Characteristics of Walking and Cycling in Metro Manila, Philippines

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Abstract: The study aimed to examine the characteristics of walking and cycling in Metro Manila through the walking and cycling distances, which is seen as a function of the locations of the built environment and the characteristics of the population that resides in the city. The study determined the distance to be between 680-872.5 meters for walking and 5,955-6,405 meters for cycling, and distances and relationships between population subgroups like trip purpose, gender, age, employment, income, and vehicle ownership were likewise determined. The distances were then used to estimate service coverage and estimate population served and found out 55-66 percent coverage of Metro Manila by all modes of public transportation, and 45-47 percent coverage access to the cycling network. The output of the study can be used by policymakers and planners to design active transportation facilities taking into consideration the different walking and cycling characteristics of each population group.

Keywords: Non-motorized Transportation, Active Transportation, Walking, Cycling, Walking Distances, Cycling Distances, Transit Service Coverage

1. INTRODUCTION

Active transport, such as walking and cycling, has been being slowly incorporated in the planning of the transportation system in recent years. The recent developments have been a reversal of years of planning the transportation network to the advantage of the private automobile. Many studies have found that promoting active modes of transport has numerous benefits in social cohesion (Hosseini et al., 2011), public health, property and land price appreciation (Carmona et al., 2017), and a modal shift from private automobile for short distance travel (Soni et al., 2016). This is aside from both modes being a non-polluting mode of transport.

Walking is the most utilized mode of transportation (MUCEP, 2015). Throughout the transport network, different trip segments are connected to each other through walking, like access to public transport, or to car parking facilities. Walking, being a link between different modes of transportation, emphasizes its role as an essential mode of transport. Cycling is being promoted as another form of active transport due to its capability to reduce automobile dependency and fossil fuel emissions, and bike units being inexpensive to buy compared to other vehicles.

Recent events such as the climate crisis, the pandemic, and increasing traffic congestion in cities increased awareness about both modes to move around with limits in the mobility in people and public transportation with less risk of infection and less greenhouse gas emissions. The increase in these modes also highlighted the struggles in both promoting these two modes of transport to the public and promoting policies that ensure the safety of these modes within the transportation system.

The pandemic disrupted the transportation system due to restrictions in both operations and capacity, especially for public transportation. Walking and biking emerged as the alternatives as these modes of transportation can still support physical distancing guidelines and prevent crowding in public and private transportation. The increase in accidents involving pedestrians and cyclists makes improving the infrastructure for their safe and secure use more urgent.

Distance is a limiting factor for any mode, but especially more for active modes such as walking and cycling (TRB, 2014). There are two different methodologies on the study of the walking distances of a sample population. The walking or cycling route is a function of the different factors why people chose that route like their regular routine, origin, destination, and other social and economic preferences when taking the trip.

The study estimates the walking distance represented by a sample of a population using the distance decay model, and as well as the characteristics of a specific trip purpose, trip end, and socioeconomic subgroups. These estimated values are used to determine service coverage to public transportation and bicycle paths. The service coverage area is significant as it gives us the accessibility of public transportation from walking or cycling in the network, and as well as the estimate population served by public transportation.

2. REVIEW OF RELATED LITERATURE

2.1. Walking and Cycling

The development of facilities and infrastructure for active transport has given renewed attention by transport and city planners in recent years because of worsening traffic congestion and pollution brought about by the dependence of cities on automobiles. There are also several benefits in promoting non-motorized transportation in reducing automobile dependency and increasing public transportation use (Soni and Soni, 2016), improving public health especially in the issues of physical activity, increasing land and property values (Carmona et al., 2017), giving increased accessibility to lower-income neighborhoods (Soni et al., 2016) and community cohesion (Hosseini et al., 2011). Southworth (2005) published in 2005 listed six criteria for a walkable city such as (1) connectivity of path network; (2) linkage with other modes; (3) fine-grained and varied land uses; (4) safety, both from traffic and crime; (5) quality of path; and (6) path context. The listed criteria emphasize how designing and providing infrastructure alone does not produce the desired shift of transport users from cars to walking. The road network and land-use patterns of cities also affect pedestrian movement and behavior. It is said that the gridline road network and mixed land uses attract more road users to walk more often because of the variety of routes and much shorter distances and duration of the trip. Cervero (1996), studied neighborhood socioeconomic patterns of the same socioeconomic profile, freeway and transit service levels, and location. The study concluded that the street network can influence mode choice. Jung (2016) studied the relationship of the improvements in Seoul's Design Street project have improved the experience in the area. The study found out that pedestrian satisfaction and pedestrian volume improved after the improvements in the area were finished. It concludes that improving physical streets can increase pedestrian movement and can increase the quality of life.

Southworth (2005) stated that walking and cycling, being both non-motorized modes of transportation, has needs that share common ground, but issues with cycling should be studied. Lindsey (2019) says that cycling is a "gendered" activity. Women generally are not encouraged to cycle because of the perceived risks to them. The study stated that women are at more risk of getting enroached in a shared lane than men. Cameña (2019) studied the different behaviors that influence an individual's propensity to bicycle in Iloilo City, Philippines. The research asked respondents on their likelihood to bike at night, peak hours, recreation fitting it with variables comprising their socioeconomic, environment and psychological factors.

Socioeconomic and Psychological factors are the most significant factors in influencing their propensity to bike. McNeil (2011) in a study in Portland states that cyclists maybe willing to travel further to reach their destinations, just like pedestrians. The distance became the basis of a service coverage area from different locations in the city using an assumed distance. The study found out which parts of the city has lesser bikeable geography and has better bikeable geography and lay out specific infrastructure recommendation to improve the bikeability of the city. The concept of an effective cycling length was used to factor the likely length cyclists are willing to cycle in a certain infrastructure or cycling facility. Most children have adequate motor skills at age 10 (Kovácsová, 2016).

