Mindanao Journal of Science and Technology Vol. 20 (1) (2022) 143-164

Factors affecting the Size of a Mass Transit Station's Pedestrian Shed in Quezon City, Philippines

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Date received: August 25, 2020
Revision accepted: April 29, 2022

Abstract

Mass transit systems are planned to alleviate traffic congestion in Metro Manila but only a few were implemented. The Metro Manila Light Rail Transit Line-2 (LRT-2) line is among the few operational mass transit lines. However, it had witnessed multiple delays during the construction process because it plies through a highly urbanized area with challenging physical constraints. This study aimed to characterize and quantify the existing street network and land parcels around a mass transit station in terms of the street pattern, extensiveness of the road infrastructure, road network connectivity, urban blocks, land plots and its land use to explore how these factors affect the size of the 400-m, 5-min walk pedestrian shed. The available road centerline vector data was used as an approximate representation of the pedestrian walk pattern and existing shape and attribute data of land parcels. These data were processed using Quantum Geographic Information System and analyzed through the use of descriptive statistics and Pearson's correlation matrix. The results suggested that even if not all the identified factors or parameters were exceptional, a station area can still achieve a large pedestrian shed as demonstrated by Cubao station area. Furthermore, land fragmentation that is dependent on the existing characteristic sizes of land uses emerged as one of the determining factors affecting the pedestrian sheds' extent. Urban planners and decision-makers may use this present work to determine the considerations and parameters influencing the access around a mass transit station in terms of maximizing the catchment area for pedestrians.

Keywords*:* urban planning, pedestrian shed, mass transit, Metro Manila

1. Introduction

Metro Manila, Philippines is a collection of cities that have varying degrees and patterns of urban growth. It is a bustling city with a core located in the city of Manila where the Spanish colonial government was established during the 300-year colonial period. During the American period, Daniel Burnham designed Manila's urban plan with multiple radial avenues, circumferential roads and small grids (Poco, 2019). However, after the devastation brought about by World War II, unprecedented and unregulated urban growth was seen. Multiple growth centers located in the suburbs sprung where private vehicles were the center of planning considerations (Camba, 2011). This resulted in an increase in travel demand causing congestion of road networks (Japan International Cooperation Agency [JICA], 2017). Multiple mass transit modes were planned and proposed but were eventually revised and implemented in a piece-meal manner which subsequently resulted in a disjointed system wherein connectivity and convenience were sacrificed (Regidor *et al*., 2017; Jose *et al*., 2018).

The Metro Manila Light Rail Transit-2 (LRT-2), a heavy-rail technology constructed during the early 2000s, was no exception to the problems that Metro Manila's urban fabric poses. It was constructed along a stretch of road that was already highly urbanized. The project was subjected to multiple delays during implementation because of property acquisition issues (Kawabata and Aoki, 2009). Its stations were located in existing urban contexts which may not be compatible in terms of urban structure (Quezon City, 2011). Pedestrian accesses such as sidewalks were not planned considering a mass transit station such as the LRT-2. Multiple studies attested the highly variable conditions of pedestrian infrastructure in Metro Manila (Leather *et al*., 2011; Mateo-Babiano, 2016). However, pedestrian accesses must lead to a wide catchment area to cater to a larger mass transit clientele (Calthorpe, 1993; Ewing and Cervero 2010). Nonetheless, redeveloping the built environment around mass transit stations to improve commuter accessibility and optimize utility of land resources can be challenging because of the financial burden of redevelopment, and the difficulty of land acquisition and consolidation in a highly urbanized area (Cervero *et al*., 2004).

The pedestrian shed was first introduced by Perry (1929) as the neighborhood unit. It is an area where people can walk at a comfortable distance of 400 m or ¼ mile within 5 min from a certain point of origins such as a community center or a mass transit station. It is considered an important indicator of walkability and proximity to important destinations. The literature suggests that the proximity of a mass transit station influences commuter mode preference. This is attested by multiple studies such as in the Netherlands where residents who lived less than 500 m away from the train station were more likely to travel by rail than residents who lived farther away from a train station (Keijer and Reitveld, 2000). In a tropical country like Malaysia, the average comfortable walking distance for residents in urban and rural areas is between 355 to 407 m depending on their place of residence and age group (Azmia *et al*., 2012). Furthermore, a study investigating the travel behavior of commuters in China found that the distance to a mass transit station and transfer time affect commuters' decision on whether to choose public transport or other modes of transportation (Liu *et al*., 2019). Thus, for mass transit to fully serve its purpose and provide optimal benefits to society, considerations concerning the macro and micro components of the urban structure such as the pedestrian shed should also be factored in.

Multiple studies considered factors such as cost of travel, time spent on commuting, existing pedestrian infrastructure, environmental quality, diversity of destinations, job opportunities and access to necessities are integral to measuring the degree of accessibility of an area (Geurs and Van Eck, 2001; Hasnine *et al*., 2019). However, the urban structure is equally as important since it can influence the functionality, connectivity and accessibility of an urbanized area (State of Victoria Department of Environment, Land, Water and Planning, 2017).

