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SITE SELECTION FOR NEW POINT TO POINT (P2P) BUS ENDPOINTS AND ROUTES IN METRO MANILA, PHILIPPINES

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ABSTRACT:

The Point to Point Bus system (P2P) is a relatively new transportation alternative available in selected areas in Metro Manila and other provinces nearby. New routes are continuously added to cater to the ever-increasing demand of the commuting public to avoid wasting time in heavy traffic and to provide alternatives to the inconvenient metro trains. This paper presents a methodology for the identification of potential sites of additional routes for P2P Premium Bus Service in Metro Manila. Trip generation, trip attraction, and friction factor were determined to show trip distribution using gravity model. A raster-based approach of gravity model was conducted to disaggregate zonal data into discrete and continuous trip distribution values. Through the generated trip distribution values, site suitability was conducted to identify origin and destination of routes, primarily the major malls. Using network analysis, 14 new routes were identified by connecting suitable sites for P2P Premium Bus Service routes.

1. INTRODUCTION

1.1 Background of the Study

A study on Economic Impact of Traffic Congestion in Metro Manila conducted by the University of the Philippines National Center for Transportation Studies (UP-NCTS) for the National Economic Development Authority (NEDA) Legislative Executive Development Advisory Committee (LEDAC) in 2000 estimated that the lost time due to grave road traffic congestion in Metro Manila was estimated amounting to Php 100 Billion each year, implying that traffic congestion in Metro Manila has already become a major economic crisis. A more recent study by the Japan International Cooperation Agency (JICA) estimated 2.4 to 3 billion pesos lost daily due to traffic, and this figure could double to about 6 billion pesos lost daily within the next 15 years. (JICA, 2014)

Based on the 2015 Population Census of the National Statistics Office (NSO), there are 12,877,253 people living in Metro Manila. Every day, approximately 13 million people go through their daily commute, not to mention the influx of people from nearby towns and provinces in Metro Manila during business hours. These commuters use buses, jeepneys, tricycles, UV Express, railways (LRT1, LRT2, MRT3), trains (PNR), and the more expensive alternatives, taxi cabs and ride hailing apps such as Grab and Uber.

The government has taken measures to deal with the long-standing problem of traffic congestion in Metro Manila by introducing the Point-to-Point (P2P) Premium Bus Service to add to the mandatory off-the-road days for cars. Instead of taking the regular buses that have multiple stops, the P2P Premium Bus Service offers comfortable and shorter travel time through its non-stop ride from origin to destination. As compared to ‘hail and ride’ services, this service follows a route rather than directly going to preferred destination of the rider which may be more costly. These features make P2P more attractive for regular commuters for significantly improving their commuting experience at an economical cost. P2P Premium Bus Service is currently available for 18 regular routes, 13 of which operate within Metro Manila and 2 additional Christmas P2P routes also within Metro Manila; but the ever-worsening traffic situation shows that more P2P routes could offer more relief to the commuting public.

Accumulated data about this P2P system could provide more insights on how to further improve and offer more alternatives to the riding public. In this study, identification of potential sites and routes for P2P Premium Bus Service in Metro Manila using trip distribution gravity model.

1.2 Study Area

Metropolitan Manila includes four (4) cities and thirteen (13) municipalities. These are the cities of Manila, Caloocan, Quezon and Pasay. The municipalities include Makati, Mandaluyong, San Juan, Las Piñas, Malabon, Navotas, Pasig, Pateros, Parañaque, Marikina, Muntinlupa, Taguig, and Valenzuela.

Figure 1. Map of Metropolitan Manila

Metro Manila is accounted for 35.7 % of the Philippines economic output, 18 % of its population and 28% of its motor vehicles, on barely 0.2% of the country's land area (Boquet, 2013). Many parts of Metro Manila experience heavy congestion, especially in areas of high population density such as Tondo and narrow streets in old neighborhoods such as Quiapo and Guadalupe. Heavy downpours during the rainy season also make some low-lying streets impassable.

In 2009, the number of registered vehicles in Metro Manila amounted to 1.77 million, or an increase of 11% from 2007 levels (JICA, 2015). As the number of vehicles increase, major roads in Metro Manila become congested and can no longer accommodate the rapidly rising traffic volume, which has more than doubled within the last decade. Of the 4.2 million motor vehicles registered in the Philippines about 1.4 million (33%) are registered in Metro Manila compared to 685,000 in 1990. Chronic problems of insufficient road space, traffic congestion, increased demand for quality public transport services, and traffic management issues have been observed and remain as challenges (Mercado, et al, 2005).

