Understanding the Correlation of Pedestrian Volumes with Land Use and Walkway Attributes in Downtown Centers: The Case of Cebu City

Konstantine Chua KOH[a]
[a],School of Urban and Regional Planning, University of the Philippines Diliman, Quezon City 1104, Philippines
Email: mykonserns@yahoo.com

Abstract: Many studies have espoused the benefits of walkable mixed-use neighborhoods, which include, among others, a more sustainable local economy driven by the presence of constant pedestrian volumes. This is most especially beneficial to old downtown cores which have faced decline over the years. However, there have been few empirical studies done in the local setting which looked into whether pedestrian volumes indeed have some relationship to land use and walkway attributes. This research attempts to find some empirical evidence of this relationship by analyzing a downtown district in Cebu City. Land use and walkway inventories were carried out and the information was subjected to correlation analysis to determine any significant relationship with pedestrian volumes.

Keywords: walkability, pedestrian behavior, land use, built environment.

1. INTRODUCTION

In terms of walking as a transportation mode, there have been many articles which espoused the benefits of walkable mixed-use neighborhoods and how it can encourage more walking, which in turn, can lead to a more vibrant and sustainable local economy (Litman, 2007). While there have been researches which tried see how the different elements of the built environment can influence walking behavior (Saelens and Handy, 2008), there have been few studies done in the local Philippine setting. This lack of empirical evidence may be a contributing factor for both the public and private sectors to hesitate in investing in quality pedestrian infrastructure, and adopt more progressive land use policies. This is especially true in old downtown centers who have experienced urban decline over the years.

As such, the objective of this research is to find some empirical evidence of the relationship between land use and path attributes with pedestrian walking behavior, specifically the volume of pedestrians walking along a particular path. The results of this Study hopefully can indicate the critical land use and pathway attributes that can generate more walking, which can be inputted into a predictive model to be used in making strategic decisions regarding pedestrian infrastructure investments in old downtown centers.

The Study Area for this research is a downtown district in Cebu City where a study has been commissioned by National Economic and Development Authority (NEDA) Region 7 in 2019 to look into the possibility of pedestrianizing some of its streets to revitalize the area. Shown in Figure 1 below is the extent of the Study Area.

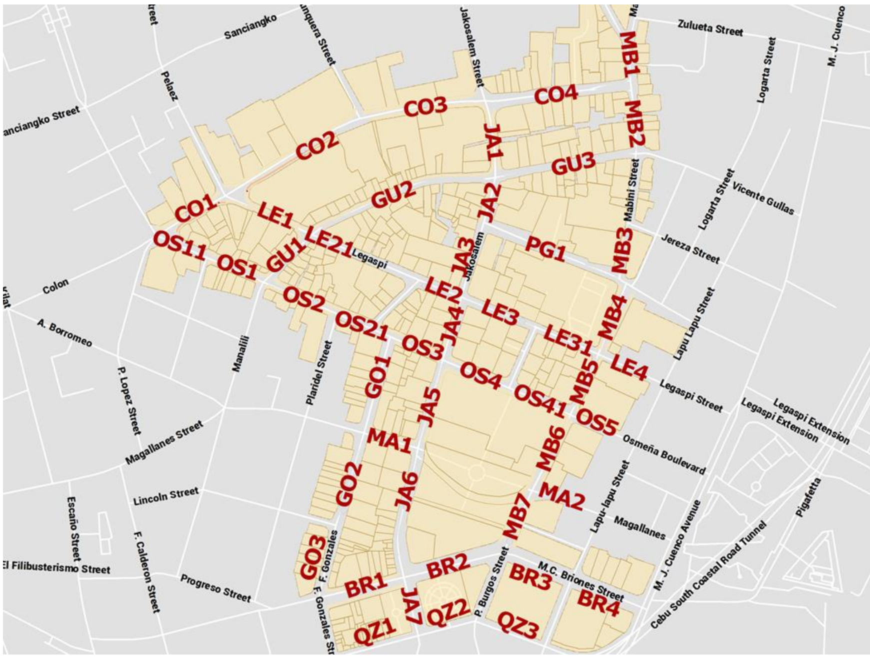

Figure 1. Map of Study Area in Cebu City
(blocks included in the Study are indicated by cream color) Source: Planades (2020)

2. STATEMENT OF THE PROBLEM

There is a lack of empirical evidence in the local setting which identifies specific land use and walkway attributes that have a high correlation with high pedestrian volumes.

3. RESEARCH OBJECTIVES

Main objective: To identify the attributes of land use and walkways that have a significant correlation with pedestrian volumes.

Specific objectives:

1) To determine the degree in which different land uses are distributed in the Study Area, herein referred to as 'land use mix'
2) To determine the correlation of the land use attributes with pedestrian volumes
3) To determine the correlation of walkway attributes with pedestrian volumes

4. REVIEW OF RELATED LITERATURE

In Planades (2020), it is posited that the bridge to understanding the relationship between economic activity and walkability is through pedestrian volumes (See Figure 2 below). Pedestrian volume is affected by built environment attributes and people attributes. The built environment is composed of walking environment factors and land use types.

The common factors that make an area walkable can be generalized into security/safety, the quality of the urban environment and the quality of the walkways. These three factors are part of the walking environment. As the walking environment improves, i.e. the area becomes more walkable, it is to be expected that more people would prefer to walk in that area, thus increasing pedestrian volumes. Carefully-planned land use types will also help increase pedestrian volumes.

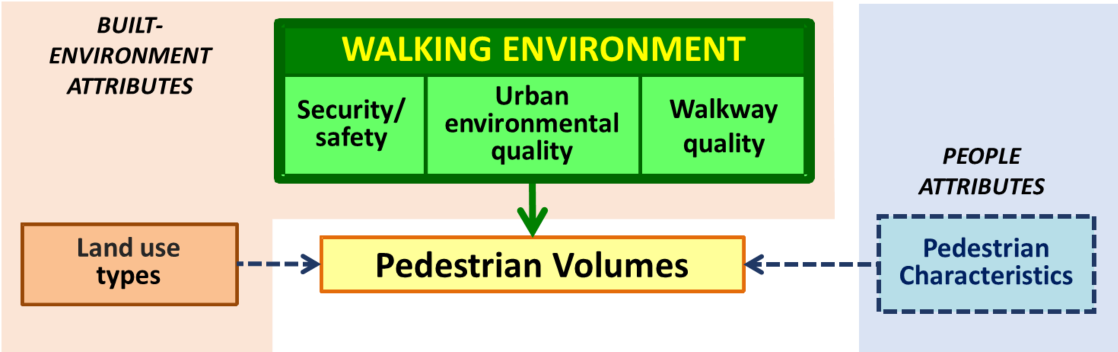

Figure 2. Connection of built environment factors to economic vitality.
Adapted and updated from: Planades (2020)