According to Sevtsuk *et al.* (2016), urban block design and plot dimensions were the most influential among the multiple factors that influence pedestrian accessibility. In their study, the level of accessibility of block designs of various global cities was compared and contrasted by their gravity indexes. Several authors theorized that smaller block sizes can enable better pedestrian accessibility (Ewing and Cervero, 2010). However, Sevtsuk *et al.* (2016) found that larger block sizes through the means of adjusting block lengths can promote better pedestrian accessibility. Furthermore, reducing the size of land plot frontages can enable more destinations accessed. However, the study focused only on one street pattern typology which is the grid; hence, the results may not apply to other street patterns.

Another study highlighted that street network design was a critical factor to improve accessibility for walking transit clientele (García-Palomares *et al*., 2018). The study employed hypothetical street network patterns around a mass transit station and compared them with the existing road networks of Madrid. Results of the study showed that street network patterns, which provided direct access to a train station with minimum detours, significantly had wider service areas or pedestrian sheds, and possessed a higher degree of accessibility in terms of the number of potential passengers served and the number of jobs accessed compared with irregular and orthogonal street patterns. However, the study did not delve into other factors that can influence street network patterns and the size of the service area such as the existing land uses. The literature underscores that there are multiple observable interactions between land use and transportation such as urban density and travel distance, urban density and fuel consumption, and urban density and public transportation use (Wegener and Fuerst, 2004).

Aurbach (2006) observed about the durability of the built environment inferring the current and historic urban development trends, which point out that lot boundaries and road infrastructure are the least likely to change compared with building facades, building uses and buildings. This emphasizes the importance of proper urban design particularly on the planning of street networks and city blocks because these can influence an area’s walkability in the long term and can be bound to financial limitations owing to the rising redevelopment costs. With the given circumstances, there could be multiple variabilities that can be explored to widen the understanding of the pedestrian shed.

There are multiple factors and components that can be associated with the size or extensiveness of the pedestrian shed such as the street pattern, extensiveness of the road infrastructure, road network connectivity, urban blocks and land plots and its land use. The study aimed to investigate the relationships of these identified factors to the size of the pedestrian shed and hoped to widen the understanding of the pedestrian shed and the factors affecting the size of its coverage. The basis concerning the factors investigated in the study is discussed in the next section. Furthermore, the findings of the study may help urban planners identify and recommend optimal urban street patterns that can create large pedestrian sheds, which may serve a greater number of pedestrians who will live, work and play in proximity to a mass transit station.

2. Methodology

2.1 Study Area

The study focuses on the five selected station areas of the Metro Manila’s LRT-2 system particularly stations within Quezon City, Philippines, namely Gilmore, Betty-Go, Cubao, Anonas and Katipunan stations. This limitation is established as a control of the study since other component cities of Metro Manila may have different land-use policies that may further complicate the variables of the study. Figure 1 shows the geographic location of each station areas.

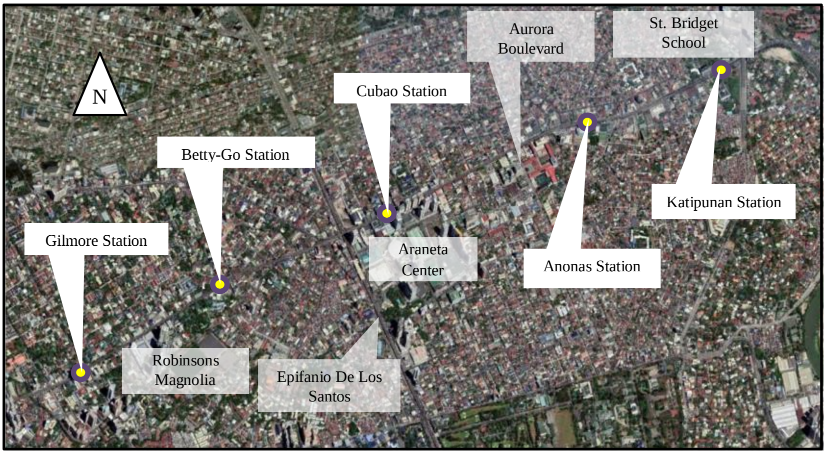

Figure 1. Study area location map (Google, 2018)

2.2 Considered Factors

The study characterized and quantified the following variables related to the physical extent of the pedestrian shed: street pattern, extensiveness of the road infrastructure, road network connectivity, urban blocks, and land plots and their land uses. The selected factors were determined based on their significance to the subject of the study; Table 1 expounds on this matter.

2.3 Data Collection

The study sourced its data from the Planning and Development Office (PDO) of Quezon City and available online data from Google Earth and Google Street View. Quantum GIS (QGIS) was the primary tool used to translate the data into geographical information.

2.4 Qualitative and Quantitative Measures and Tools for Analysis

Table 2 provides further information about the methodologies employed in the study including the qualitative and quantitative measures and the significant analysis tools utilized.

