technology in multiple research fields such as astronomy, bioinformatics, cheminformatics, geophysics and eco-informatics, scientists are increasingly turning to e-science and specifically scientific workflows as a way of improving, broadening, hastening and sharing their results.

Enhanced collaboration, ad hoc access to tools, data, and high-performance processing facilities are some of the gains to be made (Van, 2012).

2.2 Research Locale

Figure 2 shows the map where the study has been conducted. The study conducted in the Centre of Davao City in Region XI. It also shows the Philippine Archipelago and the exact location of Davao City in the Philippine Map.

Figure 2 Davao City Location

2.3 Research Instruments

This research used Geographic Information System (GIS). It was used to process the data and information in order to create the alternative mass transport system for Davao City.

2.4 Data Gathering Procedure

The following procedure will be used in gathering data:
Request letter addressed to Engr. Froilan Rigor. The researchers sent a request letter to the Division Chief of Plans and Program in Davao Region to acquire the population density and the commercial areas of Davao City.

Request letter addressed to Ms. Charlotte B. Parba. The researchers sent a request letter to the Executive Service Officer of Traffic Manager Center to attain the traffic count of Davao City. The researchers conducted an interview with the Division Chief of Plans and Program in Davao City to attain the secondary data about the population density and the commercial areas of Davao City.

Acquired the Korean LRT feasibility study: The researchers acquired the Korean LRT feasibility study with the head of the Material Testing and Quality Control Division to get information about the proposed LRT route in Davao City.

Conduct Interview with Ms. Charlotte R. Parba. The researchers conducted an interview with the Executive Service Officer of TMC to achieve secondary data about the traffic count of Davao City.
Tabulation of Data. The researchers have tabulated the map from the gathered data using the Geographic Information System (GIS).

Data Processing and Map Development: The researchers developed map by processing the gathered data and by using the geographic information system from the conceptual framework.

Analysis and Interpretation of Data: The researchers analyzed and interpreted the data gathered according to the theories presented in the theoretical framework and to the conceptual framework.

3. Results and Discussion

3.1 Map of Each Area in the Alternative light trail

Figure 3 shows the starting point of the alternative light rail, in line with the projected population in 2024 that this area is growing up to 60,366 with the Commercial Area of 36.11. According to the Barangay of Cabantian that it is growing because of housing industries in the area such as Deca Homes, Emily Home, Country Homes and etc.

Figure 4 shows the next location that the alternative light rail will be passing. According to the Korean Engineering Construction, their light rail project starts from Toril passing to Matina, Quirino, J.P. Laurel, Sasa to Davao International Airport. The Buhangin Area will reach their population up to 85,854 with the commercial area of 85.47.

Figure 5 shows the map of Paciano Bangoy and Agdao where it is the next passing area of the alternative Light Rail Route (LRT). This will increase its population by 2024 up to 24,408 with the commercial area of 83.83. According to the barangay Chairman, this area has a lot of real state or properties for sale, Churches, Mosques, or places for worships as well as schools and tourist attractions.

