Identifying Suitable Locations of Electric Vehicle (EV) Chargers in Quezon City using Geographic Information System (GIS)

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Abstract: Electric vehicles are widely used by different countries in order to address the environmental issues of the transport sector. However, one of the formidable considerations in order to sustain this type of infrastructure is the availability of electric vehicle charging stations based on the service area. This paper aims to identify the suitable location of EV chargers in Quezon using network analysis and location-allocation model. In this model, the existing location of EV chargers, gasoline stations roads and TODA routes were processed, considered and scrutinized to come up with a GIS map. Furthermore, various related literatures were reviewed and analyzed to support the viability of the proposed locations for the two (2) new charging stations. The result of this study showed that the installation of the two (2) new electric vehicle charging stations will provide a wider coverage of service area, thus this will entail the sustainability of the e-trike projects in Quezon City.

Keywords: e-trikes, electric vehicle charging station, charging station location, GIS

1. INTRODUCTION

One of the sustainable development goals agenda of the United Nations is "Sustainable Cities and Communities". According to the United Nations, the world's cities occupy just 3 percent of the Earth's land, yet, 60-80 percent of energy consumption and 75 percent of carbon emissions are being produced by the cities[1]. This is backed with the study of the International Energy Agency (IEA) on global transports, which resulted to findings that the global transport emission in 2018 accounts for 8 billion tons of CO_2[2].

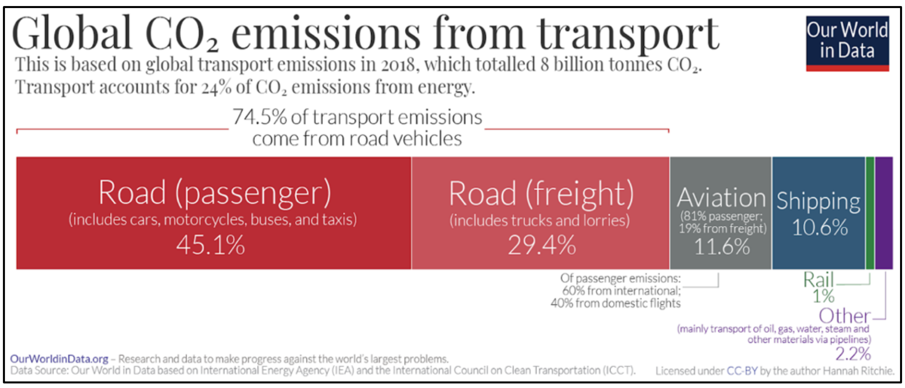

Figure 1 Emissions from Transport

[1] (2021, June). Retrieved from United Nations - Sustainable Development Goals: https://www.un.org/sustainabledevelopment/cities/
[2] International Energy Agency (IEA), 2018

Passenger vehicles such as cars, motorcycles, buses and taxis are the major contributors to this emission with 45.10% share to the total CO_2 emissions in 2018. This is followed by freight vehicles with 29.4%, aviation with 11.6%, shipping, 10.6% and other vehicles, which includes rails with 3.2%, respectively. While the population increases, the demand for transportation and private vehicles is also expected to grow. According to the projection of the International Energy Agency (IEA), as reported in their Energy Technology Perspectives report, the global transport (measured in passenger-kilometers) to double, car ownership rates to increase by 60%, and demand for passenger and freight aviation to triple by 2070[3].

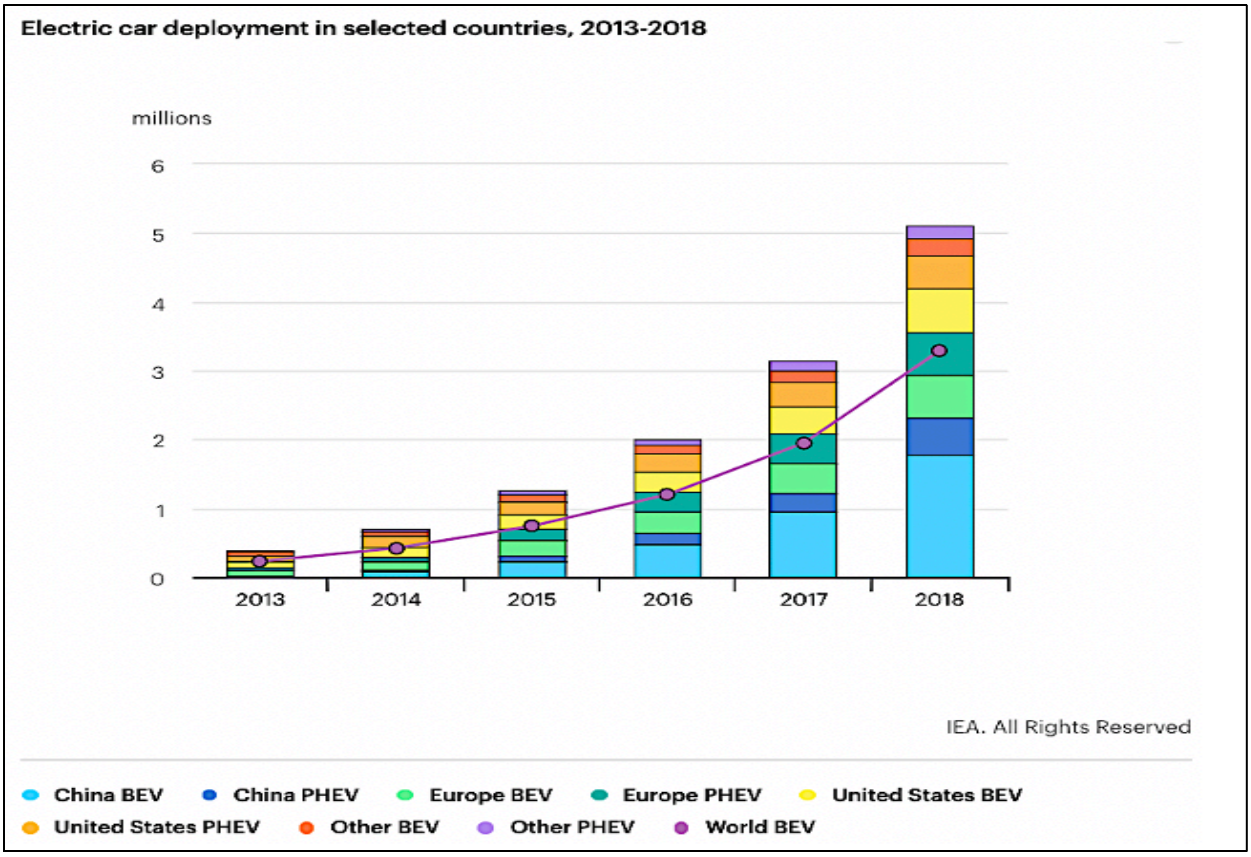

Figure 2. Electric Car Deployment in Selected Countries, 2013-2018 (IEA)

Over the past ten (10) years, the consumption of electric car vehicles has been growing rapidly. In 2018, the global inventory of electric passenger cars increased by more than 60% as compared to the previous year. In China, Europe and United States are leading in terms of electric car usage[4].