In terms of the specific attributes of the built environment that can influence travel behavior, Ewing et al. (2019), citing from Cervero & Kockelman (1997), Ewing & Cervero (2001) and Ewing et al. (2009), states that there are five principal dimensions of this influence—density, diversity, design, destination accessibility, and distance to transit. In another research, Litman (2007) identified the factors as density, mix, roadway connectivity and regional accessibility. Density, diversity/mix and design refer to the land use types in the framework of Planades (2020) above. Some aspects of destination accessibility are related to the walkway environment. Regional accessibility, distance to transit and roadway connectivity are non-built environment factors related to modal split and route assignment in the four-step model, which are not covered by this study.

Density is the number of space or people in a particular area. Ewing et al. (2019) identified density of residential population, jobs and retail areas within a particular area as having the highest positive relationships with pedestrian volumes. This means that in terms of land use, residential and commercial uses are the most significant indicators of walking trips.

Diversity or mix refers to locating different types of land uses close together (Litman, 2007). More mixed-use neighborhoods can produce more walk trips since different land uses which are located close to each other are better accessed by walking. Since "mixed-use" may seem an intangible concept (Manaugh, 2013), some researchers have attempted to come up with a quantitative measure of land use mix. One of the most commonly-used measure found in previous studies is called the entropy-based Land Use Mix (LUM) formula, as applied in Duncan et al. (2010), Manaugh (2013) and Mavoa (2018), among others.

Design can mean the characteristics of the walkways and the elements found in them that make them walkable. The better the conditions are, the more walkable it is, thus the more likely are people going to use it. There have been many attempts to develop a measure for walkable conditions, one of which was developed by Krambeck (2006) and is called the Global Walkability Index. It identified three components, namely: safety and security, convenience and access, and policy support. Among these three, it is 'Convenience and Attractiveness' which cited some specific physical attributes, like: maintenance and cleanliness of walking paths, presence of amenities (e.g. coverage) and obstacles on walking paths. Ewing et al. (2019) similarly stated that more sidewalk coverage and wider sidewalks can increase the likelihood of walking.

All of the above findings are consistent with the research done by Saelens and Handy (2008), which reviewed studies published between 2002 and 2006 that analyzed the built environment correlates of walking. Their findings showed that walking has consistent positive relations to density, distance to non-residential destinations, and land use mix. Relations of walking with route/network connectivity, parks and open space, and personal safety are not that conclusive.

5. METHODOLOGY

5.1 Data Collection and Processing

Shown in Figure 3 is the methodology for this Study.

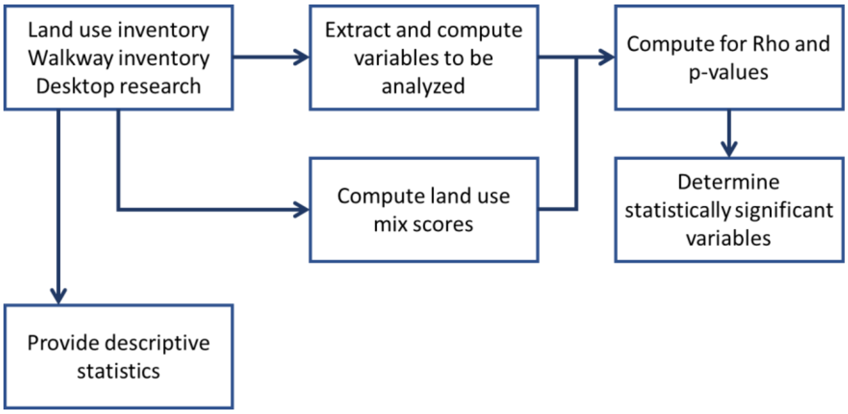

Figure 3. Research methodology for this study

For data collection, this study focused on using readily-available secondary data and easy-to-conduct surveys. This is an attempt to cover more area in the shortest possible time and using the least amount of resources. It is hoped that this method would be cost-effective and reliable enough to be duplicated by other local government units (LGU’s) in the Philippines who also wish to conduct their own pedestrian environment evaluation.

For this study commissioned by NEDA Region 7 in 2018 for a downtown district in Cebu City, the following primary surveys were conducted:

- Land use and sidewalk inventory (all lots and blocks within the Study Area)
- Road inventory
- Midblock pedestrian counts (7am to 7pm)

The unit used for the data gathering and analysis was individual lots. Cadastral maps of the Study Area were obtained from the local planning office to get info on the lot cuts. The lots were then grouped into blocks and street sections for identification and aggregation. Geographic Information System (GIS) software was used to compute for the lot areas and sidewalk lengths.

For the land use and sidewalk inventory, practicality was chosen over robustness due to limited resources and time. As such, rapid-type inventory was the method used, wherein enumerators did a walk-through of the Study Area, and observed and listed the different land use and sidewalk characteristics along the way. Some spot interviews were done with building users or tenants, but no in-depth interviews were conducted for all of the lots.

Basing on the findings from previous researches, the final list of built environment attributes to be analyzed are compiled. They are shown below (See Table 1).

Table 1. List of attributes to be analyzed

Category	Variables
Land use attributes	- Lot size - Land use categories: o Type: residential, commercial, industrial, institutional, others o Single or mixed-use o Commercial land uses were further sub-categorized into: • Light (retail, food and beverage, services, offices, etc.) or heavy (electronic appliances, machinery, construction supplies, etc.) • Is a major retailer/mall or not? - Number of lots per land use category - Gross floor areas (in sqm) per land use category - % of total area per land use category - Actual occupied area (sqm of actual occupied area) per land use category - Land use mix entropy score (to be computed)
Building attributes	- Building condition (good, poor) - Occupancy status (fully occupied, partially occupied, fully unoccupied) - No. of floors
Walkway attributes	- Sidewalk width (average width, total area) - Arcaded/unarcaded - Physical condition of pavement (good, poor) - Sidewalk area being used by vendors or businesses - Sidewalk area occupied by people (e.g. vagrants, beggars) - Presence/absence of physical obstructions - Presence/absence of flood mitigation measures

5.2 Statistical Analysis Methods

5.2.1 Land Use Mix Entropy Score

To calculate for a score to reflect the extent of land use mix, the Land Use Mix (LUM) Entropy Score LUM_{or} was computed using the Equation 1 below (from Duncan et al., 2010):

$$LUM_{or} = \frac{-\sum A_{ij} \ln(A_{ij})}{\ln N}$$

[Eqn. 1]

where A_{ij} represents the percent of each land use category *i* (measured in percent general floor area) per street section *j*. General Floor Area (GFA), and not Lot Area, was chosen for the computation because LUM requires the categorization to be nonoverlapping. Of the two variables, only the former fulfilled this condition. Further, four (N = 4) land use categories were defined: residential, commercial, industrial and institutional. The LUM score measures the level of heterogeneity of each street section, with 0 meaning singular land use, and 1 meaning equal land use per category.