Table 1. Factors considered in the study

Factors	Significance
Street pattern	Considering that sidewalks are located at the sides of the road carriageway, the existing street network pattern is integral in studying pedestrian infrastructure. However, certain street patterns manifest better connectivity than others (Marshal, 2005). This study used the ABCD typology as the basis in determining the type of street network pattern within the pedestrian shed.
Extensiveness of the road infrastructure	Road density is commonly used as an indicator of the road infrastructure development of a country (Ivanova and Masarova, 2013). This study utilized it at a localized level to determine the extensiveness of the road network within the pedestrian shed.
Road network connectivity	Higher connectivity can result in a better walking experience since pedestrians can access areas within the pedestrian shed with relative ease through minimal dead ends, multiple route choices and lesser distance traveled compared with low connectivity street patterns. Link-node ratio is one of the measures used to determine the level of network connectivity of an urban area (Dill, 2004). A higher value indicates good network connectivity. Nodes are intersections that indicate access points to inner areas or a point where a change of direction originated while links are vectors that represent accessways.
Urban blocks	Several urbanists such as Jacobs (1961) and Krier (1984) believe that smaller urban blocks can enable more complexity and diversity and better walkability than larger ones.
Land plots and land use	This factor is crucial to study how land use affects the size of the pedestrian shed since different land uses can correspond to characteristic plot size. Institutional, industrial and high-intensity commercial land use tend to be developed on large land plots while single-detached, duplexes and townhouse residential developments display highly fragmented land subdivisions. Furthermore, plot size and dimensions greatly influence how many destinations can be reached within a certain walking distance (Sevtsuk *et al.*, 2016).
Pedestrian shed/station area	The prime subject of the study and used to determine the size of the pedestrian shed around the selected mass transit stations. The pedestrian shed is an area where pedestrians can reach a certain destination such as a train station or a town center within a 5 minute 400-meter walk (Perry, 1929). It is considered a crucial metric of walkability.

Table 2. Methodology of the study

Factors	Raw data	Data source	Visualization	Measures	Analysis tools
Street pattern	Road centerline vectors	PDO of Quezon City	Network analysis map	Qualitative observation of existing street patterns	Comparative analysis of existing street patterns through the use of the ABCD typology
Extensiveness of the road infrastructure	Road centerline vectors	PDO of Quezon City	Network analysis map	Total road length (km) and road density (km/100 ha^2)	Correlation analysis and comparative analysis of total road length and road density
Road network connectivity	Intersection points and road centerline vectors	QGIS generated from road centerline vectors	Network analysis map	Link-node ratio (number of links/ number of nodes), average link length derived from the links covered within 100-m walking distance from the LRT-2 stations	Correlation analysis and comparative analysis of link-node ratios
Urban blocks	Land parcel polygons	PDO of Quezon City	GIS-generated map	Average Areas (ha^2) of urban blocks covered within 100-m walking distance from the LRT-2 stations.	Correlation analysis and comparative analysis of average urban block areas
Land plots and land uses	Actual land uses and land plot polygons	PDO, Google Street View, and Google Earth	GIS-generated map, bar chart	Average land plot areas (m^2) by land use, land use area share (%) per station area	Correlation analysis and comparative analysis of average land plot areas, and technical analysis of land use mix
Pedestrian shed/station area	Service area polygons	QGIS generated from land parcel polygons	GIS generated map	Total area (ha^2) of the pedestrian shed	Correlation analysis and comparative analysis

Walking is the mode of mobility considered by the study since the pedestrian shed is the primary subject. The study assumed that the point of origin of every pedestrian to any destination within the 400-m walk pedestrian shed was from the LRT-2 stations. This aspect of the study was related to the observation that the pedestrian flow pattern was highly influenced by the existence of an attraction or the presence of a mass transit station (Nakamura, 2016).

The study established the road centerline vector data as the approximate representation of the pedestrian walk pattern along with the existing public road infrastructure network. Also, the study assumed that public roads were accessible to pedestrians even with or without proper pedestrian infrastructure such as sidewalks or pavements with exception of roads that were fully restricted to pedestrian access. However, the researchers acknowledged that roads with minimal or no provisions for pedestrians were not ideal or safe but this study was only concerned with the two-dimensional theoretical extent of the pedestrian shed.

Network analysis was simulated through plotting line vectors that indicated average walking distance along with the existing public road network and then manipulated the color and thickness of the vectors to visually represent walking distance intervals. The 400-m distance or 4-min brisk walk is the maximum comfortable walking distance as previously determined by several studies (Perry, 1929; Azmia *et al*., 2012). Furthermore, the study employed 100-m distance intervals to locate other attributes or variables spatially such as nodes and land properties. Nodes were spatially referenced by creating a point vector layer. Points were placed on the road intersections to indicate the location of the nodes. Road network connectivity was calculated through the ratio of the number of links to the number of nodes covered within the 400-m pedestrian shed. Furthermore, the study investigated which road network enabled pedestrians to access secondary roads within a short walking distance. This was determined by measuring the average link length derived from samples within a 100-m walking distance from the LRT stations.

The number of accessed land plots, average land parcel area and pedestrian shed area were explored to understand the relationship between land fragmentation and accessibility. This was done using the QGIS geo-referencing tool. The extent of a distance interval was based on the simulated network analysis where LRT-2 stations were designated as the point of origin. Accessibility to land properties was based on existing entrances whether it was an entrance gate of a lot or an entrance door of a building. If the lot is wide and extensive without indicated walk paths, the areas of distance intervals are assumed to radiate from the main entrance. The road density was derived from the ratio of the total length of the road network to the pedestrian shed area. This determined the concentration of roads within an identified area.