Seneviratne (1985) assumed that the walking distance is a function of the different transportation facilities in the city that is, the location of parking areas, transit stops, and different traffic production and attraction areas. For regular residents, their walking patterns adopt a routine path over time, and most of the time this routine path is the shortest one. The study in the central business district (CBD) of Calgary, Canada involved different kinds of pedestrians within the CBD. These pedestrians were asked for their walking route within the CBD by tracing their walking paths into a map, their walking trip purpose, and their demographic profile. The collected distances are then fitted into a probability density function and determined the best fit distribution in order to determine the "acceptable" walking distance at the zero point of the derivative. The method has been used to study walking distances and their relation to different socioeconomic profiles in Calgary Canada (1983), Riyadh, Saudi Arabia (Koushki, 1988), Bangalore, India (Rahul, 2014), and Metro Manila, Philippines (Gerilla, 1995). Only Rahul (2014) used the methodology to obtain cycling distances in the city.

These factors are shown in the National Cooperative Highway Research Program (NHCRP) Report 770, which states many factors affect how far or how long people are willing to walk or bike, such as the purpose of the trip, quality of attractions to be reaches, how easily and directly trip ends can be reached over the travel network, characteristics of the individual traveler, etc. The report also stated that distance is a limiting factor for travel by any mode, especial more for active transport or non-motorized trips. This pattern of the behavior of the cumulative walking distances of a sample population is called the distance decay model. This method is used in Montreal, Canada (El-Geneidy, 2013) and Cincinnati metropolitan region (Zuo, 2016).

The approximated values from the distance decay method are used to determine the coverage and accessibility of public transportation through service transit coverage areas. The estimate population and the areas covered by transit service were generated, with the aid of GIS software. The method is used to determine service coverage locations, and transit service corridor overlaps (El-Geneidy, 2013), and estimating population covered or to be covered by transit and cycling corridors for use of promoting non-motorized transportation and bicycle first-mile access to public transportation (Zuo, 2016).

2.2. Transportation in Metro Manila

Metro Manila or National Capital Region (NCR) is composed of 17 different localities, sixteen of them are independent cities, and one is a municipality. It remains the primary economic center as the region accounts for 36.0% of the gross domestic product (GDP) of the Philippines in 2018 (Philippine Statistics Authority, 2019). Metro Manila has a resident population of 12.8 million (2015 Census) with a land area of 619.57 km^2. With a population density of 21,000 persons per square kilometer, Metro Manila is one of the densest urban areas in the world. The urban area has already sprawled to provinces adjacent to the region and has an impact on the traffic inside, with people travelling to Metro Manila during daytime.

Trip mode share from the MUCEP data shows trips made by walking composed 30.7% of all the trips at 10.9 million, followed by public modes of transport at 48.8% at 17.2 million.

The private modes of transport composed 20.4% at 7.2 million trips (MUCEP, 2015). Gerilla (1995) estimated the walking distance of Metro Manila to be at 251 meters, with a speed of 70.62 meters per minute or around 4.23 kilometers per hour. Metro Manila developed at a fast pace since the study and multiple central business districts and new transit lines have been built in the metropolis since then so an new assessment and approximation of the walking distances.

While well-designed central business districts in Metro Manila show good walkability index scores, areas outside of the Central Business Districts have minimal facilities that cater to pedestrians and cyclists to travel safely (Leather, 2011). The Metro Manila Accident Reporting and Analysis System (MMARAS) showed that collisions involving hit pedestrians are the type of collision that has the most fatalities in the year 2019 at 45.96% of all fatalities recorded. Meanwhile, the number of bicycles that are involved in a road crash is 1,783 or less than a percent of all vehicles listed in the MMARAS. Of this number, 20 or 1.12% are fatal, the rest are non-fatal injuries or damage to property. While bicycle ridership remained small in 2019, an increase in bicycle ridership was reported due to the limited transport options when lockdowns and community quarantines are established in Metro Manila due to the COVID-19 pandemic in 2020 (World Health Organization, 2021). The MMARAS data of 2020 shows that road crashes involving bicycles almost doubled to 3,026 from 1,783 from the preceding year or representing an increase from 0.75% to 2.40% share of all crashes from 2019 to 2020. The increase in crashes involving cyclists and the high rate of fatalities involving pedestrians highlight the immediate need to provide safe infrastructure to both modes.

(Department of Transportation and Communications, 2012) devised a pyramid of priorities when planning for transportation facilities. The prioritization considers the number of people that can be transported through a certain mode. In this pyramid, walking is ideally at the top, followed by biking, public transportation, taxis, high occupancy vehicles and cars occupying the least priority place. A separate pyramid for the priority of public transportation modes is also designed with rail occupying the top, followed by bus, jeepney, tricycles and pedicabs.

3. METHODOLOGY

3.1. Collection of Walking Trip Data

Pedestrian walking trip data were collected through intercept pedestrian surveys in location. The intercept method involved asking people to answer the survey questionnaire or get interviewed for the survey onsite for gathering data. Intercept survey method was chosen because of the question that pedestrians need to trace their walking route in a map. The chosen survey locations were central business districts in Metro Manila because of pedestrian volume, multiple public transportation modes nearby each other, and mixed land uses. The selection was also done to distribute the surveys in different parts of the metropolis. The chosen sites for the survey are shown in Table 3-1.

Table 3-1. Survey Sites

Location	City	Date of Survey	Time of Survey
Lawton	Manila	December 10, 2019	6 am to 6 pm
Cubao	Quezon City	December 11, 2019	6 am to 6 pm
Ortigas	Mandaluyong City and Pasig City	December 12, 2019	6 am to 6 pm
Ayala	Makati City	December 5, 2019	6 am to 6 pm

The survey questionnaire contained questions about the respondents' trip patterns for the walking trip, their socioeconomic characteristics like age, income, occupation, etc., their perceptions of the walking environment, and were asked to trace on a map provided to the respondent their walking route to their destination.

3.2. Cycling Trip Data Source

The data for cycling came from the 2015 MUCEP Household Interview Survey (HIS) Database. The database is composed of four different databases for Household Data, Household Member Data, Trip Data, and Miscellaneous Questions Data. To filter the individual cycling trips and match details with their individual socioeconomic characteristics, spreadsheet functions were used to merge the two databases. Only cycling trips within Metro Manila were considered for analysis.

3.3. Data Preparation

3.3.1. Walking Data

Since the intercept survey was done with paper and pen questionnaires, the data collected was encoded into a spreadsheet. The traced map data was converted to digital through tracing the path in Google Earth.