Metro Manila was divided into 268 traffic analysis zones as defined by JICA Project Team (JICA, 2015) as shown in the figure below:

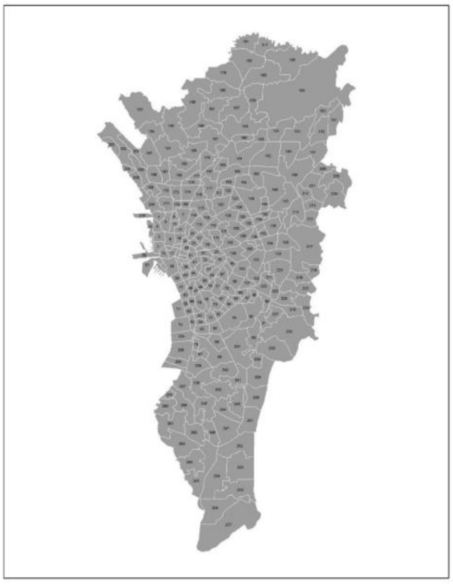


Figure 2. Traffic Analysis Zones in Metro Manila

1.3 Objectives

This paper reports on a methodology using GIS spatial analysis capabilities in finding suitable additional P2P Premium Bus Service routes for commuters in Metro Manila to help shorten their travel time. Also included are the steps in performing spatial analysis to determine suitable sites of endpoints for additional routes of P2P Premium Bus Service and performing network analysis to identify routes from and to the suitable sites of the end points.

1.4 Scope and Limitations

The focus of this report is on the determination of potential sites of endpoints P2P Premium Bus Service in Metro Manila as the study area. Through the application of spatial analyses, trip distribution, which determines the number of trips that enter a location/zone, will be the only determinant in locating suitable sites of endpoints of the P2P Premium Bus Service. Moreover, to limit the number of possible origins and destinations, only the big malls were considered as the endpoints of the P2P Premium Bus Service.
For determination of routes, primary and secondary types of roads were the only types of road networks included in the Network dataset for Network Analyses. Since there are no available dense traffic data in Metro Manila, traffic was not considered as one of the determinants in the Network Analysis. Only the shortest was used to define the connection between the endpoints and to visualize the routes.

2. RELATED LITERATURE

2.1 Trip Generation and Attraction

Trip generation is defined as the number of trips that originate in each zone for a given jurisdiction or the estimation of the number of trips produced by a Traffic Analysis Zone (TAZ). It is divided into two categories: 1) trips made by a household to pursue mandatory activities and 2) trips made to engage in discretionary activities. The first category refers to activities involving work and school while the second category refers to activities where decisions for engagement, location, timing and duration involve flexibility (Goulias, etl al, 1990). On the other hand, trip attraction is defined as the estimation of the number of trips attracted to or the number of trips that enter a TAZ (Briones, et al, 2017).

Based on several trip purpose and population surveys, different models are created to determine the number of trip attractions and trip generations per zone and per purpose (JICA, 2015). Trip generation and attraction values can be computed using the model formulated by JICA Project Team for five different trip purposes: (1) To work; (2) To School; (3) To Business; (4) To Private; (5) To Home as a function of population.

Purpose	Equation
To Work	Generation = 0.3063 x [Population>4 years old:Night] + 1124.83
	Attraction = 0.7539 x [Secondary Worker:Day] + 0.9288 x [Tertiary:Day] + 630.78
To School	Generation = 1.2885 x [Elementary:Night] + 0.6961 x [High School/Univ.:Night] + 1046.67
	Attraction = 1.0269 x [Elementary:Night] + 1.1197 x [High School/Univ.:Night] + 824.10
To Business	Generation = 0.2906 x [Primary Worker:Night] + 0.1561 x [Secondary+Tertiary:Night] + 1506.73
	Attraction = 0.2579 x [Primary Worker:Day] + 0.2006 x [Secondary+Tertiary:Day] + 776.99
To Private	Generation = 0.2001 x [Population>4 years old:Night] + 0.0435 x [Population>4 years old:Day] + 1986.04
	Attraction = 0.2891 x [Primary + Secondary +Tertiary:Day] + 0.4866 x [Student:Day] + 1543.98
To Home	Generation = 1.5509 x [Primary+ Secondary+ Tertiary:Day] + 0.7956 x [Elementary:Day] + 1.6794 x [High School/Univ.:Day] + 4339.60
	Attraction = 0.8911 x [Population>4 years old:Night] + 3868.03