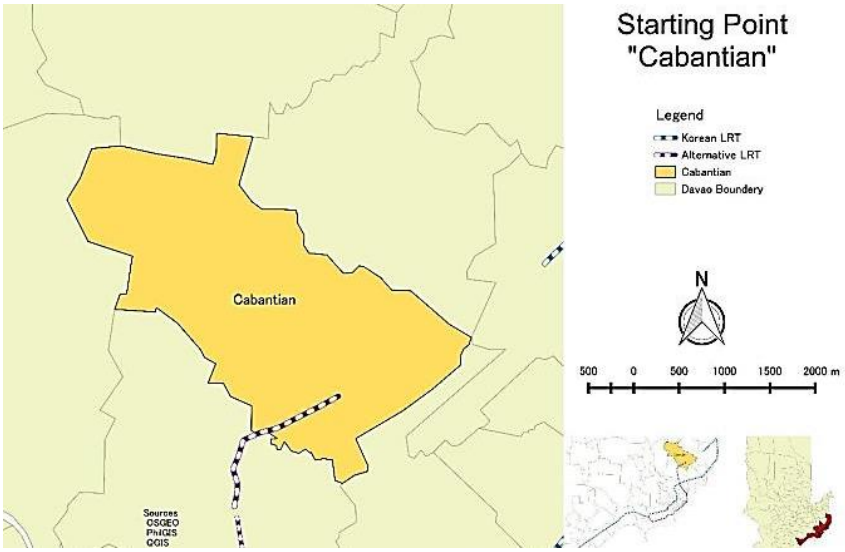

Figure 3 The Map of Cabantian

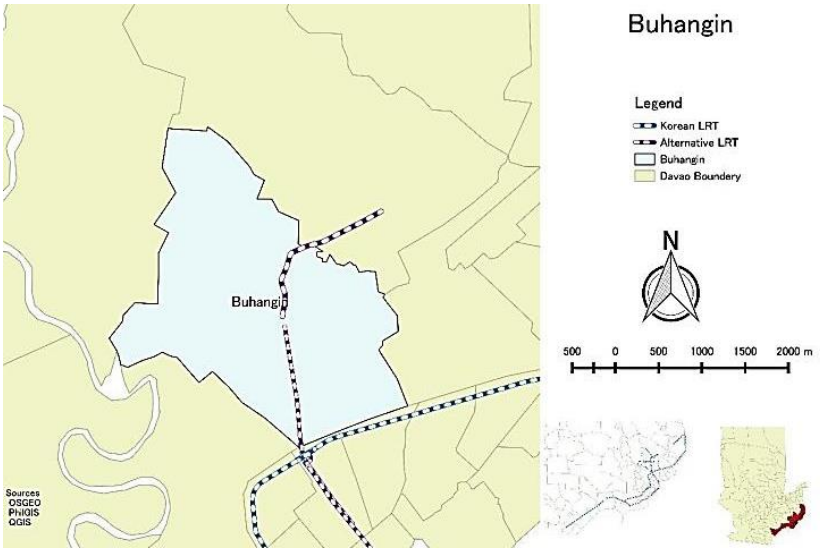

Figure 4 Buhangin Map

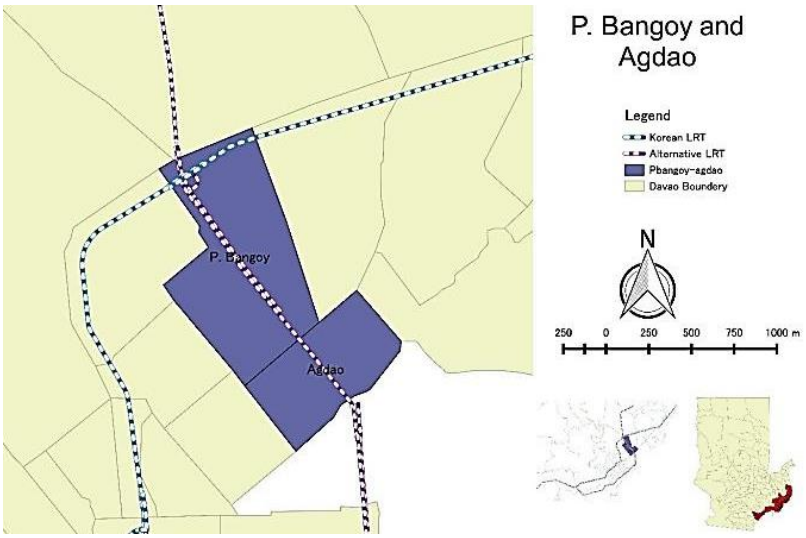

Figure 5 Paciano Bangoy and Agdao Area

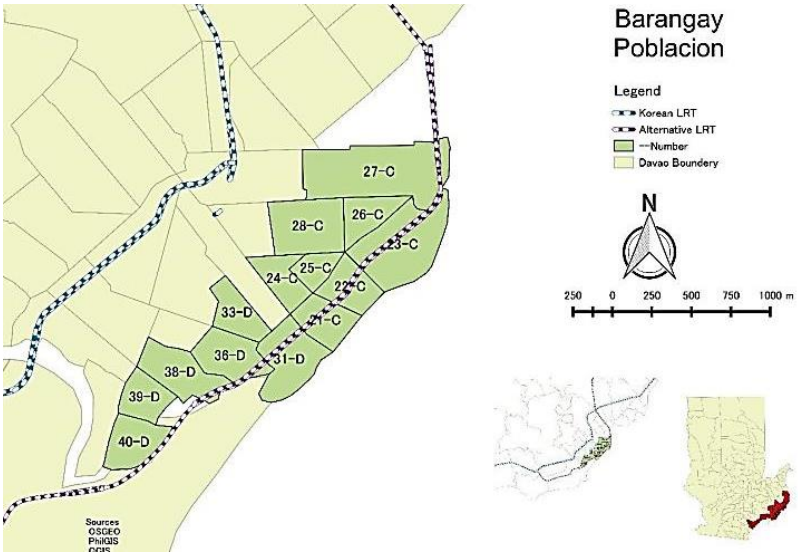

Figure 6 The Map of Barangay and Poblacion

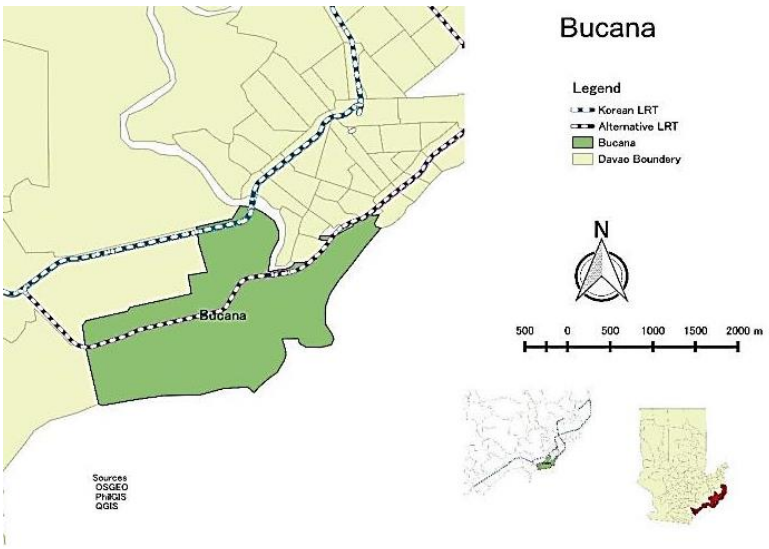

Figure 7 The Map of Bucana

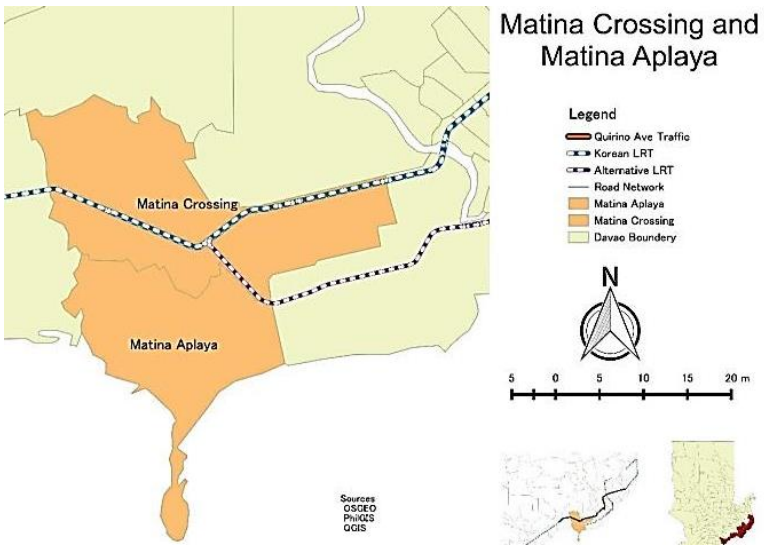

Figure 8 The Map of Matina Crossing and Matina Aplaya

Figure 6 shows the Poblacion district wherein the population as projected in 2024 will increase up to 81,848 with the commercial area of 95.72. The Poblacion district is the next area where the alternative light rail will pass by. According to city officials, this area is overcrowded and there are a lot of informal settlers.

Figure 7 shows the Bucana area which has a total population of 109,105 as projected in the year 2024 and commercial area of 86.8. Bucana is the most populated area in the area of study. According to a study by Roberto Lanolan that Bucana is the largest barangay in Davao City. It composes of public schools such as S.I.R. Elementary School, Kabacan Elementary School and Villa Abrille Elementary School, 21 Project Hope Day Care Centers, Private Schools such as the Ateneo de Davao Grade School and High School and a lot of business establishments and restaurants such as the SM Mall, Times Beach Restaurants, and Davao City Overland Transport Terminal. It is also composed of some Government Offices such as the Hall of Justice, Commission on Human Rights, Philhealth Sub Office,and Civil Service Commission.