One of the most promoted measures on how to combat this issue is the adoption of electric vehicles. EVs have been seen as an effective way to alleviate the environmental and energy crises due to its high efficiency, energy saving , low noise and zero emissions capability. However, the lack of infrastructure to support this initiative is still considered as an obstruction for the sustainability and further development of the industry (Tian, Hou, Gu, Gu, & Yao, 2018)[5].

[3] IEA (2020), Energy Technology Perspectives 2020, IEA, Paris

[4] IEA, Electric car deployment in selected countries, 2013-2018, IEA, Paris https://www.iea.org/data-and-statistics/charts/electric-car-deployment-in-selected-countries-2013-2018 (IEA, 2021)

[5] Tian, Z., Hou, W., Gu, X., Gu, F., & Yao, B. (2018). The Location Optimization of Electric Vehicle Charging Stations considering Charging Behavior. Simulation: Transactions of the Society for Modeling and Simulation International , Vol. 94(7) 625-636 .

In Philippine context, in accordance to the study of Asian Development Bank[6], Philippines produces 10 million tons of CO_2 annually. There are at least 200,000 tricycles running in the roads of Metro Manila, which contribute 6 percent to the total estimated number of motorcycles and tricycles in the country. The Department of Energy (DOE), in partnership with Asian Development Bank (ADB), initiated the implementation of the E-trike Deployment Plan - a Proposed Market Transformation through Introduction of Energy Efficient Electric Tricycles Project. This is in response to the mitigation of climate change by dint of increased energy efficiency and the use of clean energy.

The implementation of the E-trike Deployment Plan stemmed out from the initiatives on switching to alternative vehicles which includes a. the Public Utility Vehicle Modernization and b. the Low Carbon Transport Project. The PUVM project intends to phase out fossil-fuel powered vehicles, introduce transport mode alternatives that generate fewer to no- GHG emissions and to develop and construct electric vehicle charging stations. On the other hand, the Low Carbon Transport (LCT) project would like to gain policy-level support for the LCT project, in which the cities of Baguio, Gen. Santos, Iloilo, Pasig and Sta. Rosa are considered as the pilot areas.

One of the pillars of Quezon City's guiding principle is the environment, thus, the city lives up to its vision - "Build a Livable, Green, Sustainable and Climate-Resilient City". The local government unit is moving towards a low carbon development delving into sustainable mobility projects, which includes promotion of electric vehicles as an alternative mode of public transportation. To complement the initiative of the city government of Quezon City towards becoming a green city, the local government of Quezon City - one of thirty-seven (37) LGU recipients of the e-trike project, has received 292 units of e-trikes from the Department of Energy (DOE) last May 8, 2018. These e-trikes were given to at least seventeen (17) Tricycle Operators and Drivers' Association across the city. This project was directly supervised and managed by the Green Transport Office of the Department of Public Order and Safety (DPOS).

To support the e-trike project, the LGU has partnered with MERALCO to install three (3) charging stations in the city. MERALCO has constructed and installed charging stations in Batasan Hills TODA Terminal, Barangay Payatas Motorpool and Amoranto Sports Complex to cater the number of e-trikes plying across Quezon City. Each charging station is equipped with coin-operated charging pods and solar panels with net-metering service. These charging stations are capable of charging eight (8) e-trikes simultaneously. To add to the growing demand for EV charging stations, the Department of Science and Technology (DOST) is now exploring the feasibility of adding two (2) more charging stations with solar energy & fast charging capability. Based on the 2016 data of Tricycle Regulatory Unit (TRU) of Quezon City, almost twenty-five thousand (25,000) units of tricycles powered by four-stroke and two-stroke gas-fed engines are operating in the city (2015 Quezon City Ecological Profile).

1.1 Objectives

1. To identify the most optimal and suitable location of the e-trikes charging stations in Quezon City
2. To identify other parameters to consider in identifying a charging station for e-trikes
3. To provide the local government unit of Quezon City with reliable recommendations in order to sustain the operation of the e-trikes in the city

[6] ADB Project No. 43207, Philippines: Mitigation of Climate Change Through Increased Energy Efficiency and the Use of Clean Energy, Proposed Market Transformation through Introduction of Energy Efficient Electric Tricycles Project

1.2 Research Questions

1. What are the adequate locations for the EV chargers, relative to the distribution of the e-trikes?
2. What are the considerations in identifying the charging stations
3. What are possible areas of recommendations that must be considered in sustaining the operation of the e-trikes in the city

1.3 Scope of the Study

The findings of this study have to be seen in light of some limitations due to the imposition of enhanced community quarantines in Metro Manila. During the course of the preparation of this research paper, movement of the researchers to gather primary data was limited, thus, this paper is based primarily on secondary data provided by the City Government of Quezon City. Initially, the researchers aimed to collect primary data to analyze the traffic volume and ridership to its intended locations with focus in the growth centers and along the new and existing roads within the city. The figures below show the proposed study area for the primary data collection if there had been no restrictions on social interactions caused by the pandemic.