To correct for the fact that larger areas of land can theoretically accommodate more infrastructure of different types and thus possibly inflating its LUM score, Duncan et al. (2010) introduced an area-corrected LUM (LUM_{ac}) formula as shown in Equation 2 below.

$$\text{LUM}_{ac} = \frac{\text{LUM}_{or}}{\text{area}_j / \text{area}_{ss}}$$ [Eqn. 2]

Where, LUM_{ac} = area-corrected LUM score
area_j = area of street section *j*
area_{ss} = area of smallest street section

5.2.2 Correlation Analysis

To accommodate non-normally distributed data, the Spearman's Rho was used to measure correlation between the ranks of pedestrian volume and all the ranks of other variables. Specifically, it measures the strength of association between the ranks of each variable. Furthermore, it does not assume that the relationship between the two variables is linear, only that they are monotonic (either increasing or decreasing in one direction, but not both). Modeling through regression analysis was not applied for this Study yet, since the variables to be tested in this Study are still limited to a few built environment variables.

6. SUMMARY DESCRIPTION OF STUDY AREA

All in all, there are 384 lots in the Study Area, grouped into 38 blocks and 44 street sections. For this study, the analysis to be made is on a per street section basis. Thus, for some lots which abut on more than one street section (e.g. corner lots), their data will be inputted to every street section that they abut. Because of this double entry, in the different tables shown in the succeeding pages, the individual totals of each street section will not be equal to the totals for the entire Study Area. This is indicated in the table with an asterisk (*). For purposes of this paper, the summary statistics are aggregated into streets.

Another thing to be noted is that street section QZ2 only abuts one lot which is an open area (Senior Citizen's Park). Since open areas are not part of the land uses to be evaluated, this section will thus not be included in the dataset for analysis so as not to distort the results. However, it will still be included in the presentation of summary statistics.

6.1 Land Uses

Shown in Table 2 below is the summary statistics of the lots per street in the Study Area. It is estimated that the total lot area in the Study Area is 238,837 square meters, which brings to about an average lot size of 622 sqm. This area does not include sidewalks, roads and easements. For the entire Study Area, the estimated total gross floor area inside the properties is 650,350 sqm, which translates to an average building height of 2.7 floors. Osmena Blvd. (3.4), Colon St. (3.2) and V. Gullas (3.1) have the highest average number of floors, while Mabini St., P. Burgos and P. Gomez all have the lowest average at 1.9 floors each.

It is estimated that 85.5% of the total gross floor area, or about 555,743 sqm, is estimated to be occupied. All in all, there are seven streets which have occupancy rates of 90% and above, while there are three streets with occupancy rate below 80%, namely F. Gonzales (79.6%), Quezon Blvd. (77.8%) and V. Gullas (75.0%).

Table 2. Summary statistics of the lots per street (area units are in sqm)

Street Name	Total Lot Area	Ave. Lot Size	Total GFA	Occupied GFA	Occupancy Rate	Ave. No. of Floors
Colon St.	65,240	1,388	206,185	188,511	91.4%	3.2
D. Jakosalem	59,298	1,098	145,092	140,781	97.0%	2.4
F. Gonzales	18,021	334	43,214	34,384	79.6%	2.4
Legaspi	40,023	870	102,899	83,053	80.7%	2.6
Mabini St.	10,358	493	19,229	17,775	92.4%	1.9
Magallanes	5,565	618	13,570	13,083	96.4%	2.4
MC Briones	31,474	1,259	85,514	79,753	93.3%	2.7
Osmena Blvd.	36,399	597	122,425	104,172	85.1%	3.4
P. Burgos	50,538	1,743	95,578	93,973	98.3%	1.9
P. Gomez	20,681	2,068	38,263	38,263	100.0%	1.9
Plaridel Ext.	2,631	292	7,218	6,093	84.4%	2.7
Quezon Blvd.	14,112	706	28,837	22,423	77.8%	2.0
V. Gullas	29,209	370	91,838	68,839	75.0%	3.1
Study Area*	**238,837**	**622**	**650,350**	**555,743**	**85.5%**	**2.7**

Shown in Table 3 below is the breakdown of the floor area per land use type for each street. All in all, commercial land uses have the highest share of occupied GFA at 52%, which is more than double of the second-highest value. This indicates that the Study Area is dominantly commercial in nature. Although institutional land uses have the least number of lots among the land use categories, it has the second-highest share at 21%, mainly because of the big areas being occupied by schools. Residential land use has the third-highest share at 18%. Industrial land use just has a 4% share of total occupied floor area. The low share of residential uses indicates that the many people walking within the district and patronizing the different establishments actually come from outside the Study Area.

Table 3. Estimated occupied floor area (in sqm) per each land use type for each street

Street Name	Occupied GFA	Comml.	Resdl.	Indl.	Insti.	Others
Colon St.	188,511	143,992	22,661	684	13,179	7,995
D. Jakosalem	140,781	68,573	5,224	2,907	51,210	12,867
F. Gonzales	34,384	11,949	9,308	10,577	0	2,549
Legaspi	83,053	50,977	11,721	1,744	14,711	3,901
Mabini St.	17,775	5,504	3,166	0	7,245	1,859
Magallanes	13,083	13,083	0	0	0	0
MC Briones	79,753	33,969	1,431	5,102	34,860	4,392
Osmena Blvd.	104,172	65,569	16,973	0	19,539	2,091
P. Burgos	93,973	41,504	10,581	1,641	31,335	8,911
P. Gomez	38,263	3,485	8,636	281	23,994	1,867
Plaridel Ext.	6,093	5,831	262	0	0	0
Quezon Blvd.	22,423	12,300	1,922	0	4,833	3,369
V. Gullas	68,839	44,944	18,603	2,785	2,507	0
Study Area*	**555,743**	**286,381**	**97,960**	**23,977**	**117,809**	**29,616**
% of occupied GFA	**100%**	**51.5%**	**17.6%**	**4.3%**	**21.2%**	**5.3%**
% of total GFA	**85.5%**	**44.0%**	**15.1%**	**3.7%**	**18.1%**	**4.6%**

Shown in Table 4 is the breakdown of gross floor area per use type and commercial type. Total area of lots with single use is 394,684 sqm (61% of total GFA), while for mixed-uses, it is just 161,058 sqm (25%). This indicates that there is not much land use diversity in the Study Area. The most common mixed-use combination is commercial-residential, with 94 lots (or about 131,113 sqm), 25 of which are located along V. Gullas. The gross floor area of light commercial types is 248,172 sqm (38% of total GFA), while for heavy commercial types, it is 69,370 (11%). Total area of lots with no commercial land uses is 238,201 (37%).