Outliers and walking distances less than 40m were also be excluded from the analysis. Outliers were determined using the Interquartile Range (IQR). The outliers were determined using Equations 1 - 3. Walking distance values outside of the determined outliers will be excluded from the analysis.

$$IQR = Q_3 - Q_1 \quad (1)$$
$$LOF = Q_3 - 3 \cdot IQR \quad (2)$$
$$UOF = Q_3 + 3 \cdot IQR \quad (3)$$

Where:

Q3 = Third Quartile
Q1 = First Quartile
IQR = Interquartile Range
LOF = Lower Outer Fence
UOF = Upper Outer Fence

The data were grouped into different population subgroups by trip purposes, trip endpoints, by gender, income, employment, vehicle ownership and age.

3.3.2. Cycling

The database does not show the actual distance of trips; only the time of travel is shown in the database. The cycling distance for each cycling trip is estimated by multiplying the travel time with the following speeds per age group.

Table 3-1: Cycling Speed per age

Age Group	Speed (km/h)	Speed (m/min)	Reference (Year)
Below 15	12.96	216	Briem et al. (2017)
15 to 29	15.00	250	Kovácsová et al. (2016)
30 to 40	12.81	213	Kovácsová et al. (2016)
41 above	11.91	198.5	Kovácsová et al. (2016)

Cycling distances greater than 15000 m were excluded in the analysis. The data were grouped into different population subgroups by trip purposes, trip endpoints, by gender, income, employment, vehicle ownership and age.

3.4. Statistical Analysis

3.4.1. Determination of the mean, median, 75th and 85th percentile values of the walking and cycling distances

A histogram of the frequency of the walking distances in 50-m intervals was made along with the corresponding cumulative frequency graph. The method of determining them through the 75th- and 85th-percentile values was done to determine the acceptable walking and cycling distances (El-Geneidy, 2013).

3.4.2. Statistical Difference Tests

A test of statistical differences was done to determine if the distances determined are statistically different from each other. A statistical difference means that the differences in means of two different data set are not likely to occur randomly or by chance but is instead likely attributable to a specific cause.

The behavior of the population was done to determine if the sample population is normal or non-normal. Wilk-Shapiro tests were done, with the null hypothesis stating that the population behaves normally. The null hypothesis is confirmed if the p-value is greater than 0.05.

For normal populations, p-value tests were used to determine statistical differences for a pair of subgroups, and analysis of variance (ANOVA) tests were used to determine statistical difference for populations with more than two subgroups. A p-value of less than 0.05 meant that the pair of subgroups are statistically different for p-value tests, and at least one pair of subgroups are statistically different for ANOVA test. A pairwise t-test was done to determine which pairs are statistically different if ANOVA determined statistical difference.

For non-normal populations, non-parametric tests are done to determine statistical significance. Mann-Whitney tests were used to determine statistical differences for a pair of subgroups, and Kruskal-Wallis tests were used to determine statistical difference for populations with more than two subgroups. A p-value of less than 0.05 meant that the pair of subgroups are statistically different for Mann-Whitney test, and at least one pair of subgroups are statistically different for Kruskal-Wallis test. Dunn's test. was done to determine which pairs are statistically different if Kruskal-Wallis test determined statistical difference.

To check the presence of significant interactions between parameters, multiway ANOVA is used with the walking and cycling distance being the independent variable.

3.5. Determination of the Transit Service Area Coverage and Estimated Population Covered by the Service Areas

The service coverage area was determined using service area from layer processing tools in QGIS Software. The QGIS Software is a free Geographic Information Systems (GIS) software that is capable of generating service coverage maps through Network Analysis. The algorithm creates a new vector with all the edges or parts of edges of a network line layer that can be reached within a distance or a time, starting from a point feature. The distance and the time (both referred to as "travel cost") must be specified respectively in the network layer units or in hours (QGIS Training Manual).

The data input for this process are the 75th- and 85th-percentile values determined from the statistical analysis, and as well as the walking speed 4.238 km/h (70.62 m/min).

Figure 3-1. QGIS Network Analysis Service Area Sample Output

Figure 3-6 shows a sample output of the process using one point. The nodes generated were the farthest points that can be traveled within the network using the input distance, and the polylines generated were all possible roads that can be passed without exceeding the input distance. The polygon bounds of the service area were generated through the Convex Hull processing tool of QGIS (QGIS Training Manual). The output of convex hull was converted into a single feature polygon through the Dissolve processing tool. The dissolved output was divided by LGUs through intersecting it with an existing Metro Manila LGU vector file. The service area covered per LGU will be then calculated through the field calculator feature of the software.
The estimated resident population and employment population served by the catchment area are estimated using

$$P_{sj} = P_s \cdot \frac{A_j}{A_{sj}} \quad (4)$$

$$E_{sj} = E_s \cdot \frac{A_j}{A_{sj}} \quad (5)$$

where,

P_{sj} is the population in the intersecting area j that is inside the catchment area
j is the analysis zone intersecting either fully or partially with the catchment area of transit stop/corridor
P_j is the population of zone j
A_j is the area of zone j
A_{sj} is the area of intersection between the catchment area of stops

The transit service coverage area through walking was determined for all modes of public transport and using existing routes from the Land Transport Franchising and Regulatory Board (LTFRB) memorandum circulars regarding the routes of public utility buses (PUB), modern public utility jeepneys (PUJ), traditional PUJs and the UV Express. Authorized routes as of the end of December 2020 serve as the basis for the determination of public transportation stops or corridors.

The geoprocessing methods outlined for determining the service areas reached by walking are the same for determining the service coverage areas reached by cycling but using the 75th-percentile and 85th distances multiplied to the applicable effective length factor (McNeil, 2011). A framework showing the flow of the research is shown in Figure 3-7.