Table 1. Trip Generation and Attraction (JICA, 2015)

2.2 Friction Factor

In a gravity model, friction factor is a function of the travel time (or cost) between TAZs. It expresses the effect of travel time on the number of trips travelling between two zones. Each factor differs by trip type to reflect the fact that some types of trips are more or less sensitive to trip length. A high friction factor indicates that the TAZ generates and attracts more trips (HDR, Inc., 2013). A gamma function calculates friction factors for each zone pair based on travel time between zones and three parameters derived and iteratively adjusted based on model results of a similar study. For this study, the gamma function is expressed as:

$$F(t_{ij}) = at_{ij}^{-b}e^{-c(t_{ij})} \tag{1}$$

Where: $F(t_{ij})$ is the friction factor for each zone pair based on the travel time t_{ij} between zones
a, b and c are the derived parameters based on model results

Using this expression, 100, 0.265 and 0.0038 were the values used for parameters a, b, and c, respectively based on the NHCRP 716 (Travel Demand Forecasting: Parameters and Techniques) report.

2.3 Trip Distribution

Trip distribution is the quantification of the number of trips of each zone as distributed from a generating zone. There are several methods that employ trip distribution such as growth factor and gravity model each with their own assumptions. The growth factor method relies on the population growth rates in origin and destination zones to determine trip distribution. The gravity model for trip distribution is similar to Newton's theory of gravity. This model assumes that the trips produced and attracted are directly proportional to the total trip productions and the total trip attractions and inversely proportional to the distance between the origin and destination. The separation between the origin and destination zones is expressed as a decreasing function known as deterrence function. For a study area divided into Z zones, this model is expressed as (Abdel-Aal, 2014):

$$T_{ij} = \frac{O_i D_j fc_{ij}}{\sum D_j fc_{ij}} \tag{2}$$

Where: T_{ij} is the trips produced in an origin zone i and destination zone j
O_i, D_j is the total trips ends produced at i and attracted at j
fc_{ij} is the generalized function of travel costs between any pair of zones i and j

Gravity model has been widely used as a method to determine and evaluate spatial interactions of people and goods. It shows that the interaction between places decreases as the distance increases (Briones, et al, 2017).

Several studies have ventured on the use of gravity model various contexts (Metulini, 2013; Porto, et al, 2018; Khadaroo, et al, 2007; Krings, et al, 2009). Vital to transportation planning especially for urbanized areas, gravity model for trip distribution can be used to assess the current transportation efficiency and improve transportation system in the area (Boukebbab, et al, 2015; Jung, et al, 2007; Tsekeris, et al, 2006). Since this model evaluates the connectivity and distribution between zones, transportation modes can be assessed and improved through the number of trips and its distribution as manifested in the studies of Cordera, et al (2018), Wang, et al (2016), and Asmael, et al (2018). In the case of this study, trip distribution values shall be used for the determination of endpoints of P2P bus system and improve its efficiency for better alternative for mass transportation.

3. METHODOLOGY

3.1 General Workflow

The general workflow in the identification of new P2P Bus origins and destinations, and routes is shown in Figure 3. These general methodologies are explained in detail in the succeeding sections.