Table 4. Estimated gross floor area (in sqm) per use type and commercial type

Street Name	Total GFA	Type of use		Type of commercial		
		Single use	Mixed use	Light Comml.	Heavy Comml.	No Comml.
Colon St.	206,185	130,158	58,353	142,814	1,862	43,834
D. Jakosalem	145,092	113,259	27,522	59,182	12,299	69,300
F. Gonzales	43,214	17,162	17,222	7,296	15,230	11,858
Legaspi	102,899	63,673	19,380	40,493	12,628	30,333
Mabini St.	19,229	14,365	3,411	4,187	1,317	12,271
Magallanes	13,570	10,297	2,786	13,021	62	0
MC Briones	85,514	71,328	8,425	24,565	14,505	40,683
Osmena Blvd.	122,425	83,041	21,130	58,203	7,366	38,603
P. Burgos	95,578	84,460	9,513	42,671	7,657	43,644
P. Gomez	38,263	34,168	4,095	8,003	2,947	27,314
Plaridel Ext.	7,218	5,700	393	1,162	4,670	262
Quezon Blvd.	28,837	20,638	1,785	12,110	190	10,123
V. Gullas	91,838	46,927	21,912	41,352	6,377	21,110
Study Area*	**650,350**	**394,684**	**161,058**	**248,172**	**69,370**	**238,201**
% of total GFA	**100%**	**60.6%**	**24.7%**	**38.1%**	**10.7%**	**36.6%**

6.3 Land Use Mix Entropy Score

Shown in Table 5 are the average LUM_{or} and LUM_{ac} scores for each street. F. Gonzalez has the highest LUM_{or} score with 0.646, followed by P. Gomez with 0.637. For LUM_{ac} scores, F. Gonzalez still has the highest score at 0.241, followed by Mabini St with 0.128.

Table 5. Summary of Land Use Mix Entropy Scores per Street

Street Name	LUM_{or}	LUM_{ac}	Street Name	LUM_{or}	LUM_{ac}
Colon St.	0.411	0.028	Osmena Blvd.	0.328	0.037
D. Jakosalem	0.413	0.067	P. Burgos	0.408	0.069
F. Gonzales	0.646	0.241	P. Gomez	0.637	0.037
Legaspi	0.504	0.042	Plaridel Ext.	0.211	0.076
Mabini St.	0.490	0.128	Quezon Blvd.	0.415	0.111
Magallanes	0.018	0.004	V. Gullas	0.582	0.118
MC Briones	0.408	0.063	**Entire Study Area**	**0.427**	**0.079**

Shown in Figure 4 is the distribution of LUM_{or} and LUM_{ac} scores. With the exception of outliers, LUM_{or} scores tends to be evenly distributed. The average LUM_{or} score is 0.427 (See Table 6), indicating that the distribution of land use is a little bit on the homogenous side. For LUM_{ac}, the average score is even lower at 0.079, indicating further that the land use mix in the Study Area is very homogenous, regardless of the sizes of the street sections. This is to be expected since the dominant land use type—commercial—takes up already 52% of all occupied gross floor area. The other land uses have percentage shares not more 21%.

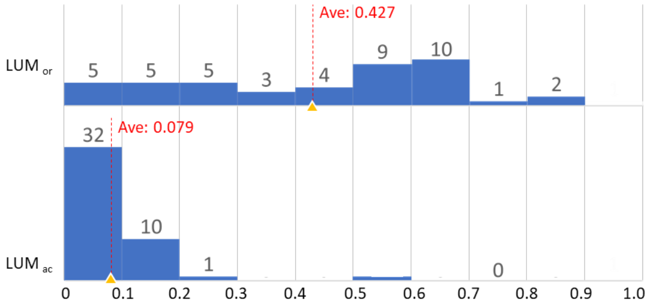

Figure 4. Histogram of LUM $_{or}$ and LUM $_{ac}$ scores of the street sections

Table 6. Summary statistics for LUM Scores

	LUM $_{or}$	LUM $_{ac}$
Minimum	0	0
Maximum	0.872	0.515
Average	0.427	0.079
Median	0.495	0.053
Standard Deviation	0.235	0.091

Shown in Figure 5 is the distribution of LUM $_{or}$ scores according to the presence of absence of a major retailer. The average LUM $_{or}$ score for street sections without a major retailer/mall is 0.477, while for those with major retailer/mall is 0.308 (See Table 7). The low score for those with a major retailer is to be expected since malls typically have big lot sizes that are singular (commercial) in use.

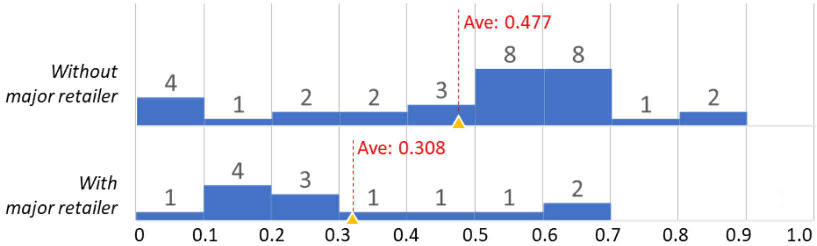

Figure 5. Histogram of LUM $_{or}$ scores for those with and without major retailer/malls

Table 7. Summary statistics of LUM $_{oc}$ scores for those with and without major retailer/malls

LUM $_{or}$	None	With Major Retailer/Mall
Count	31	13
Minimum	0	0
Maximum	0.872	0.665
Average	0.477	0.308
Median	0.522	0.255
Standard Deviation	0.233	0.198

Shown in Figure 6 is the distribution of LUM $_{ac}$ scores according to the presence or absence of major retailer. For LUM $_{ac}$, the average for street sections without major retailer is 0.101, while for those with major retailer is 0.026 (See Table 8). This low LUM $_{ac}$ score for ‘without major retailer’ indicate that even without a dominant retailer, these street sections also have a homogenous commercial character with very few non-commercial uses.