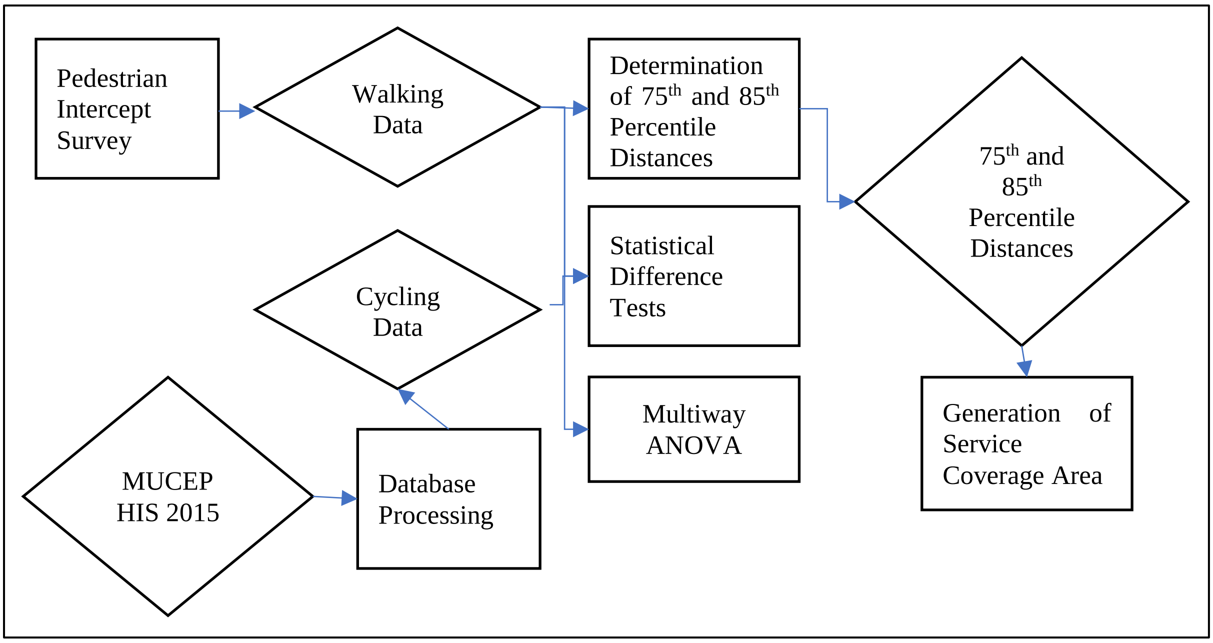

Figure 3-2. Methodology Framework

4. DISCUSSION OF RESULTS

4.1. Walking

Table 4-1 shows the results of the study with all walking trips having a 75th percentile distance of 680 meters and 85th percentile distance of 872.5 meters. The estimated walking distances correspond to a trip time between 9.53 to 10.3 minutes, calculated at 70.62 m/min walking speed (Gerilla, 1995). The data collected from the intercept survey is 616 responses, with a margin of error of 5.19% at 99% level of confidence. Applying the multi-way ANOVA with the walking distance as the independent variable results in a p-value greater than 0.05, hence no interactions of parameters can be derived from walking data.

The walking data was grouped according to trip endpoints. The first subgroup is the walking trip case of direct walk from the origin (home, school, office shopping, etc.) to destination (home, school, office shopping, etc.) without changing mode. The 75th and 85th percentile for this case is 561.5 and 742.15 meters, respectively. The second subgroup is the case of walking trips that access public transportation from the origin. This is commonly referred to as "first-mile" trips. The 75th percentile and 85th distances for this kind of trip are 703.5 meters and 863.25 meters, respectively. The third case are walking trips that both start and end in public transportation. The 75th percentile and 85th distances for this kind of trip are 480 meters and 597 meters, respectively. The last case is walking trips that start from public transportation to the destination. This is commonly referred to as "last-mile" trips. The 75th percentile and 85th distances for this kind of trip are 772 meters and 962 meters, respectively. The statistical difference test yielded a p-value of less than 0.05, meaning at least one pair of subgroups are statistically different. Table 4-1 shows the statistically different pairs.

Table 4-1. Walking Distances (all trips and by trip ends)

Population Subgroup	Population Subgroups (count)	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
All Walking Trips	(616)	680 (9.53)	872.50 (12.33)	None
By Walking Trip Ends	1. Direct to Destination Trips (60)	561.5 (7.95)	742.15 (10.60)	2 and 1 2 and 4 3 and 4
	2. Origin to Public Transportation (230)	703.75 (9.97)	863.25 (12.22)	
	3. Transfers between Modes (201)	480 (6.80)	597 (8.45)	
	4. Public Transportation to Destination (125)	772 (10.93)	962 (13.62)	

Figures 4-1 (next page) shows the extent of the estimated 75th and 85th percentile distances from the major train stations in the network, centered on the center of the survey location (red dot). The blue polygons shows the area and roads covered by the 75th percentile distance, and the red polygons show the area and roads covered by the 85th percentile distance.

For trip purposes, the work bound trips had the longest distances at 805 meters, followed by School, Home, Other purposes, and Social and Recreation. The statistical difference test resulted in a p-value greater than 0.05, meaning the differences in the distances of each subgroup has no specific reason or pattern. The destination, which is connected to the purpose has no factor in the walking distance.

Table 4-2. Walking Distances by Trip Purpose

Population Subgroup	Population Subgroups (count)	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
By trip purpose	1. To work (211)	805 (11.42)	963 (13.63)	None
	2. To School (49)	738 (10.43)	1040.2 (14.72)	
	3. To Home (156)	635 (8.90)	811.25 (11.48)	
	4. Social and Recreation (158)	555 (7.85)	746.3 (10.57)	
	5. Other purposes (41)	575 (8.13)	840 (11.80)	