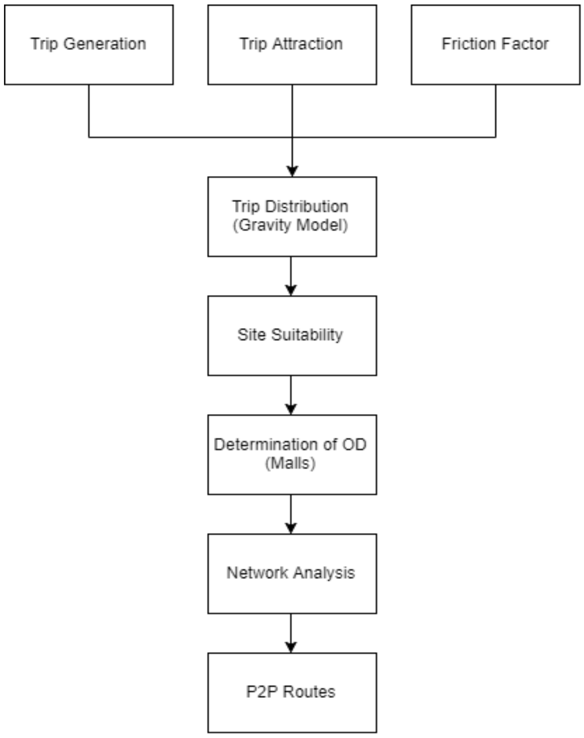


Figure 3. General Workflow

3.2 Data Used

Summarized below are the data used in the determination of suitable sites for new P2P bus endpoints:

Data	Year	Source
Traffic Analysis Zones (TAZ)	2014	JICA
Population per TAZ	2014	JICA
Road Network	2017	OSM
Malls	2017	OSM

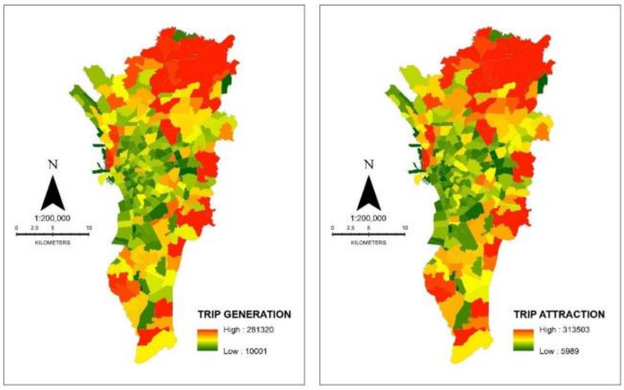
Table 2. Data Used

Other provinces surrounding Metro Manila were included in the TAZs delineated by JICA. However, only those belonging to Metro Manila were considered for analysis. Only 2014 population data was considered for the computation of trip generation and attraction based on data gathered by JICA for each TAZ. In the case of the road networks and malls, OSM data and its existing attributes at the time of the analysis were utilized.

3.3 Trip Generation and Trip Attraction

From the population data gathered by the JICA Project Team per transport zones, trip generation and trip attraction values were calculated using the models listed in Table 1. These values represent how many trips are produced per zone and the degree of "attractiveness" of each zone per trip purpose.

Given the conception that the total generation and attraction of the whole area must be equal, the total generation and attraction values per trip purpose were balanced by distributing a certain factor to every trip attraction value per zone. Since balanced trip generation and attraction values are computed per trip purpose, the summation of all trip generation values and the summation of all trip attraction values were computed to determine the total trip generation and trip attraction per zone. Serving as attribute values of the Transport zones shapefile, these total trip generation and trip attraction values were used to convert vector files to raster files to generate trip generation and trip attraction raster files.



(a) (b)

Figure 4. (a) Trip Generation and (b) Trip Attraction per TAZ

3.4 Friction Factor

To determine friction factors between zones, travel time between zones must be determined. The Cost distance tool under the Spatial Analyst Tools of ArcGIS was used to generate zone-to-zone friction factor raster files. To use the tool, a cost raster was generated using the Metro Manila road networks shapefile from OSM. Given the assumption that roads of higher order give way to a higher car speed as compared to thinner and lower order types of roads, speed values were assigned to each road type. Given that the width of the roads as polylines are similar with each other regardless of the type of road, buffers were assigned as well depending on the type of road—representing the common road width for such type of road. Moreover, since the goal is to determine the approximate time of travel from origin zone to all other zones, the inverse of the speed values was assigned to each of the cells of the raster through Vector to Raster tool. Summarized below are the assignments parameters used to generate the cost raster for Cost Distance Tool.

Road Type	Road width buffer (m)	Speed (kph)	$Speed^{-1}$ (min/m)
Primary	24	60	0.0010
Trunk			
Secondary	12	40	0.0015
Tertiary	9	30	0.0020
Residential	4.5	20	0.0030
Service			
Unclassified			
Non-road	-	10	0.0060