Figure 8 shows the end point of the alternative light rail route at Matina Aplaya and Matina Crossing since the starting point of the alternative route is Cabantian. The Population of this area is increasing up to 88,843 by 2024 according to Comprehensive Land Use Programme from the City Planning of Davao. The center of Matina is composed of wet markets, gasoline stations , schools and inside villages.

3.2 Population Density

According to the National Statistics Office (NSO) and Office of the City Planning and Development Coordinator (OCPDC), Davao City had a total population of 1,449,296 that covered the entire population including persons who were residing in institutional living quarters like hotels, lodging houses, hospitals and nursing homes, welfare institution, corrective and penal institutions, convents, seminaries, boarding schools, military camps, stations, logging, mining and construction/public work camps, ocean-going and inter-island coastal vessels and refugee camps.

The 2010 enumeration of households reported that Davao City had a total of 334,473 with an average household size of 4.3. Based on the projected population in 2024, the population of Davao City shall increase by 568,845 persons or approximately equal to 39.25 percent of the total population in 2010. While the household population is projected to increase by 566,723 or approximately equal to 39.25 percent of the total household population.

Table 1 indicates the projected population density in identified areas of the alternative LRT route. Highest populated area is Bucana with 109,105 total number of the population. Additionally, Bucana serves as the home to about 100,000 people representing almost 6% of Davao City's population. It is a section or part of the City of Davao that consists of a big squatter's area. It is located between the Davao River, the Davao Gulf , and the Boulevard. The other side of the border consists of another barangay that also contain a fair number of squatters.