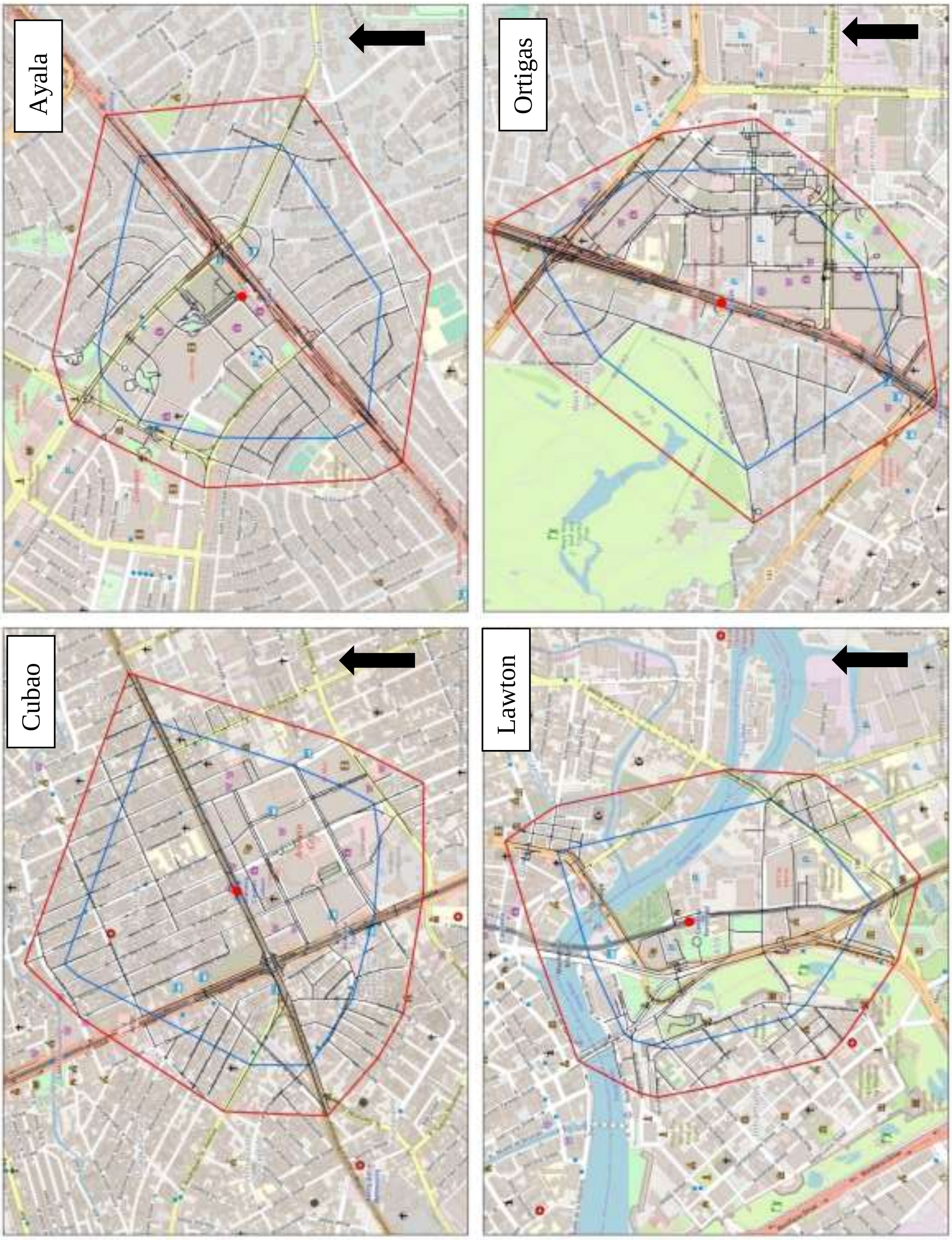

Figure 4-1. Coverage of 75th Percentile and 85th Percentile Walking Distances on Survey Sites

For the socioeconomic subgroups, walking trips were grouped according to gender, income employment, vehicle ownership and age. (Table 4-3, Table 4-6). Table 4-3 shows the populations subgroups that are statistically different. In this subgroup, only the non-income earners are different from each other subgroup (skilled workers, professional workers, and students). There are a lot of poor and low-income class that use walking, but in this study the walking distance middle and upper classes are a higher than the other classes. The statistical significance test for the pairing of both subgroups resulted in a non-significant result, meaning there is no random chance of the difference of both groups.

Table 4-3. Summary Findings for Walking Distances by Socioeconomic Subgroups (1)

Population Subgroup	Population Subgroups (count)	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
By gender	1. Men (320)	705 (9.98)	885 (12.53)	1 and 2
	2. Women (277)	631 (8.93)	830 (11.80)	
By Income	1. Poor and Low-income class (269)	680 (9:37)	877 (12.42)	1 and 2 2 and 3
	2. Middle and Upper Class (134)	818.75 (11.58)	1010 (14.17)	
	3. No Income (213)	600 (8.93)	756.8 (10.72)	
By Employment	1. Skilled Workers (169)	793.75 (11.23)	900 (12.73)	2 and 3 1 and 3 3 and 4
	2. Professional Workers (183)	793.75 (11.23)	926.75 (13.12)	
	3. Non-income earners (111)	518 (7.33)	689 (9.75)	
	4. Students (96)	713 (10.10)	900 (12.73)	

While walking distances of men and women closely track each other, their distances are different from each other. Table 4-4 shows that men have work bound trip purposes than women, and women have more non-work trip purposes than men. Table 4-5 shows that more women consider themselves poor than men.

Table 4-4: Share of Each Gender According to Trip Purpose

		Go to Work	Go to School	Go Home	Social and Recreation	Others
Men	Count	122	26	83	22	65
	Percentage	38.4	8.2	26.1	6.9	20.4
Women	Count	83	20	66	49	58
	Percentage	30.0	7.2	23.9	17.8	21.0

Table 4-5: Share of Each Gender According to Income

		Poor to Low-Income	Middle to Upper Class	No Disclosed Income
Men	Count	115	92	120
	Percentage	42.7	68.7	56.3
Women	Count	154	42	93
	Percentage	57.3	31.3	43.7

For walking distances by vehicle ownership and age, both are not statistically significant. Meaning their distances are not a product of a specific circumstance or behavior. Vehicle ownership and age does not largely influence the pedestrian's walking distance. While it does not determine and is not a factor, age should be considered as vulnerable age groups need safe walking infrastructure.