Concerning the street pattern type, the researcher used the ABCD typology as illustrated on Figure 2. Marshal (2005) sieved through all the redundancies and subjectivity on street pattern naming conventions and came up with four comprehensive street pattern types, namely Type-A (altstadt), Type-B (bilateral), Type-C (conjoint) and Type-D (distributory).

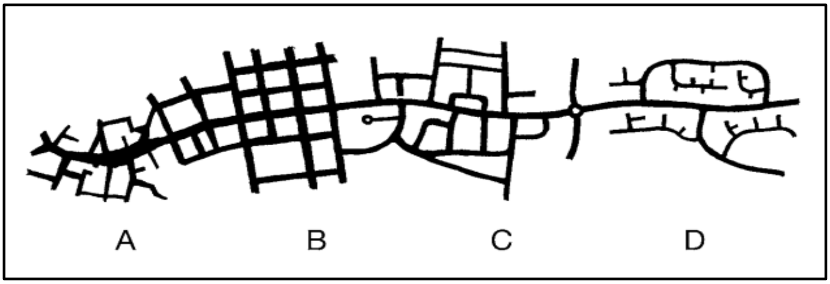

Figure 2. The ABCD street pattern typology (Marshall, 2005)

Variables used to measure the level of accessibility in an area such as travel cost, travel time, existing accessibility infrastructure, available last-mile transportation and available locations for employment and acquiring goods were not considered since these are beyond the scope and subject of the study. Furthermore, due to the limited data resources and research period, the researcher made use of the data and information that were directly accessible. The results of the study may not be the same as other station areas owing to multiple factors such as the differences of urban planning processes, conventions, methods, laws and concepts applied on other mass transit station areas and terminals of other modes of public transportation within and outside the Philippines.

3. Results and Discussion

Larger pedestrian shed area, high number of covered land properties and high road density were assumed to be the most desirable indicators of accessibility. Furthermore, according to Marshal's (2005) ABCD street pattern typology, Type-B is considered to have the highest degree of connectivity which may positively contribute to accessibility. However, the study explored other factors and employed several analysis tools that may otherwise discredit earlier assumptions or discover nuances that may affect the size of the pedestrian shed.

Figure 3 manifests that the existing urban street pattern of the study area varied from station to station. Using Marshal's (2005) ABCD typology, three out of four street pattern types were observed; these were Type-B, Type-C, and Type-D. Based on the ABCD typology, Type-B is considered to have a high level of connectivity compared with both Type-C and D. However, Type-D had the lowest level of connectivity while Type-C only had a moderate level of connectivity. There was no Type-A street pattern observed because Quezon City began to urbanize during the period when vehicle use was already growing. It was noted by Marshal (2005) that the Type-A or altstadt street pattern was created during the period when walking was the primary mode of movement characterized by narrow streets and disorganized street patterns with moderate connectivity.

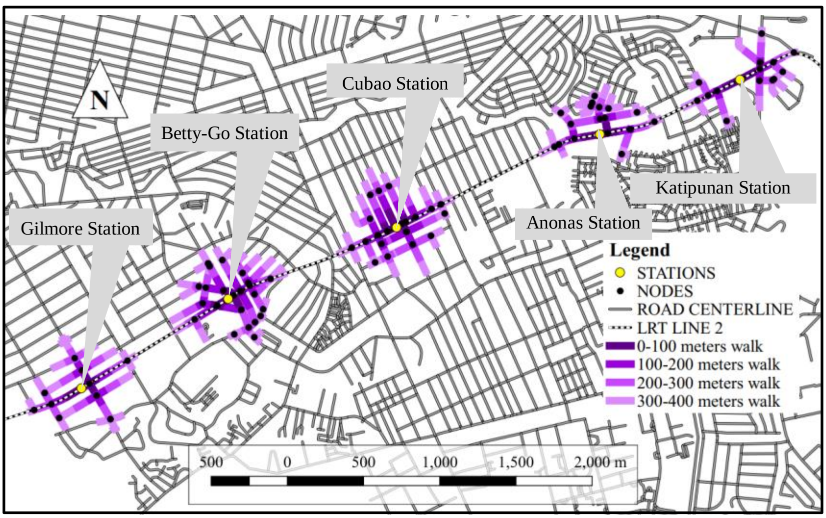

Figure 3. Mass transit stations' pedestrian shed road network

Through visual observation, the station areas with the most extensive road networks were Betty-Go and Cubao station areas. Based on Tables 3 and 4, Cubao station area had the longest road length and largest pedestrian shed area while Betty-Go had the greatest number of land properties and the highest road density. However, it should be noted that the degree of land fragmentation was highest in Betty-Go as evidenced by its relatively small average land plot area (516.75 m^2) compared with the other station areas (Table 4).