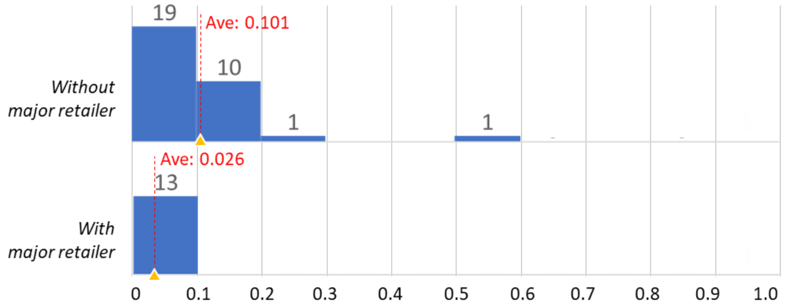

Figure 6. Histogram of LUM_{ac} scores of those with and without major retailer/malls

Table 8. Summary statistics of LUM_{ac} scores for those with and without major retailer/malls

LUM_{ac}	None	With Major Retailer/Mall
Count	31	13
Minimum	0	0
Maximum	0.515	0.059
Average	0.101	0.026
Median	0.065	0.027
Standard Deviation	0.101	0.016

6.3 Pedestrian Volumes

Shown in Table 9 is the summary statistics of the pedestrian volumes per street. Colon St. has the highest average with 25,384, followed by Osmena Blvd. with 16,287, then MC Briones with 11,377. The street section with the lowest volume is Plaridel Ext. with 950, with Quezon Blvd. having the second-lowest at 1,867. The street section with the highest volume is Colon St. with 39,828, while the one with the lowest volume is found in F. Gonzales with 939.

Table 9. Summary statistics of pedestrian volumes per street (units in pax)

Street name	Street Sections	Average	Minimum	Maximum
Colon St.	4	25,384	7,247	39,828
D. Jakosalem	7	7,563	3,363	10,827
F. Gonzales	4	2,926	939	4,352
Legaspi	3	7,750	3,610	15,377
Mabini St.	2	3,931	2,499	5,363
Magallanes	2	9,188	5,973	12,402
MC Briones	4	11,378	5,580	17,035
Osmena Blvd.	5	16,287	8,833	21,368
P. Burgos	6	8,784	1,456	14,772
P. Gomez	1	3,236	3,236	3,236
Plaridel Ext.	1	950	950	950
Quezon Blvd.	2	3,178	2,271	4,085
V. Gullas	3	7,753	3,810	10,677
All Streets	**44**	**9,753**	**939**	**39,828**

Shown in Figure 7 below is a histogram of the midblock pedestrian volumes of the street sections within the Study Area. It can be seen that the blocks are concentrated more on the left, indicating that most street sections have low pedestrian volumes.

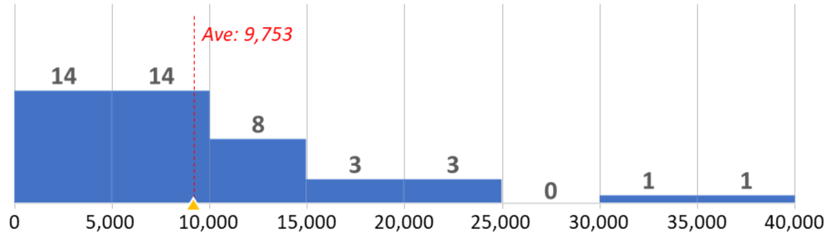

Figure 7. Histogram of pedestrian volumes of the street sections

Shown in Figure 8 is the distribution of the pedestrian volumes of street sections with and without major retailer/malls. The average of the street sections with a major retailer almost doubles that those without (14,248 vs. 7,545) (See Table 10). The street sections with the two highest pedestrian volumes (39,828 and 31,299) have a major retailer.

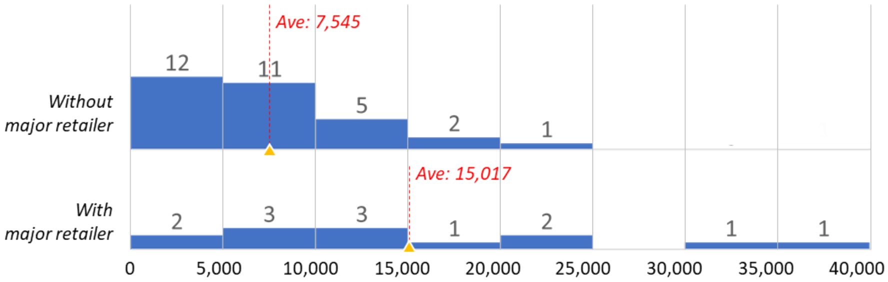

Figure 8. Histogram of pedestrian volumes of street sections with and without malls

Table 10. Summary statistics of pedestrian volumes of streets with and without malls

	None	With Major Retailer/Mall
Count	31	13
Minimum	939	1,456
Maximum	21,152	39,828
Average	7,545	14,248
Median	5,973	11,308
Standard deviation	5,115	11,139

Shown in Figure 9 is the distribution of the pedestrian volumes of street sections according to light and heavy commercial types. The average pedestrian volumes of street sections with predominantly light commercial type land uses (11,232) have more than double the average (181%) than those with predominantly heavy commercial types (4,000) (See Table 11). Street sections with the top two highest pedestrian volumes are found in the light commercial type group. There is one street section (JA7) which do not have any commercial use, since both of its sides are parks/open spaces.