Table 4-6. Walking Distances by Socioeconomic Subgroups (2)

Population Subgroup	Population Subgroups	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
By Vehicle Ownership	1. No vehicles owned (294)	657.5 (9.30)	865.75 (12.25)	None
	2. Owns at least one two-wheeled vehicles (bicycle/motorcycle) (277)	690 (9.75)	838 (11.97)	
	3. Owns at least one four wheeled vehicles (33)	740 (10.47)	798 (11.23)	
By Age	1. Age less than or equal 28 (320)	705 (9.90)	897.45 (12.70)	None
	2. Age greater than 28 and less than or equal 38 (158)	640 (9.07)	830 (11.75)	
	3. Age greater than 38 (154)	606.5 (8.58)	800.75 (11.33)	

4.2. Cycling

For the cycling distances, the source of cycling trips is the MUCEP Household Interview Survey. The data used 3,233 cycling trips made within Metro Manila only. The data resulted in a 75th percentile distance of 5955 meters and an 85th percentile distance of 6405 meters. Using the multiway ANOVA for the cycling data results in significant interactions at $\alpha = 0.05$. Table 4-7 shows the two parameter pairings that has significant interactions. The pairing of Employment and Vehicle Ownership, and Income and Employment together can directly affect walking distance. Table 4-8 shows the parameter subgroup pairings that has significant interactions.

Table 4-7. Multi-Way ANOVA Significant Interactions

Factor	F-Value	p-value
Employment * Vehicle Ownership	2.7147	0.0433
Income * Employment	3.6802	0.0053

Table 4-8. Turkey HSD Tests

Interaction	p-value
Employment* Vehicle	
Non-workers (No Vehicle)+ Blue Collar (No Vehicle)	0.000
Students (No Vehicle) + Blue Collar (No Vehicle)	0.000
Students (No Vehicle) + Nonworker (No Vehicle)	0.0282
Blue Collar (Vehicle) + Nonworker (No Vehicle)	0.000
Nonworker (Vehicle) + Nonworker (No Vehicle)	0.004
White Collar (No Vehicle) + Students (No Vehicle)	0.0000
Blue Collar (Vehicle) + Students (No Vehicle)	0.000
White Collar (Vehicle) + Students (No Vehicle)	0.004
Employment* Income	
Students (Middle to Upper) + Blue Collar (Middle to Upper)	0.008
Students (Not Employed) + Blue Collar (Not Employed)	0.010
Students (Not Employed) + Nonworkers (Not Employed)	0.0000
Blue Collar (Poor) + Nonworkers (Not Employed)	0.0230
Blue Collar (Poor) + Students (Not Employed)	0.000
White Collar (Poor) + Students (Not Employed)	0.0000

Cycling distances by purpose has home and work trips having the highest distances, followed by Social and Other purposes, Recreation and School Trips. School Trips have the least distance since most schools are located within the community. Statistical difference tests by purpose yield a p-value of less than 0.05, thus there are pairs of subgroups that are statistically different. Table 4-9 shows the summary of statistically different pairs of trips purposes. Most statistically different pair show that school is statistically different from home, school, work and social and recreation trips. Work Trips have the most count of all cycling trip purposes.

Table 4-9: Cycling Distances by Trip Purpose

Population Subgroup	Population Subgroups (count)	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
All Cycling Trips	(3,233)	5955 (27.95)	6405 (30.07)	None
By trip purpose	1. To Home (1614) 2. To School (152) 3. To Work (1153) 4. Social and Recreation (195) 5. Other purposes (119)	5,955 (27.95) 3,225 (15.13) 5,955 (27.95) 4,962.5 (23.30) 5,477.5 (25.72)	6497.5 (32.62) 4300 (20.18) 7500 (35.22) 5955 (27.95) 5955 (27.95)	1 and 2 3 and 2 2 and 4 3 and 4 4 and 5

Like in walking, cycling distances were also grouped by different socioeconomic profile like gender, income, employment, vehicle, and age. The statistical difference tests yielded statistical differences when it comes to gender, income, employment, vehicle ownership. There is no statistical difference by age.

The differences in distances and number of trip makers between men and women are evident. More than 90% of all trips are made by men, and men also cycle a much longer distance than women (Table 4-10).

Poor and low-income class also compose most of the cycling trips, followed by those who did not declare any income and then the middle and upper class. The statistical difference tests say only the poor and low-income classes and the no income classes are different. It also found out that poor and low-income class cycling have longer distances in the 85th percentile distance threshold. People with no disclosed income bike the shortest of three subgroups. Poor and low-income compose more than three-quarters of all cycling trips (Table 4-10).

Table 4-10: Summary Findings for Cycling Distances

Population Subgroup	Population Subgroups (count)	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
By Gender	1. Men (2988) 2. Women (245)	5,955 (27.95) 3,750 (17.60)	6450 (30.28) 4978 (23.37)	1 and 2
By Income	1. Poor and Low-income class (2644) 2. Middle and Upper Class (75) 3. No Income (514)	5,955 (27.95) 5,955 (27.95) 3,225 (15.13)	7500 (35.22) 6405 (30.07) 3225 (15.13)	1 and 3

In the employment subgroups, the students have statistical differences paired with every other employment group. It also found out that the skilled workers and professional workers are statistically different. Skilled workers have the most, followed by non-income earners, students and professional workers. Skilled Workers compose three-fourths of all cycling trips.

In the cycling distances by vehicle ownership, while the distances estimated are quite close in values, the statistical difference between the two have a p-value of less than 0.05, meaning these differences have a specific behavior rather than occurring on random.

Table 4-9: Summary Findings for Cycling Distances

Population Subgroup	Population Subgroups (count)	75th Percentile, m (mins)	85th Percentile, m (mins)	Statistically Different Pairs
By Employment	1. Skilled Workers (2439)	5,955 (27.95)	7500 (35.22)	1 and 2
	2. Professional Workers (244)	5,492 (25.78)	5405 (30.07)	2 and 4
	3. Non-income earners (282)	4,963 (23.30)	5955 (27.95)	1 and 4
	4. Students (268)	3,225 (15.13)	3750 (17.60)	3 and 4
By Vehicle Ownership	1. No vehicles owned (2456)	5,955 (27.95)	6405 (30.07)	1 and 2
	2. Owns any motor vehicle (77)	5,955 (27.95)	7500 (35.22)	
By Age	1. Age less than 30 (792)	5,000 (23.47)	7500 (35.22)	None
	2. Age greater than or equal 30 and less than 60 (2248)	5,955 (27.95)	6405 (30.07)	
	3. Age greater than or equal 60 (193)	5,955 (27.95)	5955 (27.95)	

To visualize the extent of 75th percentile (5955 m) to 85th percentile (6405 m) from different locations in Metro Manila, the service coverage maps in Figure 4-2 (next page) using survey locations from the intercept survey for pedestrians were also used. The blue polygon shows the extent of the 75th percentile distances and the red polygon shows the extent of the 85th percentile distance. The red dots mark the nearest road intersection or common landmark in the boundary.