Table 3. Cost Raster Parameters

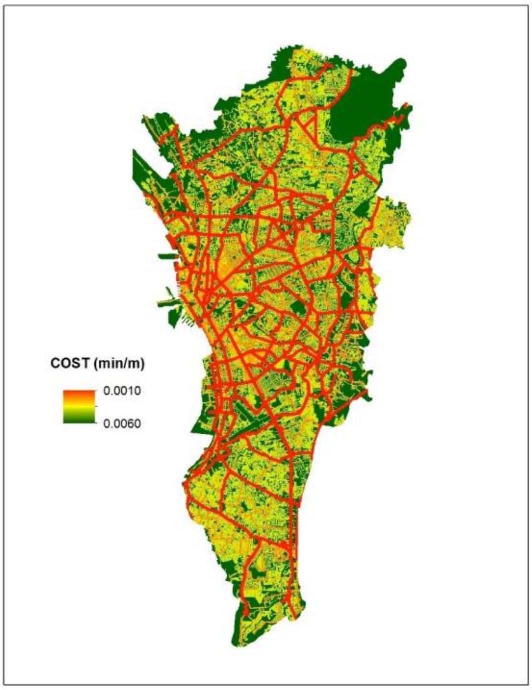


Figure 5. Cost Raster

Since the process in generating time-cost raster files involved the use of multiple files, a model was created to automate the production of these files as shown below:

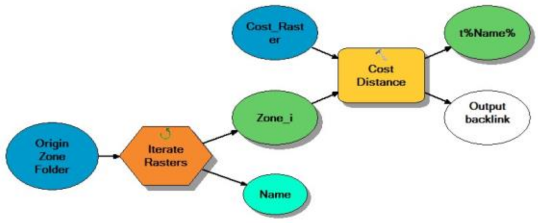


Figure 6. Time-cost Model

268 Zone-to-zones time-cost raster files were produced using the cost raster and 268 Origin Zone raster files where origin zone was assigned a value of 1 and other zones as No Data.
Now a function of time, these Zone-to-zones time-cost raster files were converted to friction factor raster files by applying the gamma function given the parameters a, b, and c using the Raster Calculator. Similar to the time-cost raster files, a model was generated to iterate through the 268 files to generate another 268 Zone-to-zones friction factor raster files.

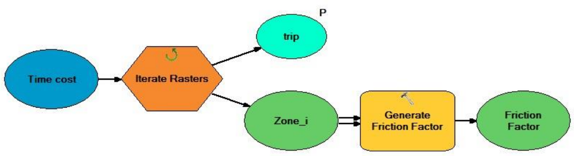


Figure 7. Friction Factor Model

Shown below are the sample zone-to-zones friction factor raster files of Zone 10, Zone 100 and Zone 200.

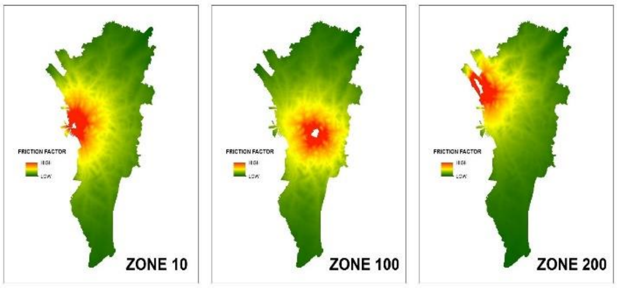


Figure 8. Sample Friction Factor Raster Files

3.5 Trip Distribution (Gravity Model)

Applying the Gravity model using the Trip Generation values, Trip Attraction raster and friction factor raster files, the zonal trip distribution was implemented. This zonal distribution shows the number of trip-transfers from the origin zone to other zones.

Involving multiple raster files, a model (as shown in Figure 9) was built to perform the Gravity Model which involves multiplying the Trip Attraction raster and the corresponding friction factor raster with the extracted Trip Generation value of the Origin zone and dividing it with the summation of the mean product of the Trip Attraction raster and the corresponding friction factor raster per zone. 268 zone-to-zone trip distribution raster files containing number of trips per cell were generated.