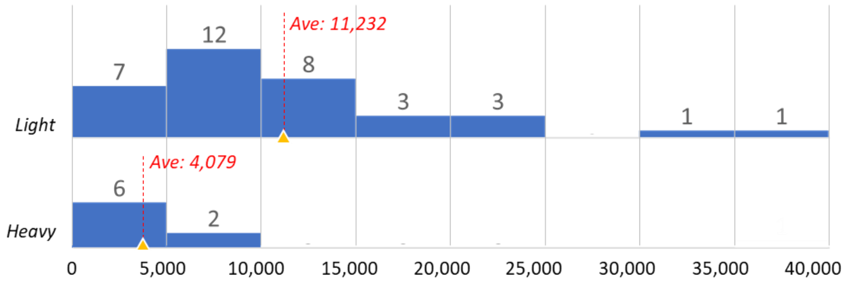

Figure 9. Histogram of pedestrian volumes according to commercial types

Table 11. Summary statistics of pedestrian volumes according to commercial types

	Light	Heavy
Count	35	8
Minimum	1,456	939
Maximum	39,828	8,857
Average	11,232	4,079
Median	8,993	4,173
Standard Deviation	8,340	2,537

7. CORRELATION ANALYSIS

The different tables below show the results of the correlation analysis using Spearman's Rho. Values of r closer to +1 indicate stronger positive relationships between the ranks of each pair of variables, while those closer to -1 indicate stronger negative relationships. Variables marked with a caret '^' symbol indicate significance at alpha level 0.05.

7.1 Lot Area and LUM Scores

Shown in Table 11 below is the Spearman Rho's values between lot area and the LUM scores. Since LUM_{or} is not significantly correlated with total lot area, but area-corrected LUM_{ac} is, it may indicate that LUM_{ac} is a more reliable LUM metric to compare with other variables. This is because the formula does not capture the effects attributed to lot area size. The negative value of Rho also indicates an inverse relationship—as lot area increases, the LUM_{ac} score decreases. A possible explanation for this is that in the current Study Area, the bigger lots tend to be occupied by major retailer and institutions (e.g. schools, church, government buildings), which are more homogenous in land use, but still have high pedestrian volumes among them as they are major destinations.

Table 12. Spearman's Rho Values between Lot Area and LUM Scores

Variable	**ρ**	**p-value**
LUM_{or} Score	0.210	0.171
LUM_{ac} Score^	-0.394	0.008

7.2 Pedestrian Volume and Land Use Attributes

Shown in Table 13 below is the Spearman's Rho values between pedestrian volumes and the different land use attributes. The attribute '% of lots with light commercial types' showed the highest correlation (ρ = 0.505), followed by 'Total sqm with light commercial types' (ρ = 0.485). Additionally, the total gross floor area (ρ = 0.346) and occupied gross floor area (ρ = 0.334) is statistically significant to be correlated to pedestrian volumes. This is consistent with transportation planning practices that posit that trip rates are dependent on the intensity of development (Regidor, 1997); denser developments are expected to generally produce and attract significantly different larger number of trips.

Table 13. Spearman's Rho Values between Pedestrian Volumes and Land Use Attributes

Attribute	Variable	ρ	p-value
Lot Attributes	Lot area	0.174	0.2596
	Average size of lot	0.210	0.1712
	Total gross floor area^	0.346	0.0214
	Occupied gross floor area^	0.334	0.0265
	% of area is occupied	0.041	0.7905
Land Use (% of lots)	% of lots with commercial use^	0.415	0.00512
	% of lots with residential use	-0.215	0.1607
	% of lots with industrial use	-0.168	0.2759
	% of lots with institutional use	-0.052	0.7364
Land Use (sqm)	Total sqm with commercial use^	0.371	0.0132
	Total sqm with residential use	-0.006	0.9685
	Total sqm with industrial use	0.211	0.1702
	Total sqm with institutional use	0.018	0.9053
Land Use (% of total sqm)	% of area with commercial use	0.229	0.1341
	% of area with residential use	-0.157	0.3090
	% of area with industrial use	-0.195	0.2040
	% of area with institutional use	-0.034	0.8289
Types of Commercial Use (% of lots)	% of lots with light commercial types^	0.505	0.00047
	% of lots with heavy commercial types	-0.148	0.3390
	% of lots with no commercial uses	-0.180	0.2415
Types of Commercial Use (sqm)	Total sqm with light commercial types^	0.485	0.00085
	Total sqm with heavy commercial types	-0.246	0.1078
	Total sqm with no commercial uses	0.072	0.6435
Types of Commercial Use (% of sqm)	% of area with light commercial types^	0.415	0.0051
	% of area with heavy commercial types	-0.240	0.1168
	% of area with no commercial uses	-0.161	0.2979
Ground Floor Retail	No. of lots with ground floor retail	0.267	0.0798
	% of lots with ground floor retail^	0.398	0.0075
	Total ground floor retail area^	0.424	0.0041
	% of total ground floor area with retail^	0.352	0.0191
Major retailer	No. of lots with major retailer^	0.306	0.0433
	Total combined area of major retailer/s^	0.301	0.0472
	% of area that is a major retailer	0.228	0.1372
Land Use Mix Type	No. of lots with single use	0.192	0.2118
	No. of lots with mixed uses	0.015	0.9215
	Total area with single uses^	0.302	0.0460
	Total area with mixed uses	0.163	0.2898
	% of area with single uses	0.035	0.8232
	% of area with mixed uses	-0.021	0.8938
Land Use Mix Entropy Score	LUM_{or} score	-0.185	0.2283
	LUM_{ac} score^	-0.407	0.0061

Among the different land use variables that were tested, those relating to the presence of light commercial types have the highest Rho values at $p<0.01$ level, whether it be the percentage of lots (p-value = 0.00047), percentage of total square meters (p-value = 0.0051), or total square meters (p-value = 0.00085). This indicates that the presence of light commercial types is a very good predictor of high pedestrian volumes. Additionally, the values for this attribute are higher than the values for the general 'commercial land use' attribute. This suggests that when analyzing land use inventories, it is best to disaggregate commercial land use further into light and heavy categories for greater predictive accuracy.

Related also to the commercial land use category, the variables of 'ground floor retail' and 'presence of major retailer' showed statistically significant correlation with pedestrian volumes. For 'ground floor retail', the specific attribute which have the highest correlation is 'total square meters' (ρ = 0.424). For 'major retailer', both 'number of lots' (ρ = 0.306) and 'total square meters' (ρ = 0.301) showed statistically significant correlation. All of this is consistent with Ewing's study (2019) that states greater retail floor area ratios have positive relationships with walk choice behavior.

Among the different land uses, it is only 'commercial land use' which showed statistically significant correlation with pedestrian volumes. This can partly be due to the low shares of the other land uses in the Study Area (none greater than 21%), which did not allow for a more robust testing of the correlation analysis for the non-commercial land uses.

In terms of LUM scores, LUM_{ac} scores are found to be statistically significant to be correlated to pedestrian volumes (ρ=-0.407), although the rho value is negative. This means that as the land use mix is more diverse, pedestrian volumes goes down. This is inconsistent with the findings made by Ewing (2019) which showed that more diverse land use characteristics, i.e. more land use mix, have more positive relationships with walking mode choice. This can partly be attributed to the fact that some street sections with high shares of mixed-use are street sections where there are also significant number of industrial use and heavy-type commercial uses, which do not generate high pedestrian volumes (See Table 14).