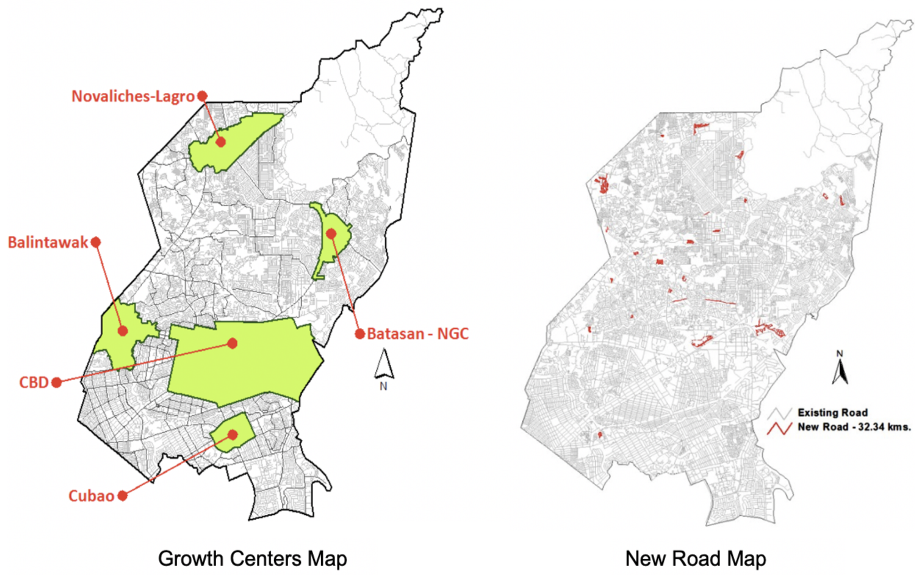

Figure 3. Growth Centers and New Road Maps

The group used shape files of the following data in Quezon City to generate a GIS map to have a better understanding and analysis on the proposed study: a. existing roads as of 2018 and, b. TODA routes for the 292 units of plug-in e-trikes from the DOE. This excludes the plug-in jeepneys that roam around Araneta Avenue. For the socio-demographic profile, the Comprehensive Development Plan (CDP) 2021-2025, 2015 Ecological Profile of the city and population projection from 2015-2025 were used. While much of the data used in this paper were sourced out from the city government - Department of Public Order and Safety (DPOS), reviews of related literature were used also to further support the arguments and influence the interpretation of the findings of this paper. The land use of Quezon City was not used for the purpose of this study, though it is acknowledged that it is significant to be taken into consideration for a better analysis and recommendation. This paper is limited only to the identification of the optimal and suitable location of the two (2) additional charging stations on top of the three (3) existing charger stations in Quezon City. To add, this paper will focus only on the identification of the two (2) new charging stations to be funded by the DOST. Due to heightened pandemic restrictions, the group was not able to gather relevant data needed to quantify the societal benefits of electric vehicles and how the EV charging stations affect the travel and charging behavior of the EV users, thus this area will be proposed under further study.

2. REVIEW OF RELATED LITERATURE

In this section of the study various journal articles were reviewed based on the theory, methodology and results. However, the majority of which revolved around the methodology on the use of the GIS and on the results related to EVs.

Zhang, et.al (2018) used a dynamic traffic network simulation model and considered the time and space constraints of the traffic model to obtain the optimal capacity and location of the EV charging station based on the demand distribution in residential areas. The distribution network planning is divided into two parts one is to minimize the loss of the distribution system and the offset of the node voltage and the other is to maximize the service capacity of the charging station by the capture of the electric vehicle traffic.

While Tian, et.al (2018) factored in the model the "waiting time". Wherein the target optimization model is to minimize the time cost to electric vehicle drivers. The researchers use the SCE-UA algorithm to solve the optimization model. In the case of optimization with or without behavior prediction of EV drivers, the total time cost without behavior prediction of EV drivers is 27.28% more than the total time cost in driver behavior prediction mode, and the average waiting time is 1.68 min more. Therefore, before optimizing the charging station location. It is necessary to forecast the charging behavior of drivers. We also analyzed the constraints on investment cost. It is believed that the methodology followed here can provide the government with good insight into charging facilities and the development of EVs.

Moreover, Calvo, et.al (2019) introduced the Geographically Weighted Regression (GWR) concept which allows the dimensional factors affecting the daily trips and its relationship among variables in a selected area. In their study, they emphasized socio-economic model, accessibility and transportation variables as the key parameters in the model.

Information generated using the GWR model is very useful in evaluating the socio-demographic structure, land use, accessibility and transportation system characteristics in the mobility of the urban areas and when introducing new transport modes, which are important in linking regional to transportation planning. Improving the transportation system in a zone would generate different impacts to another zone, based on their independent variable. GWR therefore is very significant in local land use and transport decisions, as interventions for each stakeholder can be identified based on their zones.

Like in the case of May et.al (2018) who evaluated the impacts of EVs using georeferenced data and thematic maps with specific environment information along the course lines. Classic Cluster Analysis though ArcGIS was used based on the Environmental Relief Plans prepared.

Results shows that urban areas particularly affected in Dresden are: along the major roads that lead to the highway A4, at bridges such as the Blue Wonder, and at the intersection of the districts Altstadt, Neustadt, Lobtau, Srehlen and Sudovorstadt. Almost all areas are vulnerable except for the peripheral zones. Environmental impacts occur in time and space, the Life Cycle Analysis (LCA). Approach used contributes to the comprehensive assessment of the situation at a local and regional level. Two bus lines out of the 28 show that due to their specific characteristics and frequency of service are suitable for the introduction of electromobility in Dresden, Germany. Six shows a medium potential independently. Next steps are applying the same methodology to other cities, however calculation feature variables in the GIS must be simplified. Cluster model is specific for this study only.

Dimitrios, et,al (2017) highlighted that EV charging infrastructure is an optimization problem that can be approached by programming multi-objective optimization and genetic algorithms. Data used are derived data from conventional vehicles and assumptions were made. As a result, in order to deploy a plan for installing adequate charging infrastructure to cover full electric vehicles charging demand, there is a need to encourage the widespread adoption of e-mobility.

Focusing the discussion on optimization, Shahraki, et.al (2015) mentioned that the basis for these models had been on the quantity of EV users, their socio-economic profiles, and volume of road traffic. This is to determine the most optimal quantity of charging stations and their distances. However, he cited that most studies do not take into consideration actual conditions and behavioral habits regarding charging. Thus, the researchers used vehicular travel data to determine the demand for charging stations and the most suitable locations in their study. The choice on focusing on PHEVs is because they run both on fuel and electricity. This is to study the travel and charging behavior of drivers once the batteries no longer have energy. For determining the best suitable location of the proposed charging stations, the drivers' travel behavior within a certain area was also analyzed. Travel data spanning three weeks has been gathered, which includes the geographic location (coordinates), timestamp, and vehicle ID. For site selection for charging stations, gas stations have been chosen as these may be replaced with EV charging infrastructure once EV usage is more widely used and accepted. Increasing the amount of charging stations in the city accounts for any changes in the EV users' behavior. It is also noted that other charging stations located further away from the city center are not as concentrated as the city center. By using actual travel habits and behavior of EV users, better)r siting and planning can be made in determining the best possible locations of these charging infrastructure.