Table 1: The Projected Population Density 2024 in Identified Areas

Area	Project Population
Cabantian and Buhangin Area, District II	
Cabantian	60,366
Buhangin Poblacion	85,584
Agdao District II	
Agdao	10,877
Gov Paciano Bangoy	13,531
Poblacion Barangays, District I	
Barangay 1-A	4,230
Barangay 21-C	9,883
Barangay 22-C	8,393
Barangay 23-C	21,062
Barangay 24-C	2,945
Barangay 25-C	2,083
Barangay 26-C	2,988
Barangay 27-C	2,948
Barangay 31-D	10,132
Barangay 33-D	2,853
Barangay 34-B	1,522
Barangay 36-D	2,156
Barangay 38-D	2,071
Barangay 39-D	5,718
Barangay 40-D	2,864
Bucana	109,105
Matina Area, District II	
Matina Aplaya	41,276
Matina Crossing	47,567

Figure 9 demonstrates the overall population density of each area by which the alternative mass transport system will be located. The tables gathered have been analyzed in order to generate a map using the Geographic Information System (GIS). It shows the density of the barangays which also contains residential zones in Davao City following the sequence of the alternative route. It will range from 2071-17362 and 93814-109105 residence occupied the study zone of Davao transportation model plan.

The highest residential area in Davao City is Bucana followed by Talomo, Buhangin, and Poblacion area. These areas are composed of subdivisions, villages, informal settlers, and housings in the vicinity of the district I and II.

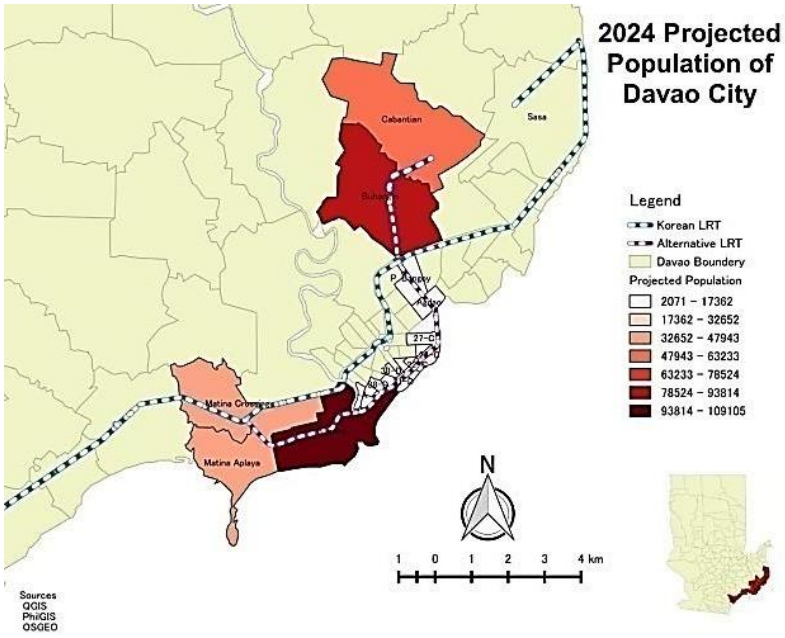

Figure 9 2024 Projected Population

3.3 The Commercial Areas

The spatial development strategy of Davao City identified District I as the Central Business District (CBD) where the concentration of commercial areas can be found. This is where the goods of establishments reach both local and international markets. Most of the barangays in District I are urban barangays which explain such concentration of commercial establishments. In 2010, the commercial areas in Davao City spanned 1,583.32 hectares more than half of which, (57.36 percent), were found in District I followed by District II that covered 36.77 per cent and the remaining areas in District III (OCPDC, 2010). The commercial areas were determined by the Business Bureau of Davao City from the secondary data that the researchers have gathered from the City Planning. These were the areas that business takes place and provides economic development for the city. These are one of the significant basis in order to locate the alternative mass transport system. For these areas existed meant that business was having a rotating flow for the economic development. Thus, the entry of the proposed Light Rail transit and the alternative mass transport system meant as the newly added industry that will maximize the rotation of the business sector of the city. These two factors have an exchange contribution to each other. In contrast, the alternative mass transport system provides time efficiency, transportation and opening to bigger and innovative instruments. The researchers only determined the following commercial areas where the alternative mass transport system will be positioned.

Table 2 shows the Inventory Commercial Areas which was acquired from the City Planning Office. It shows that Bucana has the highest commercial area index which is 86.08 while the lowest in the alternative route is Baranfay 21-C with 0.89. Bucana area is composed of Sandawa Road, Quimpo Boulevard, Times Beach and Washington. SM City Davao is also part of Bucana area. Matina Crossing with 60.95, composed of NCCC Center Point and Matina Market while the lowest in Talomo District is the Matina Aplaya with 34.95 composed of commercial strips or/and the Gutierrez Talipapa along Matina Aplaya Road. The Davao International Airport is also located at Buhangin area.