Table 14. Street sections with top 15 highest mixed-use areas and corresponding pedestrian volumes, heavy commercial areas and industrial areas

Section Code	Ped volumes	Ped volumes rank	Mixed use area %	Mixed use Rank	Hcomml area %	Hcomml rank	Indl area %	Indl rank
MA2	5,973	27	68.1%	1	0.0%	30	0.0%	16
GU1	10,677	16	60.7%	2	11.9%	15	0.0%	16
GO3	4,352	31	56.9%	3	30.2%	5	23.9%	3
GO4	2,328	40	49.9%	4	0.0%	30	0.0%	16
MB7	9,240	17	47.3%	5	0.0%	30	0.0%	16
OS2	21,152	5	46.9%	6	5.9%	23	0.0%	16
JA2	8,993	18	46.1%	7	12.3%	14	0.0%	16
MB2	5,363	30	43.9%	8	19.6%	11	0.0%	16
CO3	23,163	3	41.6%	9	0.0%	30	0.0%	16
CO4	7,247	25	39.6%	10	6.8%	20	2.5%	12
GO2	4,083	34	38.4%	11	42.6%	3	38.7%	1
JA5	5,898	28	32.1%	12	0.0%	30	0.0%	16
JA3	8,857	19	31.4%	13	28.0%	8	9.4%	6
GU3	3,810	35	30.1%	14	7.8%	18	4.1%	10
LE2	4,262	32	29.3%	15	18.9%	12	0.0%	16

** Yellow-highlighted cells indicate values in the top 15.*

To really check whether there is indeed an inverse relationship between land use entropy scores and ped volumes, it is recommended that the same methodology and analysis be applied to other areas where there are more variety and more even distribution of land uses.

7.3 Pedestrian Volume and Building Attributes

Show in Table 15 below is the Spearman's Rho Values between pedestrian volumes and building attributes. Based on the correlation analysis, the physical condition and the occupancy status of the building does not seem to have much of an effect on pedestrian volumes. Only building height was found to be positively correlated to pedestrian volumes ($\rho = 0.474$). Building height could be a proxy variable for the density attribute mentioned by Ewing et al. (2019) and Matuke et al. (2020) as a contributing factor to high walk mode choice. Based on the statistical summary (see Table 2), the minimum building height to have an impact on pedestrian volumes is at least three floors (rounded up from 2.7).

Table 15. Spearman's Rho Values between Pedestrian Volumes and Building Attributes

Attribute	Variable (measured in % of lots)	ρ	p-value
Building Condition (no. of lots)	No. of lots with buildings in good condition	0.041	0.7940
	No. of lots with buildings in poor condition	-0.132	0.3943
Building Condition (% of lots)	% of lots with buildings in good condition	0.157	0.3092
	% of lots with buildings in poor condition	0.014	0.9298
Occupancy (no. of lots)	No. of lots with buildings w/ full occupancy	-0.291	0.0554
	No. of lots with buildings w/ partial/no occupancy	0.158	0.3061
Occupancy (% of lots)	% of lots with buildings w/ full occupancy	-0.158	0.3068
	% of lots with buildings w/ partial/no occupancy	0.221	0.1501
Building Height	Average building height^	0.474	0.00116

7.4 Pedestrian Volume and Walkway Attributes

Shown in Table 16 below are the results of the correlation analysis between pedestrian volumes and walkway attributes.

The correlation analysis indicates that the width of the sidewalk and its level of coverage have significant positive correlation with pedestrian volumes. The wider the sidewalks, the more people tend to walk along it. Based on the p-value results, the 'ideal' minimum width is around three meters, as it has the highest Rho value at $\rho<0.01$ among the different widths. This is consistent with the study done by Ewing et al. (2019) that states wider sidewalks increase the likelihood of walking. Similarly, the more overhead coverage is provided along the pedestrian paths, the more people tend to walk on it.

The moderate correlation between pedestrian volumes with '% of sidewalks in good condition' and '% of flood mitigation measures' also suggest that pedestrians prefer paths that are clean, properly drained and/or without puddles of water. These results are consistent with Krambeck's concept of walkability (2006) which identified that maintenance and cleanliness of walking paths, and presence of amenities (e.g. coverage) improves a path's walkability, thus attracting more pedestrians.

The higher p-values of these variables in terms of percentages instead of total length seem to suggest that what pedestrians seek more is not just about the absolute length of the covered and well-maintained paths, but rather the continuity of these amenities throughout a street section, whether short or long. The more contiguous are the covered paths in a street section, the more likely are the pedestrians to walk along them.

Table 16. Spearman's Rho Values between Pedestrian Volumes and Walkway Attributes

Attribute	Variable	ρ	p-value
Sidewalk dimensions	Total sidewalk length	0.100	0.5187
	Total sidewalk area^	0.305	0.0445
	Average width^	0.525	0.00025
Sidewalk width (Total length)	Wider than 1m	0.216	0.1582
	Wider than 2m	0.295	0.0517
	Wider than 3m^	0.454	0.0020
	Wider than 4m^	0.353	0.0186
Sidewalk Width (% of total sidewalk length)	Wider than 1m	0.245	0.1083
	Wider than 2m^	0.333	0.0271
	Wider than 3m^	0.511	0.00039
	Wider than 4m^	0.352	0.0192
Favorable Conditions (Total length)	In good condition	0.240	0.1162
	Arcaded^	0.466	0.00142
	Without obstructions	-0.031	0.8395
	Not being used by business	-0.001	0.9935
	Not occupied by people	0.044	0.7775
	Total without obstructions	-0.053	0.7312
	With flood mitigation measures	0.259	0.0897
Favorable Conditions (% of total length)	In good condition^	0.313	0.0385
	Arcaded^	0.512	0.00038
	Without obstructions	-0.068	0.6623
	Not being used by business	-0.294	0.0531
	Not occupied by people	-0.163	0.2904
	Total without obstructions	-0.093	0.5472
	With flood mitigation measures^	0.301	0.0471

Interestingly, variables relating to obstructions were not found to be significantly correlated to pedestrian volumes, meaning that their presence or absence did not seem to affect pedestrian volumes. Relating this to the previous observation about sidewalk widths, this can suggest that the presence of these obstructions does not seem to deter people from using these paths, as long as the sidewalk is wide enough (probably at least 3 meters), have sufficient overhead coverage and are decently clean or well-drained.