Table 3. Qualitative and quantitative data of existing public road infrastructure

Station areas	Street pattern type	No. of links	No. of nodes	Link-node ratio	Avg. link length (m)	Total road length (km)	Road density (km/100 ha^2)
Gilmore	B	29	12	2.42	185.27	3.43	157.95
Betty-Go	C	47	22	2.13	110.40	4.82	217.52
Cubao	B	47	22	2.13	120.09	4.90	194.76
Anonas	C	36	17	2.12	151.59	2.84	163.38
Katipunan	D	24	13	1.85	304.70	2.52	113.12

Table 4. Spatial data of station areas

Station areas	No. of land plots covered	Avg. land plot area (m^2)	Avg. block area (ha^2)	Pedestrian shed area (ha^2)
Gilmore	178	1,220.30	2.13	22.17
Betty-Go	429	516.75	1.21	21.72
Cubao	269	935.09	1.23	25.15
Anonas	269	646.99	3.13	17.40
Katipunan	158	1,410.20	8.10	22.28

Nodes are road intersections that indicate access points to inner areas or a point where a change of direction originated. Based on Table 3, the stations that possessed the greatest number of nodes were Betty-Go and Cubao. It was noted earlier that those two stations possessed a dissimilar number of prominent variables that indicated a high degree of accessibility such as the pedestrian shed size, road density and the number of land properties covered.

Katipunan station area had the least road density, number of nodes and land properties covered but had the second most extensive pedestrian shed area. However, it was observed that Katipunan had the least fragmented station area, which may indicate that it had several land plots with large land areas. In contrast to the Katipunan, Anonas had the least extensive pedestrian shed area with a moderate number of land properties covered yet comparable with the Cubao station area in terms of the latter variable despite it having the largest pedestrian shed. Figure 4 visually represents the size of the pedestrian shed of every station area.

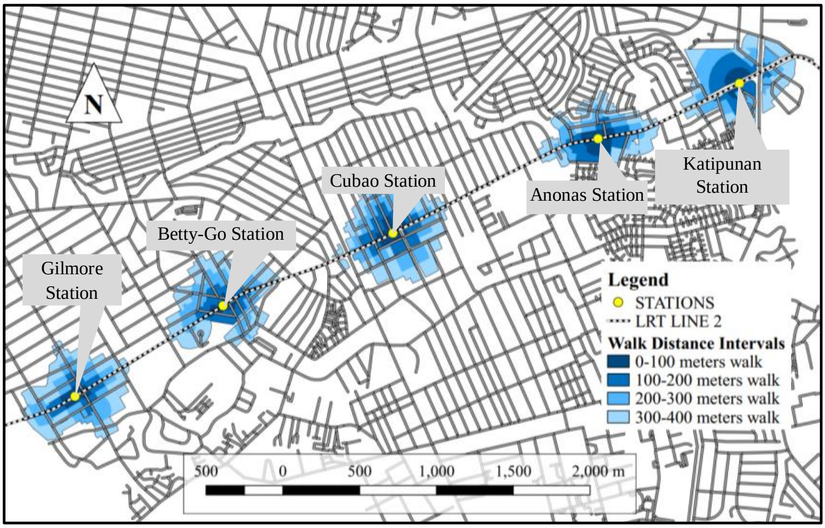

Figure 4. Mass transit stations' pedestrian shed areas

Through visual observation in Figure 4, the most extensive station areas were Cubao and Katipunan but had conflicting indicators when comparing other variables such as road density, number of nodes and number of land properties covered. To further investigate, the study utilized the Pearson's correlation quotient displayed in Table 5 to find the interrelationships of every variable. Table 6 provides the summarized data interpretation and analysis to notable results from Table 5.

Table 5. Pearson's correlation matrix of the study's variables

	Link-node ratio	Avg. link length	Road density	No. of land plots covered	Avg. land plot area	Avg. block area	Pedestrian shed area
Link-node ratio	1						
Avg. link length	-0.52276	1					
Road density	0.39070	-0.94535	1				
No. of land plots covered	0.05432	-0.76404	0.88222	1			
Avg. land plot area	-0.15658	0.83355	-0.81199	-0.90237	1		
Avg. block area	-0.72603	0.95649	-0.89720	-0.62330	0.66681	1	
Pedestrian shed area	0.00753	-0.01132	0.17297	-0.08572	0.39187	-0.13106	1