Table 2: Inventory of Commercial areas in identified barangays

Area	Commercial Area
Cabantian and Buhangin Area, District II	
Cabantian	34.11
Buhangin Poblacion	45.87
Agdao District II	
Agdao	32.83
Gov Paciano Bangoy	51
Poblacion Barangays, District I	
Barangay 1-A	1.69
Barangay 21-C	0.89
Barangay 22-C	1.22
Barangay 23-C	2.04
Barangay 24-C	8.19
Barangay 25-C	5.25
Barangay 26-C	8.57
Barangay 27-C	25.84
Barangay 31-D	1.35
Barangay 33-D	8.24
Barangay 34-B	7.37
Barangay 36-D	7.16
Barangay 38-D	7.84
Barangay 39-D	10.07
Barangay 40-D	1.69
Bucana	86.08
Matina Area, District II	
Matina Aplaya	34.95
Matina Crossing	60.95

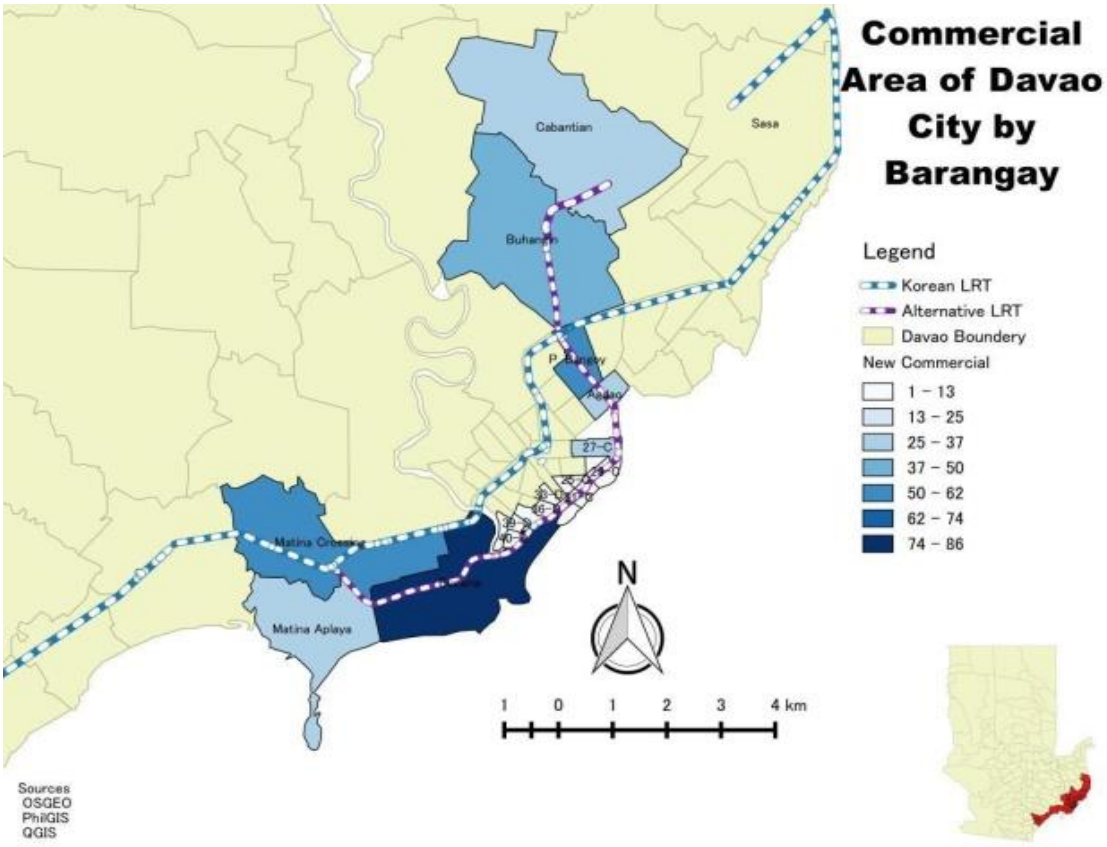

Figure 10 The Commercial Area of the identified areas

Figure 10 illustrates the analyzed area of commercial zones of Davao City using GIS specifically where the alternative mass transport system will be located and will be passing through. Paciano Bangoy, Buhangin, Bucana and Matina Crossing have the highest commercial zone in the routes that the alternative mass transport system will be passing by in Davao City. These areas composed of a commercial building, City Hall, wharf, small scale business, large enterprises, shopping malls, restaurants, public markets and etc. Paciano Bangoy with 51.00 is composed of commercial establishments. Buhangin with 45.87 meanwhile have lots of commercial areas, hotels, and restaurants. The Bucana with 86.08 which includes the Sandawa road with commercial establishments. Another coverage of Bucana area is Quimpo Boulevard with inns, restaurants, commercial buildings where SM City Davao is located. Additional coverage of Bucana area is Times Beach. Last coverage of Bucana area is the Washington Street with boarding houses and some commercial establishments. Matina Crossing with 60.95 has a lot of commercial establishments, fast food chains, and public market. The hue shown in the legend shows the intensity of the commercial zones in an area; from highest to lowest or/and vice versa. It is ranging from 1 which is the lightest means lowest to 86 which is the darkest means the highest commercial area. According to the theory of Transport Infrastructure and New Economic Growth by Achauer (2000) that the transport infrastructure affects the options to interact inside and between regions, and in the way, it influences economic efficiency. Therefore, with the alternative route, and the problems that will be given solutions that may arise with the proposed LRT route, the economy of a certain area will increase and the establishment of commercial buildings will improve. In contrast, the commercial areas found in the LRT route will help amend the possibilities of developing the LRT.