4.3. Transit Service Coverage Area

The 75th percentile and 85th percentile walking distances estimated (Table 4-1) were used as a basis for the extent of the service coverage areas for different modes of public transportation. Table 4-11 shows the coverage of each mode of public transport in terms of the land area coverage and the population served. The mode with the highest coverage area and population served are the Traditional Jeepneys, followed by modern jeepneys, UV Express, buses and railways. This is contrary to the public transportation hierarchy outlined in the MMPTPSS (NCTS, 2012) and Omnibus Franchising Guidelines (OFG 2017) stating the trains, and buses should have the largest service priority followed by jeepneys, multicabs, tricycles and pedicabs. When the overall transit coverage is calculated, only 55-66 percent of the whole NCR is covered by any mode of public transportation, leaving 34-45 percent without coverage to any public transport stop or corridor.

Figure 4-2. Biking Distance Maps for all survey locations

In generating service coverage for cycling, a factor of 0.14 was multiplied with the estimated cycling distances because all built Bayanihan 2 cycling lanes are parallel with the major roads of Metro Manila which makes cyclists share the same road space with motorized vehicles (McNeil, 2011). The resulting effective distance is 833.7 m and 896.7 m. The land area covered by the cycling network is 45.21% to 47.63%, with an estimate 6.1 to 6.3 million Metro Manila residents that could potentially benefit from an accessible cycling network (Figure 4-3).

The same distances are then used to determine service coverage if cycling is used as a first-mile access to public transportation. The scenario assumes that the cyclist can park their bicycles in transportation hubs or bring the bicycle with them in transit. The service coverage covered is between 72.32% to 74.84% of the total land area, or an estimate of 9 to 9.3 million resident population served. The covered area by this scenario is an increase of almost 30% coverage area than the cycling lanes alone.

Table 4-11. Summary for Service Coverage Area

	75th Percentile Distance			
Mode	Land Area Covered (%)	General Population (thousands)	Workers (thousands)	School (thousands)
Railway	7.69	1,312.16	433.75	262.28
PUB	24.02	3,149.64	942.12	615.31
Modern PUJ	38.83	5,153.95	1,504.74	1,016.22
Traditional PUJ	48.86	6,700.84	1,975.90	1,317.13
UV Express	29.72	3,749.77	1,112.00	732.89
All Modes	55.28	6,888.97	1,940.46	1,368.21
All Modes (additional walking distance)	67.50	8,411.02	2392.60	1670.50
Cycling	45.21	6,109.28	1,819.43	1,195.97
Cycling as the first mile access to Public Transportation	72.32	9012.30	2564.71	1789.92
	85th Percentile Distance			
	Land Area Covered (%)	General Population (thousands)	Workers (thousands)	School (thousands)
Railway	11.42	1,880.63	615.24	375.82
PUB	32.23	4,450.55	1,322.82	871.19
Modern PUJ	49.16	6,500.34	1,892.86	1,282.94
Traditional PUJ	57.31	7,731.55	2,259.12	1,521.87
UV Express	37.50	4,708.90	1,389.51	921.58
All Modes	66.11	8,237.74	2,344.29	1,636.09
All Modes (additional walking distance)	75.79	9443.82	2687.52	1875.62
Cycling	47.63	6,304.81	1,900.81	1,252.04
Cycling as the first mile access to Public Transportation	74.84	9325.87	2653.95	1852.20