Table 6. Pearson's correlation results summary

Variables	*r*	Relationship	Analysis
Link-node ratio – avg. link length	-0.52276	Moderate	Long link lengths may result in less road network connectivity while shorter links have relatively high connectivity. Longer and shorter links were observed in Katipunan, and Betty-Go and Cubao stations, respectively.
Link-node ratio – avg. block area	-0.72603	Moderately strong	Large urban blocks may result in less road network connectivity – observed in Anonas and Katipunan stations.
Avg. link length – no. of land plots covered	-0.76404	Moderately strong	Longer link distance to access the secondary roads may result in fewer land plots accessed compared with shorter ones – observed in Katipunan station.
Avg. link length – avg. block area	0.95649	Very strong	Longer link lengths correlated to the existence of large urban blocks (observed in Katipunan station) while shorter link lengths correlated to the existence of smaller urban blocks (observed in Betty-Go and Cubao stations).
Road density – no. of land plots covered	0.88222	Strong	Higher road densities (evident in Betty-Go and Cubao stations) resulted in a higher amount of plots accessed compared with smaller road densities.
Road density – avg. land plot area	-0.81199	Strong	High road densities results in smaller land parcels – evident in Betty-Go station.
No. of land plots covered – avg. block area	-0.62330	Moderate	Large block sizes indicated the existence of large plot sizes as indicated by their correlation index (r = 0.66681). However, large plot sizes may result in a lower number of accessed plots as evidenced by the strong negative correlation of the number of land plots covered to the average land plot area (r = -0.90237), thus indicating the negative correlation between the number of land plots covered and the average block area.
Avg. land plot area – avg. link length	0.83355	Strong	Large plots resulted in longer link lengths compared to smaller plots. This was highly evident in Katipunan station.
Pedestrian shed area – link-node ratio	0.00753	Very weak	Higher connectivity should have contributed to a wider pedestrian shed area as it can enable a greater degree of direction and routes to walk; however, the results suggested that it was not always the case.
Pedestrian shed area – avg. link length	-0.01132	Very weak	Shorter link length within the first 100-m walking distance should have enabled a larger degree of permeability within pedestrian shed areas. However, the nuances of the data can be observed in Cubao station where it has the largest ped shed (25.15 ha^2) with shorter average link length (120.09 m) but Katipunan station rivals it with size (22.28 ha^2) while having a longer link length (304.70 m).

Table 6 continued.

Pedestrian shed area – road density	0.17297	Weak	A well-provisioned/extensive road network within the pedestrian shed should have resulted in a wider pedestrian shed area. However, the weakness of the relationship can be exemplified by Betty-Go station area (21.72 ha^2) exhibiting a very dense road network (217.52 km/100 ha^2) but has a relatively smaller pedestrian shed compared with Katipunan station area (22.28 ha^2), which has the least dense road network (113.12 km/100 ha^2) but has a large pedestrian shed.
Pedestrian shed area – no. of land plots covered	-0.08572	Very weak	Larger amount of plots covered should have resulted in a wider pedestrian shed but the weakness of the correlation indicated that other factors may have affected the relationship. However, several indicators suggested that having large unfragmented plots of land can increase the size of the pedestrian shed such as the case of the Katipunan station area but can sacrifice the number of destinations reached as evidence by the relationship between sizes of land plots and the amount of land plots covered was negatively strong (r = -0.90237). However, consolidated lands can be advantageous to pedestrians if developed and planned as in the case of Araneta Center within the Cubao station area.
Pedestrian shed area – avg. land plot area	0.39187	Moderately weak	The existence of larger land plots indicative of a lower degree of land fragmentation may contribute to a larger pedestrian shed. This is evident in both the Katipunan sta area (22.28 ha^2) and Gilmore sta area (22.17 ha^2) with avg. land plot areas of 1,220.30 m^2 and 1,410.20 m^2 respectively. However, larger land plots can sacrifice road density evident by the variables' negative correlation index (r = -0.81199).
Pedestrian shed area – avg. block area	-0.13106	Weak	Larger blocks have negative effects on connectivity and extensiveness of the road network as mentioned before but these factors do not directly result in a larger pedestrian shed. The weakness of the correlation between the pedestrian shed area and the avg. block area may indicate that other factors affected the relationship.

It should be expected that Type-B street pattern would yield the most extensive pedestrian shed due to its high connectivity as observed in Cubao station area. However, Gilmore had a Type-B street pattern but attained a relatively smaller pedestrian shed compared with Katipunan station area despite that the latter had a low connectivity street pattern. It should be noted that Katipunan had a low degree of land fragmentation as evidenced by its large average land plot area. Furthermore, Katipunan was bounded by two large and deep land properties on both sides which enabled it to extend its pedestrian shed. The land use classification of these two large plots directly adjacent to Katipunan station was institutional and vacant. The presence of these land uses may explain the nuances and weaknesses of the relationships concerning the size of the pedestrian shed to the earlier factors investigated. The last factor (existing land uses) may further shed light on factors that affect the size of a pedestrian shed. Figure 6 reflects the diverse mixture of land uses within the study areas.