3.4 Road Networks

Figure 11 shows the road networks of the Davao City, District I, District II, and District III and is shown on the map the Cabantian, Buhangin, Agdao, Poblacion, Bucana, Matina Crossing and Matina Aplaya. The analysed road networks were used to specify the Davao City's road network. These were needed to determine the identification of the areas where the alternative mass transport system will be presented. The researchers focused on the areas where the alternative mass transport system will take place or and whether it is accessible for the alternative route. The Road network was acquired from the website of Quantum Geographic Information System and Open Source Compass. The Road Network was used to determine the Primary, Secondary and National Highways of Davao City and was analyzed by the Geographic Information System.

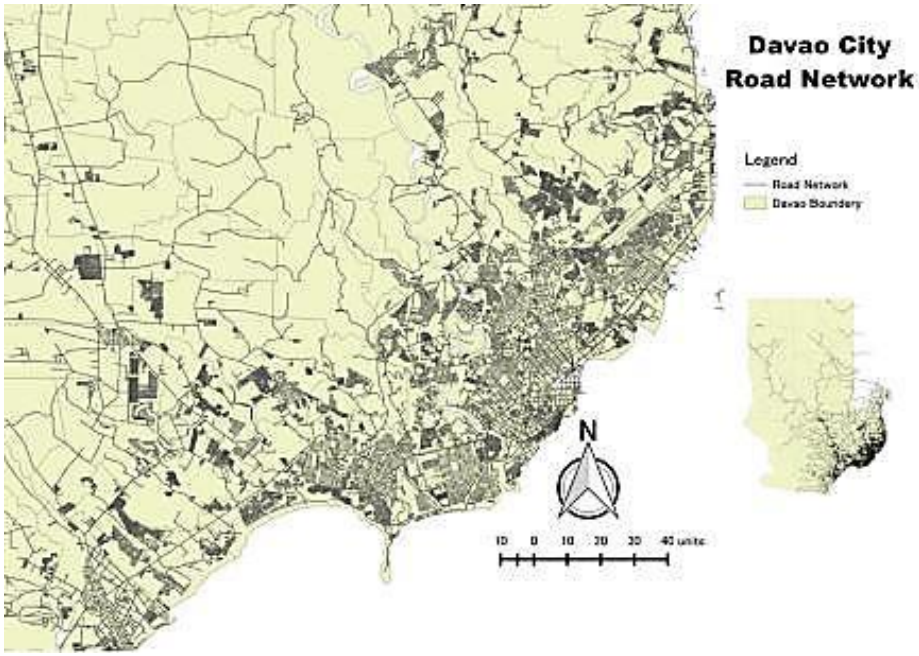

Figure 11 Davao City Road Network

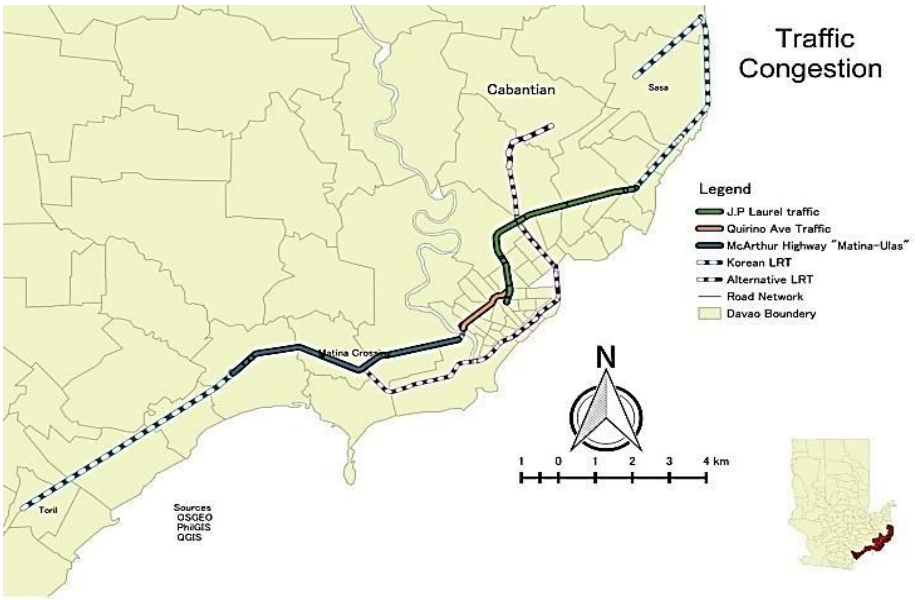

Figure 12 Traffic Congestion

3.5 Traffic Congestion

Traffic congestion is a condition on road networks that occurs as use increases and is characterized by slower speeds, longer trip times, and increased vehicular queueing. Davao City currently has a total of 15,115 registered public utility vehicles (PUVs), a majority of which at 13,985 ply city routes while only 1,130 cover regional routes (Business world online, 2015). The types of transportation that Davao City has are the Taxi Cab, Jeepneys, Tricycles, Trucks, Private vehicles and Buses. However, due to the increasing number of these transportation models, congestions, air pollution and worse, global warming arise. In 2013, greenhouse gas emissions from transportation accounted for about 27% of total U.S greenhouse gas emissions after the electricity sector. The number of vehicle miles travelled by passenger cars and light-duty trucks increased 35% from 1990 to 2013 (Transportation, 2014). The traffic count that we have gathered was particularly specified by Charlotte B. Parba, the Executive Service Officer of Traffic Management Center. The traffic counts in Central business district area are as follows and can be seen on the map.