When the study was conducted, there were already 40 existing charging stations in Beijing. However, taking into consideration the travel behavior of the selected taxis, it has been consistently shown that the locations of the proposed new charging stations are clustered within the city's innermost area. Increasing the amount of charging stations in the city accounts for any changes in the EV users' behavior. It is also noted that other charging stations located further away from the city center are not as concentrated as the city center. By using actual travel habits and behavior of EV users, better siting and planning can be made in determining the best possible locations of these charging infrastructure. This study of Sharaki, et, al. in 2015, were usually the reference for most studies, Fiori, et.al (2018) based their optimum routing of battery electric vehicle study in the microsimulation approach with the addition of Matlab as a tool for data extraction of actual GPS data acquired using Wide Area Augmentation System (WAAS) enabled GPS receiver. The GPS receiver was placed inside a test vehicle and was operated during peak hours. The study result showed that an energy efficient route for battery electric vehicles is affected by the regenerated energy.

Luo and Qui also used GIS mapping and spatial analysis to generate a navigation map and map out the locations of the existing charging stations. While model formulation was projected through demand estimation, waiting time and idle rate. Luo and Qui concluded that the location of EV charging stations influences the demand on EVs, behavior of its end-users and sustainability of EV industry. Further, insufficient number of charging stations lead to congestion. This issue has a direct implication on social cost in terms of waiting time. Thus, they have concluded that electric vehicle charging stations are crucial in attaining sustainable electric mobility in the cities.

Relative to the results of these studies that used GIS as the key methodology, results of these studies each showed or highlighted that the key parameters in identifying the optimal locations are: the driving patterns of the EV users (which includes the idle time and waiting time); the residential areas/activities; the number of e-trikes that needs the charging station, and distance of the charging station to the units.

The adoption of battery electric vehicles (BEVs) or alternative-fuel vehicles are widely promoted and translated into policy in many countries. However, the limited number of fast charging stations hinders and limits the use of such vehicles. The difference between the ranges of these vehicle types affects the willingness of the users to adopt those energy saving vehicles.
Results have shown that additional fast chargers would be more economically efficient rather than providing long range battery electric vehicles (BEVs). Thus, He and Perrine (2019) demonstrated that behavioral analysis of EV users goes through a branch and branch-and-bound algorithm. Meaning they prefer to charge the vehicle more often, based on their distance of usage. However, the limited number of fast charging stations usually hinders the willingness of the users to adopt the EVs. Thus, He and Perrine suggested that these chargers be strategically put in accessible locations, i.e. gasoline stations and parking lots.
Luo, et.al (2017) mentioned that since EV charging facilities are an investment, placement of chargers should balance the benefits and welfare of the EV users, charging station service providers and power grid operators to ensure the sustainability of the EVs. Thus, to achieve this, it is important to render a sound policy pertaining to the optimal placement of EV charging stations. The locations should be aligned to the plans and programs on transportation of the local government.
In addition, the continuous development and innovations in battery and electric drive-trains have made EVs a viable solution for a sustainable transportation system. However, as the market of EVs grows, the demand, as well as the placement of commercial charging stations also increases. Appropriate placement of EV charging stations is fundamental to obtain a good return on investment. Taking into account the incremental EV penetration rates (parameters used were: number of EVs, EV Charging penalty coefficient, distance, active and reactive power vector, etc.) ,Luo, Huang and Gupta developed the EV Virtual City 1.0 using Java to investigate the interactions among the EV users, transportation network graph, electric power graph and the existing charging station.

3. CONCEPTUAL FRAMEWORK

The presence of electric vehicle infrastructures directly impacts the demand and the behavior of users and the sustainability of the EV industry. The insufficiency in charging stations results in traffic congestion due to the long queue of EV users at the station. In effect, traffic congestion leads to social cost in terms of waiting time[7].
Based on the data of the Tricycle Regulation Unit (TRU), there are 150 Tricycle Operators and Drivers Associations (TODAs) in the city with about 24,713 tricycle units powered by four-stroke and two-stroke gas-fed engines operating within the jurisdiction of Quezon City. Tricycle operation has become one of the sources of income of those in the informal sector. In response to the environmental sustainability initiatives of the city government, the LGU has partnered with DOE for the distribution of 292 e-trikes across the city. At present, three (3) charging stations were strategically installed in Batasan Hills TODA Terminal, Barangay Payatas Motorpool, and at the Amoranto Sports Complex. The adoption of the e-trikes is expected to reduce the annual CO_2 emission of the city by about 260,000 tons. As cited in the official website of Quezon City, a gasoline-fueled tricycle produces over two-thirds of the air pollution generated by the transport sector in the country[8].
On the average, tricycle drivers are working at least thirteen (13) hours a day, seven (7) days a week with an average of 100 kilometer per day[9]. This would require expansion of charging stations to foster long-distance trips with multiple stops for charging backed with a sustainable policy on the adoption of

[7] Luo, X., & Qiu, R. (2020). Electric Vehicle Charging Station Location towards Sustainable Cities. International Journal of Environment Research and Public Health.
[8] https://quezoncity.gov.ph/program/e-trikes-and-meralco-for-e-trike-charging-stations-across-the-city/
[9] ADB, Implementation of Asian City Transport - Promoting Sustainable Urban Transport in Asia Project - Moving Davao on the Green Road, July 2011

e-trikes in the city. The three charging stations installed by MERALCO are equipped with coin-operated charging pods and solar panels with net-metering service and are capable of charging eight (8) e-trikes simultaneously.

Furthermore, to augment the charging stations installed by MERALCO, distributed e-trikes will be primarily charged at home of the recipients, following the pre-approved specifications imposed by the City Engineering Office, as stated in the e-trike deployment plan. However, this type of arrangement may hinder the adoption of e-trikes in the city as this would incur additional burden to the user. Aside from the fact that parking areas are considered as one of the major concerns in the city, charging of electric vehicles consumes more energy as compared to the regular residential appliances, thus this will entail added cost to the users. Thus, this paper aims to identify the location of the additional charging stations based on the existing routes of e-trikes in Quezon City.

With limited secondary data and upon reviewing the changes on the initial plans for the e-trike locations, the group came up with the conceptual framework where it is limited to the existing EV charging stations, the barangays with e-trikes and the locations of the gasoline and parking lots as the input variables.