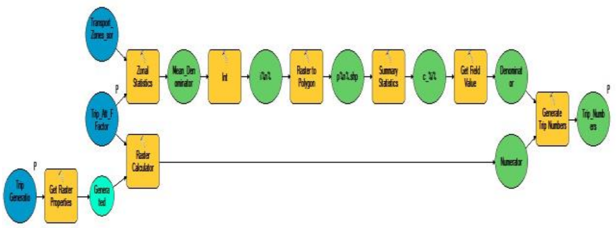


Figure 9. Trip Distribution Model

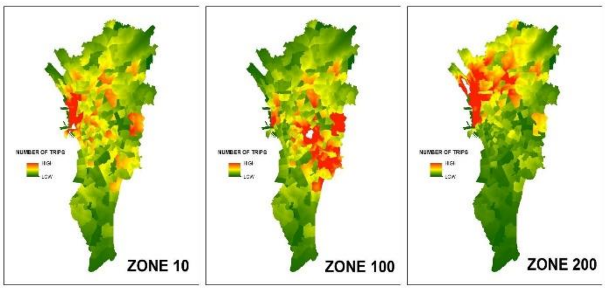


Figure 8. Sample Trip Distribution Raster Files

3.6 Site Selection

With the use of the zone-to-zones distribution raster files, the determination of suitable sites for P2P Premium Bus Service endpoints can be accomplished. Raster Calculator was used to add all the zone-to-zones distribution raster file to compute for the total number of trips per cell in the raster. To determine the suitable sites since there are no available related literatures in identifying suitable sites for endpoints of P2P Bus-type routes, the upper 33% in the range of values in the Total Trips raster was set as the sites suitable for endpoints of the P2P Premium Bus Service system. Reclassification and Raster to Vector tools were used to create suitable sites shapefile features to be used in identifying the possible malls as origins and destinations.

3.7 Determination of OD (Origin and Destination) Malls

Only top-tier malls were selected as possible endpoints since P2P Premium Buses require large spaces for pick-up and drop-off. These point files were then intersected with buildings shapefile of OSM to extract the polygon shapefiles of the malls. Suitable endpoints/malls were extracted by intersecting it the suitable areas shapefile.

As a limitation in determining the origins of the P2P Premium Bus Service Routes, malls used as endpoints in the existing routes were not considered as origins of the proposed routes but were considered as possible destinations. Moreover, malls located in the same zone were considered as one origin due to proximity with each other.

To distinguish the corresponding destination of the set origin, the equivalent Zone-to-zones distribution raster was used as the base raster in performing zonal statistics. The shapefile containing the polygon features of the suitable malls was used as zones to get the mean of the trip distribution values from the zone of the origin mall. However, to avoid choosing nearby malls as destinations, a 5-km buffer was set to remove nearby malls as possible destinations. A table containing the statistics of the number of trips arriving at the possible destinations malls from the origin mall was generated. The mean number of trips arriving at the malls were ranked accordingly and the highest mean value was selected as the destination mall pair of the origin mall.

3.8 Network Analysis

Once the origin-destination pair was determined, routes were determined by performing simple network analysis. A network dataset was created using the road network containing primary and secondary roads in Metro Manila. By means of the Network Analyst tool of ArcGIS, stops (the origin and destination) were marked on the workspace and integrated with the Route Solver to determine the shortest route from the origin to the destination to finally establish the proposed additional route for P2P Premium Bus Service.

4. RESULTS AND DISCUSSION

4.1 Total number of trips

All trip distribution raster files were added with each other using Raster calculator. The summation of all the raster files correspond to the total number of trips that arrive at the location or zone. It can be seen below in Total Trips raster the distribution of trips all over the study area. Ranging from 906 to 315766, red cells indicate areas where there is a high demand for people and green areas indicate low demand for people. This output raster file shall be the only basis for the determination of suitable sites.

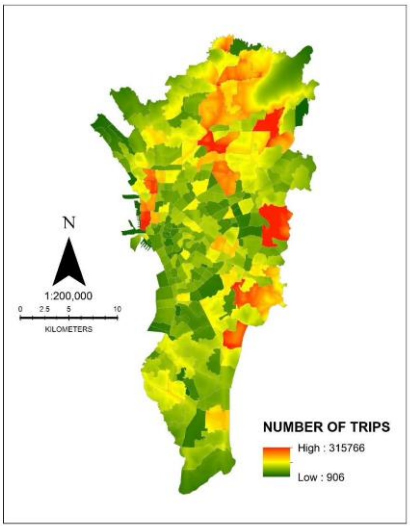


Figure 9. Total Number of Trips

4.2 Suitable Sites

The upper 33% trip values were considered as the most suitable areas for endpoints of P2P Premium Bus Service routes. Shown below are the areas suitable for endpoints of P2P Premium Bus Service