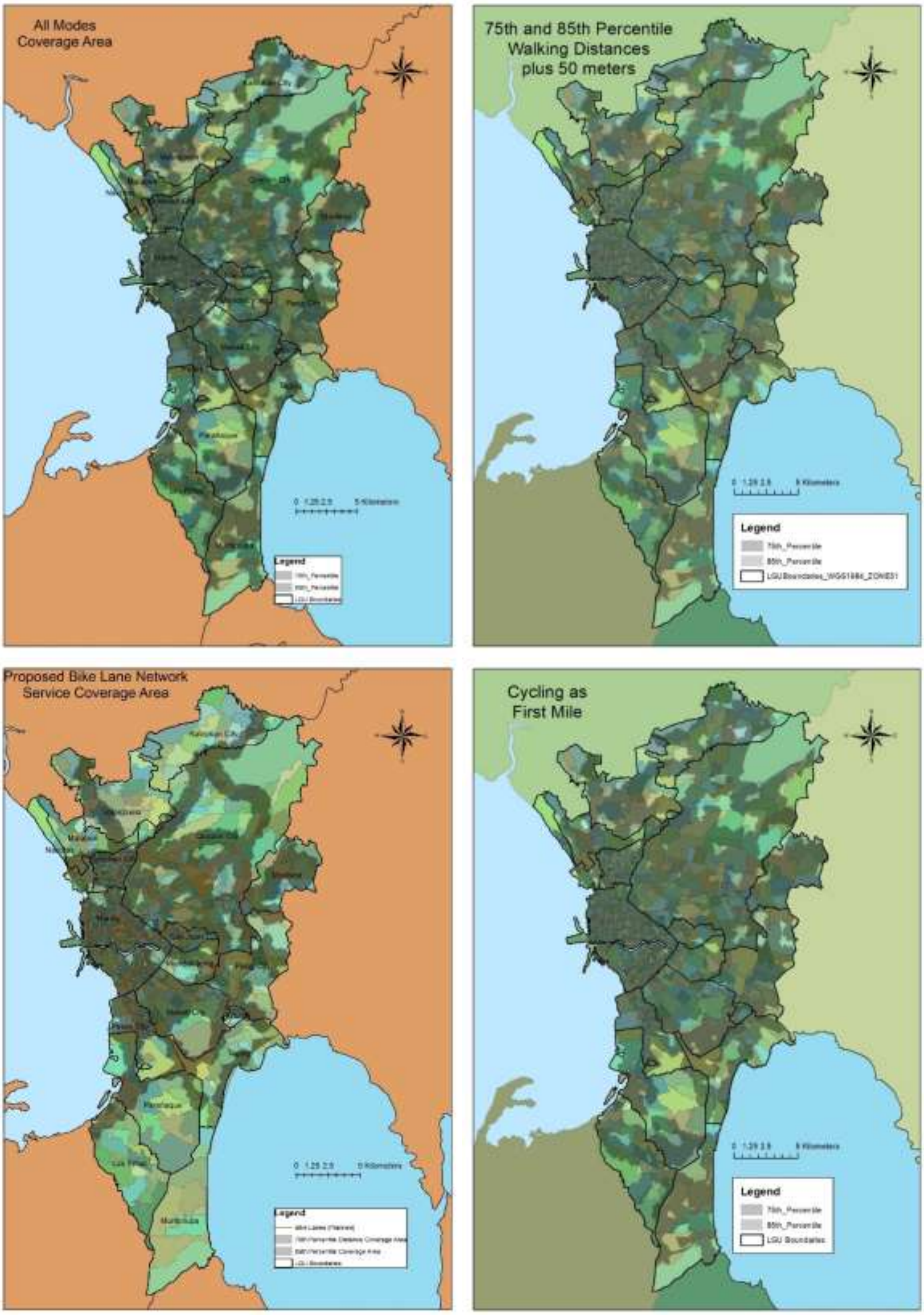

Figure 4-3. Service Coverage for All Modes (left) and Additional 50 meters (right)

5. CONCLUSION

The research used both intercept and existing HIS database to come up with an estimate of the walking and cycling distances of a sample of Metro Manila population. The determined distances are 680 meters for walking, and 5,955 meters for cycling. Seneviratne (1985) mentioned that the walking distances are a function of the road network, population, and the locations of different trip generators and attractors of the city. Comparing the current walking distances from the earlier study with a walking distance of 251 meters, the current distance reflects how the central business districts, and in the larger scale, the setup of the business districts and the transportation network changed to force some behavioral changes on the pedestrians.

The usage of multiway ANOVA resulted in a no significant interactions between parameters of walking, but with significant interactions between pairing Employment and Vehicle Ownership, and Employment and Income. While multiway ANOVA is a useful method to determine if there are possible interactions that can affect walking and cycling behavior, future studies can be done to determine relationships or interactions between populations subgroups.

Walking and cycling distances for different trip purposes, walking endpoints and socioeconomic demographic such as gender, age, income, employment, vehicle ownership and age were also estimated. It is found that many walking trips are linked to public transportation, this improving walking facilities adjacent to public transport hubs and corridor should be prioritized. The public transportation transfers or the third case of walking trip endpoints is 480 meters and is statistically different from both first-mile and last-mile trips. This signifies that this case is a unique walking type and can impact infrastructure through the effect of pedestrian flow and speed of transiting pedestrians and resident pedestrians. For future research, an approach to study transfers between specific modes or routes should be studied.

The research also found out the following have the most walking trips by socioeconomic profile: men, poor to lower income class, skilled workers, no vehicle ownership, and age less than 28 years. The distances and behavior of the vulnerable groups should be taken into consideration when building and planning for infrastructure for pedestrians. The needs of male and female pedestrians and their perception of walking should be done in future research to precisely capture the different needs of each gender in walking.

For cyclists, the estimated distance based on the cycling trips of MUCEP HIS data is 5,955 meters. This distance validates the need of a widespread cycling path network that supports long distance cycling. Men have greater distances and number of cycling trips than women. A study pointed out that women are not encouraged to bike because of the risks they perceive. Cycling should be designed to be more comfortable to women, and safe and secure cycling infrastructure for women should be studied. Most cycling trips were done by the low income and skilled labor classes, establishment and improvement of cycling infrastructure will greatly benefit these groups. Privileged groups like the middle and upper classes will also benefit as cycling infrastructure also provides them more mode choices that can minimize their dependence on cars. While it is shown that cycling by age is not is not statistically significant, young and elderly cyclists are vulnerable so their needs must be taken into account when designing cycling infrastructure.

The service coverage of each mode of public transportation in Metro Manila was also generated using the walking and cycling distances estimated from the data collected. Service coverage area and estimate population served by each more were done. Traditional jeepneys serve the largest area and population served, followed by modern jeepneys, UV Express, Public Utility Buses and Railway service. This order is contrary to the hierarchy outlined for public transportation where higher capacity modes are given more priority than lower capacity modes because of their capability to serve more in a few vehicle units. The service coverage for all modes covers between 55.28 to 66.11 percent, or about 6.8 to 8.7 million residents of Metro Manila having access to public transportation. A total of 34 to 45 percent of the total area does not have access to public transport, leaving them dependent on cars or paratransit modes. An improvement of pedestrian infrastructure will entail an increase of 50 meters in additional walking distance, and consequently will increase service coverage by 11 to 12 %.

The current cycling network was planned and built can cover 45 to 47 percent or approximately 6.1 to 6.3 million residents having access to cycling infrastructure. Beyond the bicycle lanes, the service coverage was also generated in a situation where cycling can be used as an access to public transportation. The service area covered is between 72 to 75 percent of Metro Manila or between 9.0 to 9.3 million having better access to public transportation through cycling. It is a big increase in accessibility than building bike lanes alone. Promoting cycling or even bike sharing as a first mile trip to public transportation can possibly increase both cycling and public transport demand.

Walking and cycling gained renewed attention because of the pandemic, traffic and climate crisis that is why there is a need to rethink and redesign our transportation system that includes and prioritizes these two modes. In the design of facilities, the distance people usually travel through these can be a basis of the area and scope of design improvements. These results can be a guide to policymakers and planners in designing facilities and infrastructure that considers the different characteristics and behaviors of different people and cyclists.

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