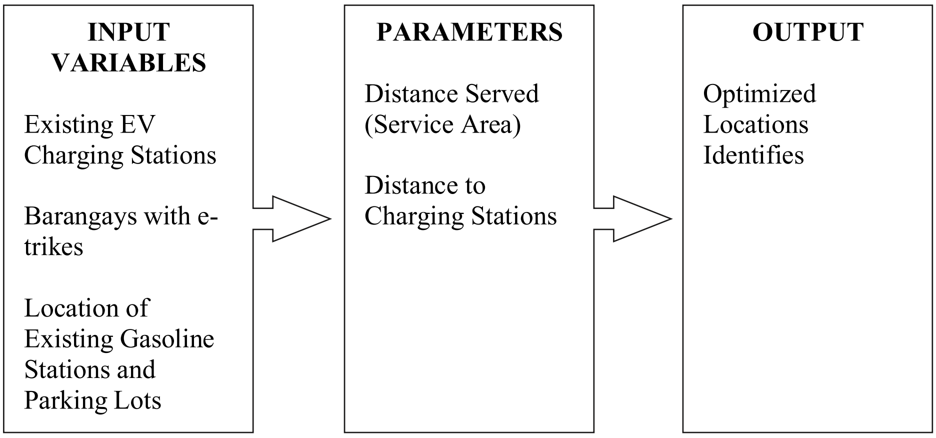

Figure 4. Conceptual Framework

The parameters that were used are the distance served from the service area (service areas are the EV charging stations, gasoline stations and parking lots) to the barangays/TODA with e-trikes. While the distance to the charging station is measured using the distance from the charging areas to the terminal of the e-trikes.

4. METHODOLOGY

Majority of the data acquired by the group are secondary data from the City Planning and Development Department (CPPD) of Quezon City. An official request letter was sent to this office. Upon request the group acquired the scanned copy of the CDP and Ecological Profile and the E-trike Deployment Plan; and GIS file of their road network, tricycle TODA locations and terminal. Other data, such as the location of the gasoline station and parking lots were acquired through Google Earth.

The analytical framework shows how the study processed and analyzed its data from the LGU and Google Earth using GIS as the main tool of analysis. Following the conceptual framework due to limited in primary data, the following assumptions were made in order to conduct the GIS-based analysis of the study:

- The three locations of the e-trikes from Meralco were chosen based on the location of the growth centers presented in the limitations of the study;

- There is a demand for e-trikes in the selected barangay locations based on LGU's initial study
- Generated locations of gasoline stations and parking lots through Google Earth are still available/open as potential locations.
- The methodology is based on the location-allocation model which technically defines a form of optimization model devised to find the optimal location of a specific infrastructure given the spatial distribution of demand for the service[10].
- The two hundred ninety-two (292) units of e-trikes given by the DOE represents the demand and the gasoline station across Quezon City represents the possible locations of the two (2) new EV charging stations.

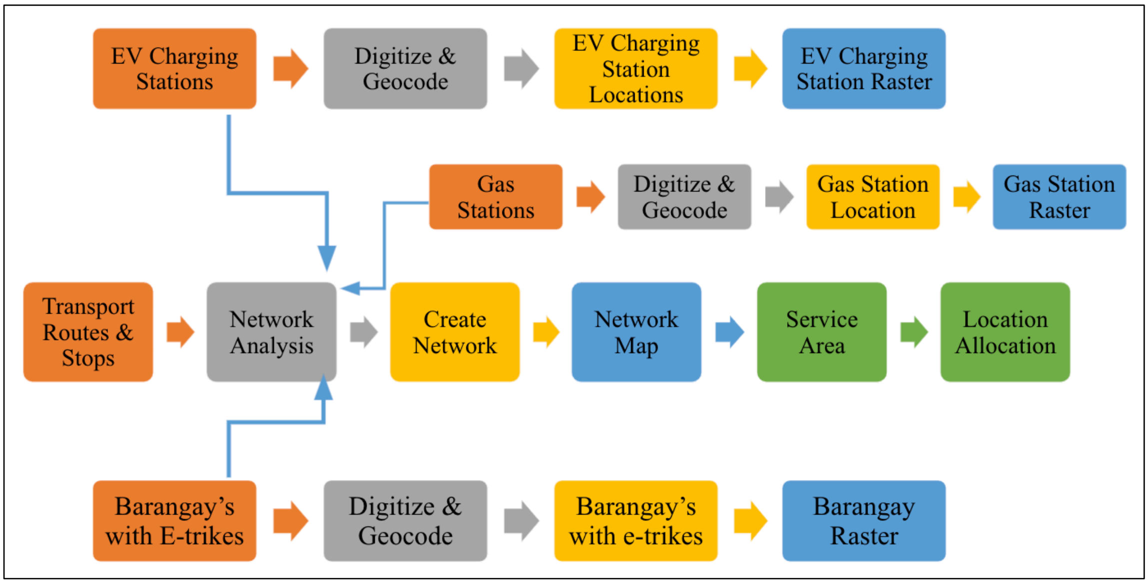

Figure 5. Analytical Framework

The analytical framework summarizes the methodology on how the data will be analyzed using the ArcGIS Tools and Google Earth. The first step of the study is the digitizing of the EV charging stations acquired using Google Earth. The locations of the EV charging stations were based on the list available in the website of Quezon City. A raster layer of these charging stations were prepared using ArcGIS. Then the barangay routes with e-trikes were also located using Google Earth. Due to the limited information on the exact location of the e-trikes, which serve as the specific terminal / storage area, the specific location is based on the name of the route origin (i.e. for Batoda – Batasan Hills, QMC TODA – QMC). The center of the specific areas were chosen, as it was difficult to locate their specific locations in the map with the coordinates.

Data for the gas stations and parking areas were acquired using the search feature of Google Earth. This information was digitized then converted to raster through the ArcGIS.

Upon completion of the digitization and creation of the raster layer, the QC Road 2018, TODA route and TODA Terminal GIS shape files data from QC LGU were used to create the transport network, including the boundaries, edges, restrictions, etc.

In the ArcGIS Network Analysis tools, Location – Allocation, Service Area and Closest area were used to process the data. Results will be discussed in the succeeding chapter.

[10] Tomintz, M., Clarke, G., & Alfadhli, N. (2019). Geocomputation: A Practical Primer. 185.

5. RESULTS AND DISCUSSIONS

5.1 EV Charging Stations

In order to verify the identified suitable and optimal location of the two (2) new electric vehicle charging stations in Quezon City, the number of e-trikes per barangay, location map of the gasoline stations and EV charging stations across the city were used. Quezon City is composed of six (6) districts with a total land area of 16,112.58 hectares, and with about 17,000 tricycles and 292 e-trikes. At present, Quezon City has three (3) existing EV charging stations located in Batasan Hills TODA Terminal, Barangay Payatas, Motorpool and Amoranto Sports Complex catering the 292 e-trikes in the city. The map below shows that these EV charging stations are placed linearly. However, it is noticeable that those TODAs located in the center and eastern portion of the city may not be able to serve by these charging stations efficiently.

The identified locations on the sustainability plan of the LGU was based on the parameters - flood susceptibility and vulnerability. While this paper is based on the distance and service area of the proposed additional charging stations.