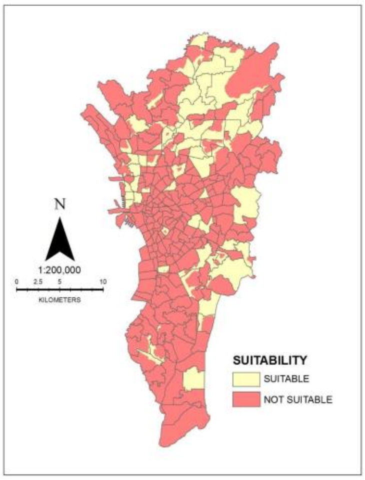


Figure 10. Suitable Sites

The intersection of the suitable areas with the suitable areas was the basis for extracting malls that are suitable as endpoints for P2P Premium Bus Service Routes. Malls were the only landmarks considered as endpoints since these are usually public transport interchanges in Metro Manila. Most of the mass public transportation modes (Light Railway Transit and Metro Rail Transit) in the city have stations near or connected to such infrastructures. These kinds of establishments also allow this system to acquire more passengers due to the influx of individuals. Lastly, these infrastructures provide adequate space for buses to temporarily park to drop-off and pick-up passengers.

A total of 37 malls passed the suitability test and considered as endpoints proposed additional routes for P2P Premium Bus Service. Shown below is the map visualizing the malls that are suitable endpoints for P2P Premium Bus Service.

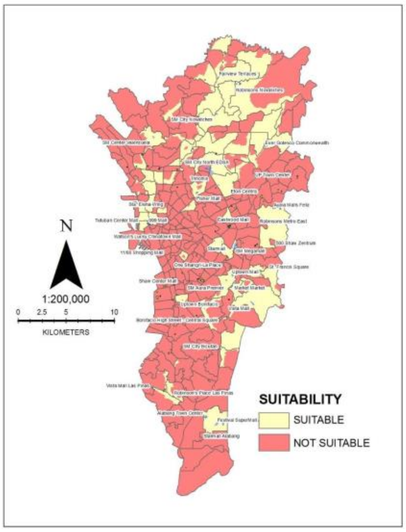


Figure 11. Suitable OD Malls

To limit the number of proposed routes, existing stations were not considered as possible origins but considered as possible destinations. Moreover, malls located in the same transport zone were considered as one origin/destination due to proximity with each other. With that, a total of 14 origin of routes were generated with 36 other malls as possible destination of each origin. Summarized below are the malls considered as origins of the proposed routes for P2P Premium Bus Service.

Number	Origin
1	Ever Gotesco Commonwealth
2	Ayala Malls Feliz, Robinson's Metro East
3	Vista Mall Las Pinas
4	Market Market
5	Eastwood Mall
6	Divisoria (11/88 Shopping Mall, 999 Mall, Sta. Elena-Wing, Tutuban Center Mall, Watson's Lucky Chinatown Mall)
7	Fisher Mall
8	SM Center Valenzuela
9	SM City Bicutan
10	SM City Novaliches
11	Vista Mall Taguig
12	Bonifacio High Street - Central Square, Uptown Bonifacio, Uptown Mall
13	Robinson's Place Las Pinas
14	SM Aura Premier

Table 4. Origins of Routes

4.3 Proposed P2P Bus Routes

The destination pairs of the 14 origins were determined by using the zone-to-zones trip distribution raster file of the zone where the origin mall is located. The 36 other possible destinations were used as zones to determine the mean number of trips that arrive to those malls from the zone of the origin mall. Considering the proximity and the highest mean number of trips from the origin mall, 14 destination pairs were identified which in turn outputs 14 additional proposed routes for P2P Premium Bus Service. Summarized below are the 14 proposed routes for P2P Premium Bus Service and their corresponding driving distances.

Route #	Route	Driving distance (km)
1	Ever Gotesco Commonwealth - Robinsons Metro East/Ayala Malls Feliz	11.59
2	Ayala Malls Feliz/Robinsons Metro East - Market Market	16.09
3	Vista Mall Las Pinas - Alabang Town Center	6.59
4	Market Market - Eastwood Mall	9.33
5	Eastwood Mall - SM Megamall	10.30
6	Divisoria - Trinoma	10.78
7	Fisher Mall - Trinoma	8.85
8	SM Center Valenzuela - Divisoria	9.50
9	SM City Bicutan - Vista Mall Las Pinas	12.71
10	SM City Novaliches - SM City North EDSA	7.08
11	Vista Mall Taguig - Eastwood Mall	10.14
12	Uptown Mall - Ayala Malls Feliz/Robinson's Metro East	11.43
13	Robinson's Place Las Pinas – SM City Bicutan	10.62
14	SM Aura Premier - SM Megamall	6.44