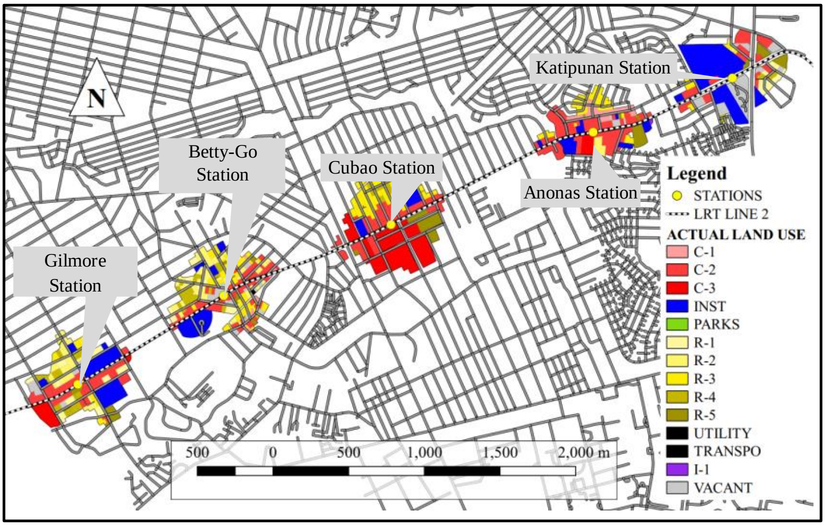

Figure 5. Actual land use map of pedestrian catchment areas

Visually, the structure and components of each of the pedestrian sheds in Figure 5 were distinct from one another. Cubao and Katipunan station areas, in particular, had identifiable dominant land uses. Cubao station area showed vast lands developed for commercial-3 (C-3) uses while Katipunan station area exhibited large areas for institutional (inst.) and vacant lands. The other station areas were visually mixed with scattered representations of multiple land uses. Figure 6 qualitatively expresses the distribution of the identified land uses.

Cubao station area, having the largest pedestrian shed, had several notable characteristics based on the factors studied. Concerning road density, Cubao station area (194.76 km/100 ha^2) was second only to Betty-Go (217.52 km/100 ha^2), which possessed a higher road density. It had a relatively small average block area (1.23 ha^2) and average link length (120.09 m) but was second only to Betty-Go, which had the smallest value of both variables (1.21 ha^2) (110.40 m). Despite having a Type-B street pattern, it still had a moderate degree of connectivity based on its link-node ratio of 2.13 compared with Gilmore, which had the highest link-node ratio of 2.42. Cubao covered fewer plots (n = 269) compared with Betty-Go, which encompassed more land plots (n = 429). Furthermore, Cubao had a low-moderate degree of land fragmentation based on the average plot area (935.09 m^2) but less than Gilmore (1,220.30 m^2) and Katipunan (1,410.20 m^2). However, a significant amount of consolidated land was planned and developed into a mixed-use Transport Oriented Development (TOD) with commercial, community and residential uses while other station areas did not possess any TOD model of development.

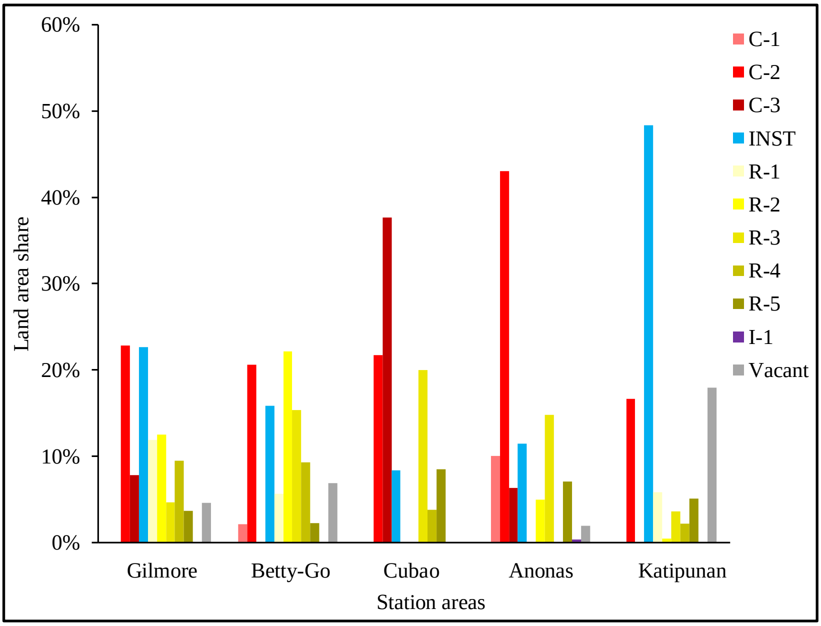

Figure 6. Distribution of land uses within pedestrian catchment areas

Figure 7 shows that every land use corresponds to different plot sizes. However, the data derived from this research can only depict the current situation of the study area and may not show similar results in other station areas located in a different locality, city and country. However, the results corroborate with the descriptions provided within the National Building Code of the Philippines concerning land use. The comparison analysis table (Table 7) compares the sizes of pedestrian sheds and shows prominent land uses within each station area, description of land uses from the National Building Code of the Philippines, identification of notable destinations, and remarks about how these existing land uses contribute to the level of land fragmentation.