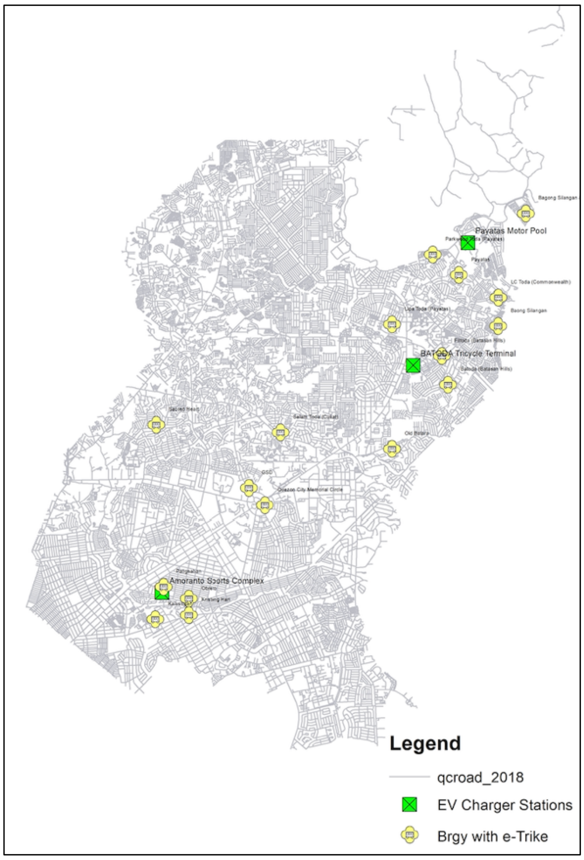

Figure 6. EV Charger Locations and Brgy with e-Trikes

5.2 Gasoline Stations (and Parking Stations)

Using Google Earth, the first 19 gas stations within Quezon City were used to run the Service Area and Closest area tools in the GIS.

Based on the initial results on the right, the gas stations identified are limited only to Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City and the Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127 which are also near the areas served by the current EV Chargers from Meralco. However, the Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127 is a potential area for the EV charger intended for Old Balara TODA.

Using the additional 14 gas stations from Google Earth, the following gas stations and the barangays with e-trikes will be served: Clean Fuel Gas Station, Congressional Ave. Quezon City for Culiat TODA and Shell, 52 Visayas Ave Quezon City for GSD TODA.

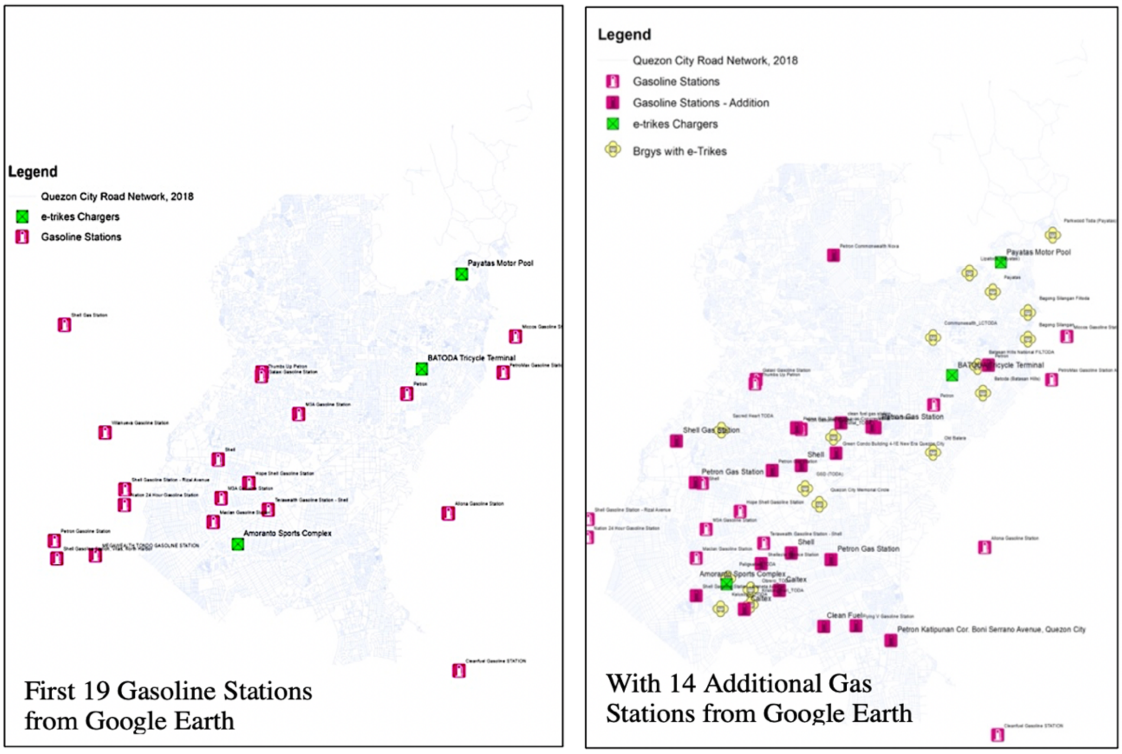

Figure 7. Gasoline Stations in Quezon City derived from Google Earth

Using Closest Facility tool in GIS, the same gas stations appeared with the addition of Petron Gas Station in V. Luna Ave. Diliman Quezon City for QMC and Petron Gas Station 1109 Epifanio de los Santos Ave, Balintawak, Quezon City.