Table 5. Proposed P2P Premium Bus Service Routes

Shown below is a sample map of the proposed new P2P Bus Routes:

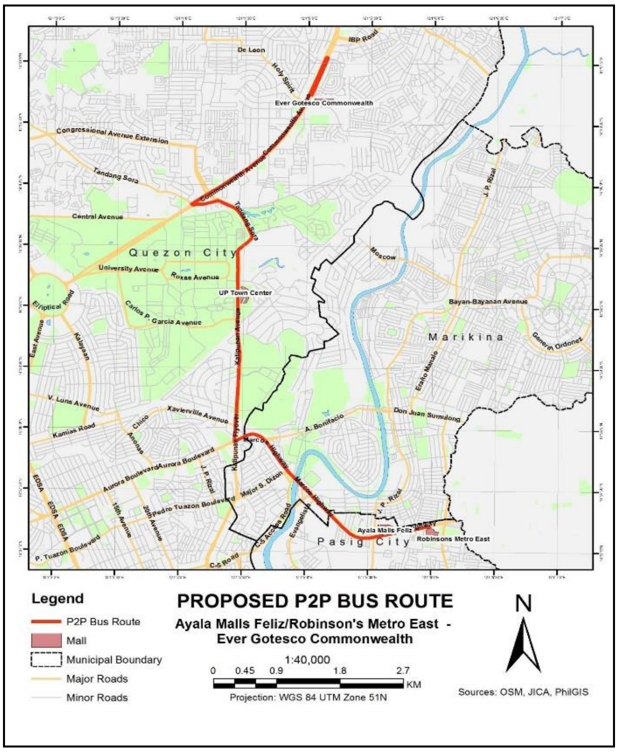


Figure 12. Sample Proposed P2P Bus Route 1 Map

4.4 Verification of Selected Sites

To verify the results of the suitability done to determine the endpoints of the P2P bus routes, malls already part of the existing routes of P2P Premium Bus Service were compared to the malls selected in the Suitability Analysis. The table below shows which malls already part of the existing routes of P2P Premium Bus Service were chosen in the suitability analysis and those who were not.

Correctly identified	Not identified
SM North EDSA	Glorietta 5
SM Megamall	Glorietta 3
Trinoma	Greenbelt 1
UP Town Center	Greenbelt 5
Robinsons Galleria	Ayala Malls South Park
Robinsons Novaliches	
Alabang Town Center Eton Centris	

Table 6. Verification of Suitability Analysis

It can be seen that most of the malls already existing as P2P Premium Bus Service stations were also chosen as suitable sites from the trip distribution method applied as suitability analysis. However, 5 malls were not identified as suitable sites. Since the only basis for the selection of sites is population, the zones where these malls reside do not have sufficient population data. When the population data of these zones looked upon to, it can be seen that no data were available for some aspects which caused these zones to have less trip generation and more importantly, trip attraction; this, in turn, led to less trip arrivals to these zones. Moreover, other socio-economic data were not considered in the process of suitability analysis and that may have affected the analysis and the extraction of the suitable sites.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

This paper demonstrates the applicability of suitability analysis in determining new possible sites for P2P Premium Bus Service routes using trip distribution as its main parameter. The paper also verifies the trip distribution method performed as most malls deemed as suitable sites were already stations in the existing P2P Premium Bus Service routes.

From the chosen suitable sites, a simple network analysis was performed to identify the routes connecting the origin-destination pairs. A total of 14 new routes were determined and proposed as additional routes to the existing P2P Premium Bus Service routes. These routes were determined based on the optimal distance from the origin mall to the destination mall and shows the effectivity of the methodology.

4.2 Recommendations

The following recommendations are offered as possible ways to improve this study. The researchers only used the 2015 data from the research conducted by JICA. To validate the results, recent transport status and traffic data of Metro Manila may be used. Due to newly established commercial areas in the past two years, actual commuter count survey would also help provide more accurate results.

Other methods of finding the total trips in a transport zone such as Fratar method, which extrapolates future growth without differentiating trips by purpose, will also help consider trends and expected growth or traffic for each zone.

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