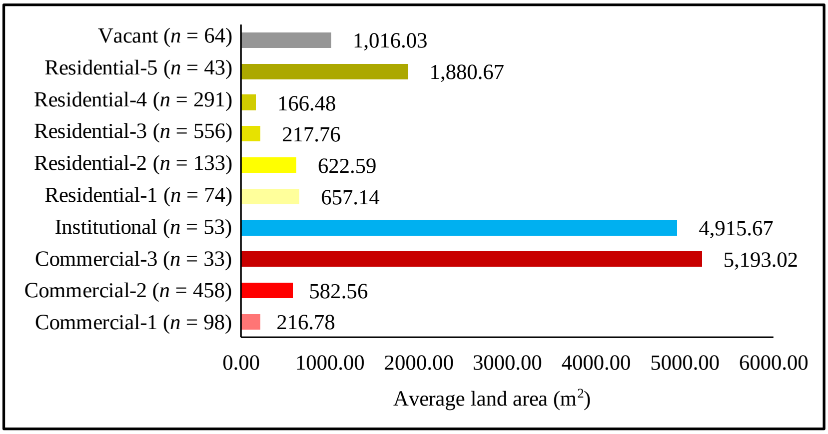

Figure 7. Average area of identified land uses

Table 7. Comparison of LRT-2 stations' pedestrian sheds

Station area	Pedestrian shed size	Prominent land use/s	National Building Code of the Philippines (Presidential Decree No. 1096, 1997)	Notable destinations	Land fragmentation
Gilmore	Large	C-2 (23%), Inst. (23%)	C-2/medium commercial – municipal or city level of commercial use, medium-rise building/ structure (e.g., retail stores, wet and dry markets, shops, office buildings). Refer to General Institutional	Gilmore Street electronics shops St. Paul University Carmel of St. Therese of the Child Jesus New Manila Subdivision Princeton Residences Tower	Medium intensity land uses and vast lands allocated for institutional uses resulted in a low-medium degree of land fragmentation.
Betty-Go	Medium	R-2 (22%), C-2 (21%)	Residential-2/medium density residential – low rise single attached, duplex, or multi-level building/ structure for exclusive use as multiple-family dwellings. Refer to C-2	Barangays Mariana and Immaculate Concepcion residential areas Aurora boulevard commercial establishments Religious of the Virgin Mary Compound	These low-medium intensity uses require smaller plots of land, which manifests to a high degree of land fragmentation.
Cubao	Very large	C-3 (38%)	C-3/ metropolitan commercial – medium-rise to high-rise building/ structure for high to	Araneta Center Gateway Mall Araneta Coliseum	The prominence of this high-intensity use requires vast amounts of

Table 7 continued.

			very high-intensity commercial (e.g., large shopping malls and large office).	Farmers Plaza Mall Activa Flex Mall Stella Maris College Manhattan Parkway & Parkview Towers	consolidated land, which results in a low-medium degree of land fragmentation.
Anonas	Small	C-2 (43%)	Refer to C-2	Anonas LRT City Center Hi-top Supermart Aurora Boulevard Commercial Est. World Citi Medical Center Infina Residential towers	This medium intensity use require smaller plots of land, which manifests to a high degree of land fragmentation.
Katipunan	Large	Inst. (48%)	General Institutional (GI) – a community to national level of institutional use or occupancy, low-rise, medium-rise, or high-rise building/ structure (e.g., schools, religious structures and health care facilities).	St. Bridget School complex Good Shepherd Convent Philippine School of Business Administration Real Monasterio de Santa Clara de Manila Alta Vista Subdivision	Vast lands allocated for academic and religious complexes possess a low degree of land fragmentation.

4. Conclusion and Recommendation

To a certain degree, the study expressed how multiple factors affect the size of the pedestrian shed such as the factors explored by this study. The results demonstrated that even if not all the identified factors or parameters were exceptional, a station area can still achieve a large pedestrian shed as demonstrated by Cubao station area. Furthermore, land use can influence the structure of a pedestrian shed since every type of land use had a characteristic land area. In this study, certain land uses such as metropolitan commercial and general institutional tended to have large land areas that contributed to the size of the pedestrian shed as observed in Cubao, Gilmore and Katipunan station areas. This was highly evident in Cubao where mixed-use high-intensity/metropolitan commercial occupied vast lands developed by one private entity, while Katipunan station area possessed several institutional-academic uses encompassing vast swaths of land established in a low-density manner. These station areas were observed to have a low-medium degree of land fragmentation based on the average land plot area. In contrast, Betty-Go and Anonas station areas were composed of residential and other lower-intensity uses that occupied smaller land plots such as low- and medium-intensity commercial, duplexes, townhouses and single-detached residential; hence, high land fragmentation was observed.

In the case of Cubao, a great expanse of land was solely owned and developed by the Araneta Group of Companies which became an advantage in terms of the ease of redevelopment. Although developed and implemented earlier than the LRT-2 line, it was redeveloped into a TOD and designated as a growth area by the local government during the LRT-2 implementation. Its redevelopment involved providing a diverse network of pedestrian accesses on the street and interconnected commercial establishments. What was clear is that consolidated properties such as the Araneta Center have created opportunities to optimize commuter accessibility by integrating the LRT-2 stations into the proponent's land developments.

The implementation of a mass transit project such as the LRT-2 system was financially prohibitive; thus, planners and government agencies may consider the findings of this study to achieve better accessibility for mass transit users. Urban planners and decision-makers may refer to this study to know the considerations and parameters that affect the access around a mass transit station in terms of maximizing the catchment area for pedestrians. Further investigation to determine the ideal value of each parameter, best street pattern design and right mixture of land uses to achieve the optimal extent of the pedestrian shed can further be explored. Furthermore, future studies may look into other aspects that the present work did not cover such as socioeconomic implications in accessing mass transit and other accessibility factors like the existence or absence of above-grade-level walkways and the connecting last-mile transport to further enrich the basis for mass transit development policies.

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