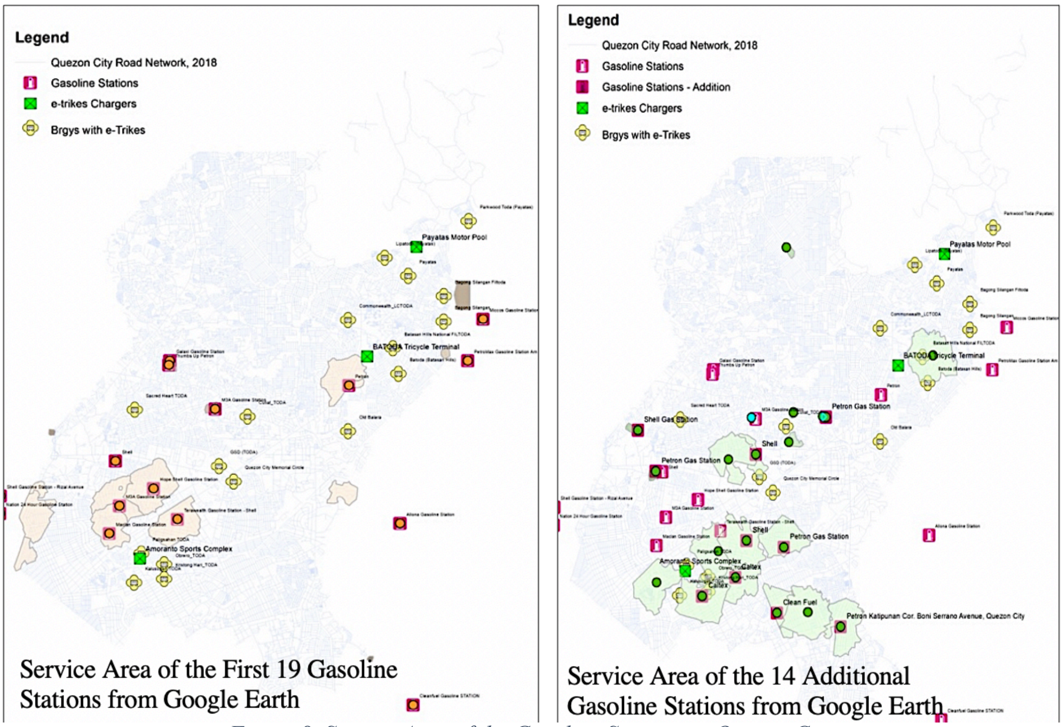

Figure 8. Service Area of the Gasoline Stations in Quezon City

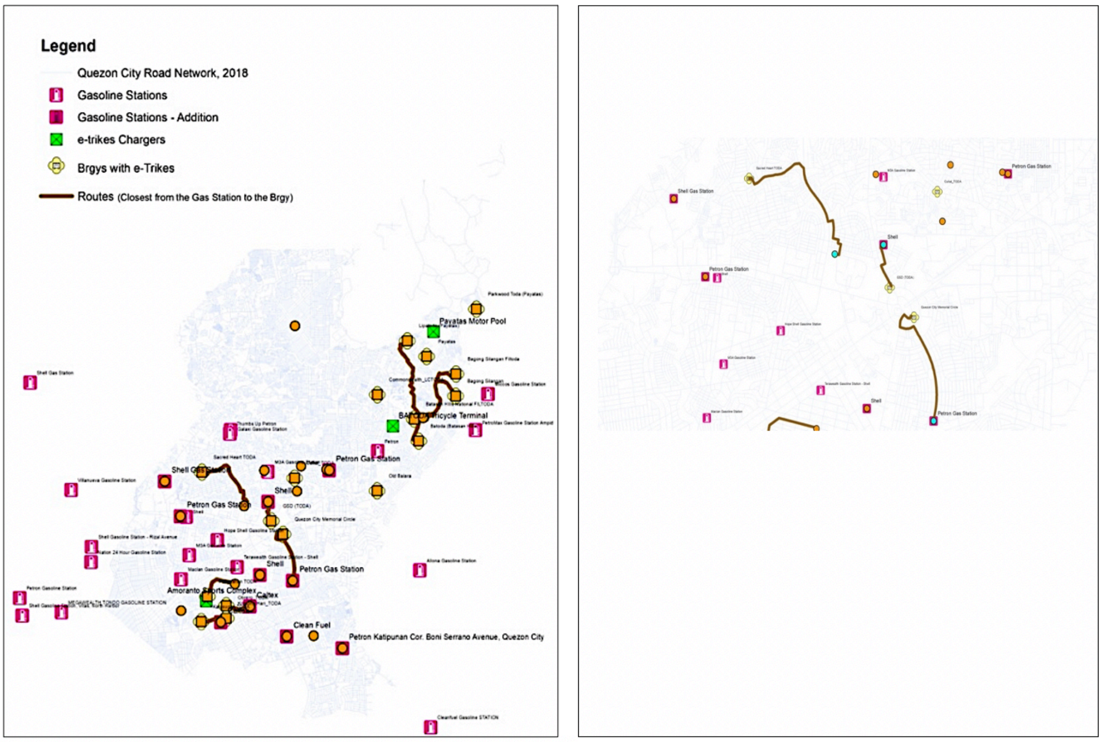

Figure 9. Closest Area (a) Brgys.with nearest access (b) Sacred Heart, GSD and QMC TODA

To identify potential other areas in order to serve all e-trike routes, nine (9) Parking Lot as an option for the location of the chargers were identified using Google Earth.

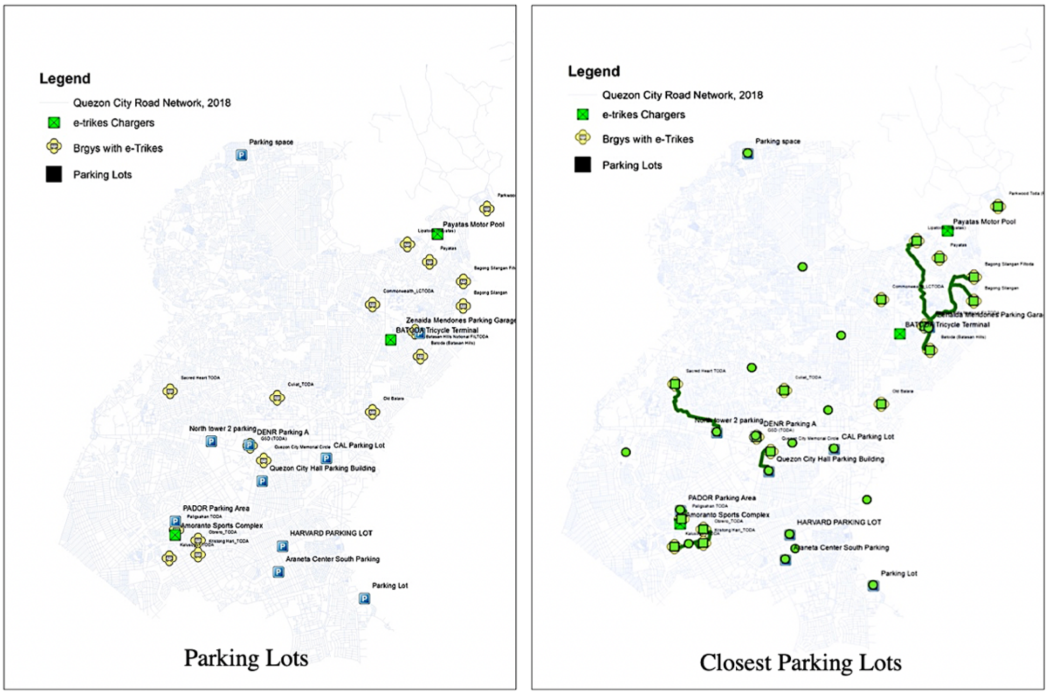

Figure 10. Parking Lots in Quezon City and Closest Brgy with e-Trikes

These were run in the ArcGIS to identify its service area and closest area or Brgy/TODA be served. Resulting to the inclusion of the Zenaida Mendones Parking Garage, as the nearest parking area for Old Balara. However, when the location was verified in the Google Earth, this is a private property. Further this lot is also near the BATODA Terminal which is the location of the Meralco EV-Charger. The table below summarizes the location of EV chargers, Closest Gas and Closest Parking area vis a vis the Barangay/TODA and number of e-trikes. In the table, the QMC TODA has 5 and GSD TODA has 2 e-trikes. Thus, placing the chargers in the closest parking area would be more feasible and cost efficient for GSD and QMC as they are in the government property.