Figure 12 shows the overall combination of the major traffic area of the proposed LRT route using GIS Approach. The blue line represents the area of Matina

McArthur Highway. It is considered an area with a constant traffic especially during rush hours in the morning and afternoon. During the rainy season, this area experiences floods due to heavy rainfall and because it is near to a river. Due to this, traffic congestion is inevitable. Aside from this, Matina McArthur Highway served as the main road for travellers from the Del sur side going to Downtown and vice versa. The usual vehicles in this area are jeepneys, private vehicles, taxis, buses and trucks that tend to cover huge spaces on the road and causes delay. People in this area is frequent that also cause congestion. This traffic congestion is ranging all the way to Ulas. The orange line represents the Elpidio Quirino Avenue Traffic area. It has a long-stretched highway. Quirino Avenue covers from Banko Sentral ng Pilipinas area to near San Pedro Extension Crossing. Because of its long coverage, it has minor roads and streets from different inside villages and barangays that lead to the main road. These minor streets are all the way to Bankerohan area. A lot of tricycles and other vehicles came out from these which causes traffic. The green line represents the Jose P. Laurel Bajada traffic area. It is visibly traffic especially during rush hours because of the malls, hotels and other major shopping establishments located in the area. People's flow in this area also causes traffic congestion. The usual vehicles in this area are jeepneys, private vehicles, and taxis that tend to cover huge spaces on the road and causes delay. People in this area is frequent that also causes congestion. Moreover, the J.P Laurel Avenue is also considered the main road, a lot of vehicles and commuters pass by this area.

3.6 The Alternative Mass Transport System

Due to the increasing number of problems occurred in the proposed LRT route, the researchers using the GIS Approach came up with an alternative mass transport system that would cater one of the fast mounting problems of the LRT, the traffic congestion. Traffic congestion is a condition on road networks that occurs as use increases and is characterized by slower speeds, longer trip times, and increased vehicular queueing.

The most common example is the physical use of roads by vehicles. When the traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream, this results in some congestion (Downie, 2008). Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity; this point is commonly termed saturation. There are a number of specific circumstances which cause or aggravate congestion; most of them reduce the capacity of a road at a given point or over a certain length or increase the number of vehicles required for a given volume of people or goods. About half of U.S. traffic congestion is recurring, and is attributed to sheer weight of traffic; most of the rest is attributed to traffic incidents, road work, and weather events (Congestion: A National Issue, 2008) In terms of the Proposed LRT route, traffic will happen if the number of accumulated commuters will be unstoppable. With this, commuters will find an alternative route to take than risking hours in waiting for the next stop of the proposed LRT.

Traffic congestion due to the numerous commuters every day that will take the proposed LRT route does not only gives headaches to the commuters but can also causes motorists to waste time. It serves as a non-productive activity for most people because congestion reduces regional economic health. It is a cause for delays, that in result loses business, disciplinary action or other personal losses. And an inability to forecast travel time accurately, leading to drivers allocating more time to travel "just in case", and less time on productive activities.

Figure 13 illustrates the overall map of the alternative mass transportation system in Davao City using the GIS Approach. As you can see on the map, the route will start from Barangay Cabantian, next is Buhangin passing all the way to Agdao, then in Bucana and lastly in Matina Crossing and vice versa.

According to a theory presented by Richter Dresden (2007) given the increasing number of cars in the last decades, there are also other concerns including noise, congestion, traffic accidents, and encroachment on land. In addition, the reduction in the number of rail and bus passengers leads to worse public transport services.

Another theory presented by Achauer (2000) in Transport infrastructure and new economic Growth Theory that the transport infrastructure affects options to interact inside and between regions, and in the way it influences economic efficiency. This is to measure transport infrastructure in terms of its "physical" attributes, an approach the primarily is applied to regional cross-sectional or panel data from a set of regions. The alternative mass transportation system is created based on the presumed Korean LRT route shown in the next figure.

Figure 14 shows the proposed Korean LRT route by the Korean Engineering Construction (KEC). This map was acquired from Engr. Froilan Rigor, the Division Chief of Plans and Program in Davao Region. The proposed Korean LRT route will cover the Toril to Davao International Airport route.

The map is created based on three variables; major commercial zone, high-density residential, and the tourism development zone. The map was divided with 2 Phases, Phase 1 with the length of 18.9km while Phase 2 have the length of 9.5 km.

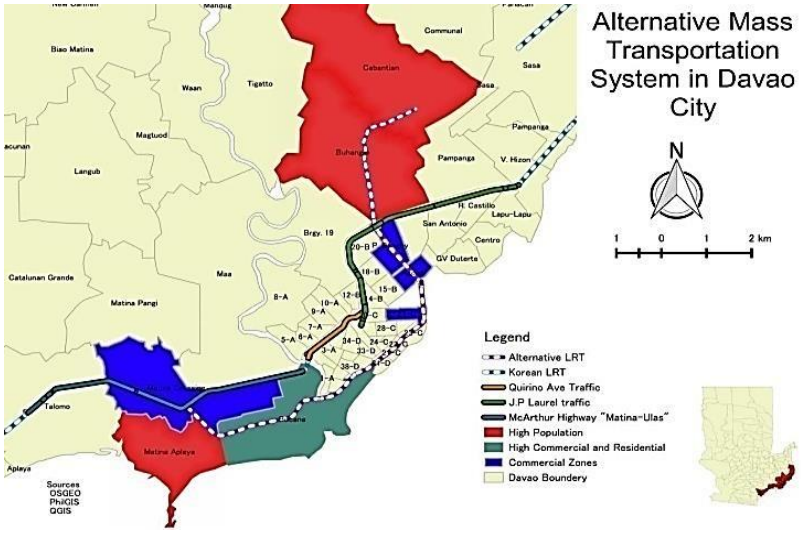

Figure 13 Alternative Mass Transport System in Davao City

Figure 14 Korean Light Rail Project

4. Conclusions and Recommendations

4.1 Findings

Based on the aforementioned data, the findings are as follows:

1) In the Projected Population of Davao City by 2024, the highest and most dense residential area is barangay Bucana ranging 93,814 – 109,105 then followed by the Buhangin Poblacion ranging 78,524 – 93, 814 then 47,943 – 63,233 of Cabantian and followed by the Matina Aplaya and Matina Crossing ranging 32, 652 – 47,943 then followed only by the Area in Poblacion District 28-C with the population ranging from 17,362 – 32, 652 and the Least Density are Poblacion Area ranging from 2,071 – 17,362.
2) The areas that have the least quantity on Commercial area are the Poblacion District ranging the area of 1 – 3 then reaching to Bucana ranging 74 – 86. In the Poblacion area, the very least commercial zone is the 21-C with the Commercial Area of 0.89 the followed by the 22-C with the area of 1.22 and the highest Commercial area in the Poblacion District is the 27-C with the Area of 25.84. Matina Aplaya and Agdao followed with the commercial area of 25 – 37 then the Cabantian with 37 – 50 the followed by Buhangin with 50 - 62 then Matina Crossing and Paciano Bangoy with 62 – 74 then the highest Commercial area is the Bucana ranging to 74 – 86 commercial area.
3) The identified Road networks of Davao City with the Area Measurements of 467.194km2 is composed of Primary Roads, Secondary Roads and the National Highways that are connected to General Santos City, Cagayan De Oro City and to Surigao City.
4) The major traffic congestion areas in Davao City are located on the National highway of ULAS up to the

primary highway going to downtown passing by Matina Crossing and then the traffic continues in El Pido Quirino Avenue then turning left in Jose P. Laurel Avenue from Bajada area to Lanang Area.

5) Matina Aplaya, Cabantian, and Buhangin are the Highest Residential zones ranging from 63,233 – 93, 814 in the selected twenty barangays of Davao City and Matina Crossing, 27-C, Agdao and Paciano Bangoy are the highest Commercial Zones ranging to 37-62 area that is rounded to the nearest tense. The Traffic Congestion in Davao City is located in National highway, primary Roads and Secondary Roads of Davao City.

4.2 Conclusion

Based on the foregoing findings and analysis, the following conclusions were drawn:

1) The Population of Davao City is gradually increasing per year and the implementation of Light Rail Transit is necessary to provide a solution to the uprising dilemma.
2) The commercial areas in Davao City are located in areas where the population is high and the people's flow is consistent and the road network is accessible.
3) The Road Network in Davao City is accessible to have an alternative route for Mass Transit.
4) The Traffic Congestion is Davao City are located in the Primary Roads, Secondary roads, and National Highways and also pinpointed in Commercial Zones with high-density residential zones.
5) The alternative Mass Transport System in Davao City are the combination of 2024 projected population, traffic congestions and the commercial areas in Davao City.

4.3 Recommendations

Based on the conclusions drawn the researchers came up with the following recommendations.

1) This study can be used for the future feasibility study of the Government Agencies or Non-government agencies
2) The future researchers should choose a specific Light Rail Transit Model for Davao City.
3) The researchers also recommend making collaborations with engineers who are in the field and in charge of the study for further questions, clarifications and unavoidable problems that may occur.
4) The government agencies involved in this study should also consider conducting further research about the topography of Davao City.

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