Table 1 Summary of EV Charger Locations, Closest Gas station and Parking Lot per Brgy/TODA

Barangay/TODA	No. of E-Trikes Per TODA	EV Chargers Location (Areas Served)	Service Area	Closest Gas Station	Closest Parking
Sacred Heart	14			Shell, 1109 Epifanio de los Santos Ave Balintawak, Quezon City Metro Manila	North Tower 2 Parking (farther than Shell)
Salam Toda (Culiat)	26			Clean Fuel Gas Station, Congressional Ave. Quezon City	
Batoda (Batasan Hills)	37	Batasan - Meralco			
Quezon City Memorial Circle	*5*		Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City	*Petron Gas Station V. Luna Ave Diliman, Quezon City*	*Quezon City Hall Parking*
Paligsahan	15	Amoranto - Meralco	Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City		Quezon City Sports Club Parking
Kalusugan	5	Amoranto - Meralco	Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City		Quezon City Sports Club Parking
Obrero	9	Amoranto - Meralco	Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City		Quezon City Sports Club Parking
Kristong Hari	5	Amoranto - Meralco	Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City		Quezon City Sports Club Parking

Barangay/TODA	No. of E-Trikes Per TODA	EV Chargers Location (Areas Served)	Service Area	Closest Gas Station	Closest Parking
Filtoda (Batasan Hills)	28	Batasan - Meralco	Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127		Zenaida Mendones Parking Garage
Old Balara	20		Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127		*Zenaida Mendones Parking Garage*
Payatas	50	Payatas Motorpool - Meralco			Zenaida Mendones Parking Garage
Parkwood Toda (Payatas)	12	Payatas Motorpool - Meralco			
Bagong Silangan / Filtoda	5	Batasan - Meralco	Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127		Zenaida Mendones Parking Garage
LC Toda (Commonwealth)	24	Batasan - Meralco	Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127		Zenaida Mendones Parking Garage
Lipa Toda (Payatas)	20	Payatas Motorpool - Meralco			
Bagong Silangan	15	Batasan - Meralco	Petron Gas Station, Holy Spirit Dr, Lungsod Quezon, 1127		Zenaida Mendones Parking Garage
GSD	2			Shell, 52 Visayas Ave. Quezon City	DENR Parking Area

6. CONCLUSION

In terms of gasoline stations, the potential locations are five viable areas namely: Petron Gas Station, Holy Spirit Dr, Lungsod, Terawealth Gas Station, 1606 EDSA Quezon Ave. Diliman Quezon City Quezon, 1127, Shell, 1109 Epifanio de los Santos Ave. Balintawak, Quezon City Metro Manila, Clean Fuel Gas Station, Congressional Ave. Quezon City, Petron Gas Station V. Luna Ave Diliman, Quezon City, Shell, 52 Visayas Ave. Quezon City. However, putting these up, would require more resources. Other locations that were considered included the Parking Lots which includes public areas like the DENR Parking Area, Quezon City Sports Club Parking, Quezon City Hall Parking which are viable areas for EV chargers.

Therefore, in order to serve all e-trikes the following locations are the best suitable locations as they would complement the existing E-trike charging stations from Meralco and at the same time serve the routes not included in the current e-trike locations:

a. Quezon City Hall Parking Area for QMC and GSD TODA
b. Terawealth Gas Station to complement the areas served by the AMORANTO Sports Complex with the addition of QMC TODA

This assumes that the capacity of the EV chargers can accommodate all the e-trikes and the charging time would not affect the operation time of the e-trike drivers. Additional assumptions include that the current demand for the E-trikes will be maintained, thus making the investment for additional the e-trike chargers rationale.

The adoption of electric mobility is expanding at a rapid pace. Thus, to keep up with this development in the transport sector, the national government, local government and private sectors are the key players in achieving electric mobility sustainability in the country. The result of this paper should be backed with a sound policy. Leading countries in electric mobility used a variety of measures such as standards, incentives and provisions on how to close the socio-economic gaps of the electric vehicles and conventional e-tricycles. More so, the importance of the battery technology should be part of the bigger picture if we want to sustain the industry of electric vehicles as this will imply the bigger demand for EVs in the automotive sector. (Energy Technology Perspective, 2020, n.d.)

7. RECOMMENDATIONS FOR FURTHER STUDIES

Due to movement restrictions caused by the pandemic, there are a number of gaps in this paper following the results of the study that would benefit from further studies. Insufficiency of EV infrastructures such as EV charging stations directly impacts the behavior of its users. This as well impacts the further development of the EV industry. These issues may affect the future use of electric vehicles toward sustainable cities and communities. Hence, this paper suggests to conduct further studies on the following:

1. In-depth analysis on the socio-political factors affecting the willingness of the end-users to convert their gasoline-fueled tricycles to e-trikes. Further, the charging behavior of the existing users should be assessed deeply to come up with a more precise forecast on the demand for additional charging stations.
2. In accordance with the study on charging behavior of the EV users, it is recommended also to conduct an in-depth study on the EV's battery capacity for long distance trips. This may include a behavioral analysis of EV users in order to identify a modified flow-refueling location mode of the EV users. In addition to this, it is suggested to establish a dynamic traffic network simulation model considering the other factors and constraints in the serviceable areas to achieve the optimal capacity and location of the EV charging station.
3. Research on the sustainability of e-trikes using cost-benefit analysis and operations and maintenance cost analysis is beneficial not only for the LGU and other funding agencies and institutions but also to its users. Normally, the operations and maintenance cost of any interventions provided by the government are shouldered by the project beneficiaries, thus, using these models for further analyses of e-trikes may answer the sustainability of use of e-trikes in the future.
4. Research on the value chain of the battery technology to sustain the adoption of electric mobility
5. Lastly, after a series of data analysis using network analysis and location-allocation model, a further study on what will happen if the charging stations to be set up in the city are not limited to two?

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