Among the different attributes related to obstructions, the attribute of '% of sidewalk not being used by business' has the lowest p-value (0.0531) and is negative (-0.294). The negative value suggests an inverse relationship: as there are more sidewalk vendors along the sidewalk, there are more pedestrians. From here, it can be surmised that pedestrians may actually prefer to walk in footpaths where there are some sidewalk vendors as they offer quick access to some services and goods. It can also be argued that sidewalk vendors and businesses form an integral part of a vibrant sidewalk culture.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 About the Methodology Used

The land use inventory that was undertaken was a rapid-type one, relying on street observations and spot interviews with the building users, as practicality was chosen over robustness. Although some level of detail was not able to be obtained, in the end, it was sufficient enough to use for area-wide analysis. The rapid-type approach was also easy enough to be executed and is easily duplicable in any setting, as it does not require specialized skills or equipment. Planners, local government units and policy-makers can adopt this pragmatic method to determine the critical variables that are absent in a particular area which can generate significant pedestrian volumes.

In terms of classifying land uses, it was discovered that disaggregating commercial uses into light commercial and heavy commercial types can produce a more accurate correlation analysis between commercial activity and pedestrian volumes, compared to just generalizing all commercial uses as one land use category. Commercial uses can be further categorized into retail/non-retail and ground/upper floors, since it was discovered that ground floor retail also have a correlation to pedestrian volumes.

Since pedestrian counts were conducted up to 7pm only, data on night-time pedestrian volumes were not captured, which might have helped serve as an indicator for residential population. Thus, the research was unable to do a time period-based correlation analysis of pedestrian volumes and land uses. As such, in future researches, it is recommended that pedestrian counts be conducted until evening, say 10 pm, so that the night-time population can be captured. This is to better see whether mixed-use residential-commercial neighborhoods have some correlation to pedestrian volumes.

8.2 Land Use Mix

Based on the calculations of the land use entropy score, the Study Area is dominantly homogenous in character, with an average LUM_{ac} score of 0.079. (0 indicates 100% single use, while score of 1 indicates perfect distribution among land uses). This is primarily due to the fact that 51.5% of the total occupied gross floor area (more than one-half) is commercial in nature, with the rest of the land uses do not have shares of more than 25% (See Table 3).

8.3 Correlation Analysis Between Pedestrian Volumes and Built Environment Variables

Based on the results of the correlation analysis, it can be posited that there is indeed some relationship between the characteristics of the built environment with the pedestrian volumes. Among the different types of attributes that were tested, walkway attributes have the highest statistically significant correlation with pedestrian volumes, followed by land use attributes and finally, building attributes.

- Among the different walkway attributes, sidewalk width and arcaded sections were found to be the most correlated to pedestrian volumes, while the percentage of sidewalks in good condition and presence of flood mitigation measures are moderately correlated. This indicates that more walkable sidewalks indeed attract more pedestrians compared to those with poor walking conditions.
- Among the different land uses, presence of commercial uses, particularly light commercial types, ground floor retail and major retailer, are found to be the most correlated to pedestrian volumes.
- Contrary to pre-conceived theories, the attribute of area-corrected land use mix score (LUM_{ac}) was found to be statistically significant to be inversely correlated to pedestrian volumes, although the low number of mixed-use use lots across the entire Study Area may have contributed to low LUM_{ac} scores.
- Among the different building attributes, only building height appeared to have a significant correlation to pedestrian volumes. Building height can be interpreted as a proxy for density.

For land use attributes, absolute figures in terms of area sizes, instead of percentages, were found to be more correlated to pedestrian volumes. For walkway attributes, it is percentages of the attributes over the entire street section which were found to be more correlated, instead of absolute length.

8.3 Future Studies

Due to the limitations of the study scope, some surveys were not able to be carried out, like counts of people going in and out of the buildings/establishments, and more detailed interviews with building managers or owners to ascertain the actual number of people working and living in a building. As such, the correlation analysis was not able to test some attributes like population and job densities, as well as average trips per type of establishment. Related to this, patron/pedestrian attributes were not tested, like origin-destination distance, typical mode used, car ownership, average spending per visit or average visits per month. Future researches and studies can add these surveys to further test these attributes and see their correlation to pedestrian volumes.

Other physical environment attributes variables, like trees, street furniture and lighting, were very few in the Study Area, thus they cannot be tested for correlation accurately. Future studies can identify areas where these are prevalent or common, so that they could be tested properly.

Although studies have shown that mixed-use neighborhoods—particularly residential-commercial communities—tend to have higher volumes of pedestrian traffic, such effects were not clearly seen in this Study Area. This can be due to the fact that the Study Area is currently predominantly commercial (52%) and single use (61%). As such, the impact of an in situ residential population to the LUM score and subsequently to pedestrian volumes cannot be seen clearly. Additionally, parks or open spaces which could also attract pedestrian traffic were not able to be tested, since there are very little open spaces in the area.

It is thus recommended that the similar methodology be applied to an area where there are more pronounced mixed-use residential-commercial land uses (as well as other common mixed-use combinations). Similarly, areas where there are more parks and open spaces can also be studied. This could be applied to areas with varying densities and different levels of mixes to provide more robust analysis. Pedestrian counts would also have to extend into the night to capture any night-time population.

Once more factors have been tested and more areas have been studied, regression analysis can be applied to determine the combination of attributes that could generate more people walking in a particular street. Results of this analysis can then aid planners, designers and policy-makers to introduce specific and targeted different combinations of land use, walkway and policy interventions to encourage more people to walk. Such analysis can help provide more concrete basis to convince the public and private sectors to invest in quality pedestrian infrastructure.

It should be noted that the above analysis done is just a correlation analysis, and correlation does not necessarily mean causation, i.e. that these built environment attributes were actually the reasons why pedestrians preferred to walk along these streets. To this end, some pedestrian interviews can be conducted to ask about their opinions and responses to built environment improvements, and whether these can entice them to visit the area more frequently, and ultimately spend more during their visit. This would provide more conclusive basis to introduce walkway improvements, as this could translate to more revenues.

REFERENCES

Choi, Y. and Guhathakurta, S. (2020). Do people walk more in transit-accessible places? *The Journal of Transport and Land Use*, Vol, 13 no. 1, pp. 343-365.

Diaz, C. and Koh, K. (2022). Estimating the potential retail impact of improving the pedestrian environment in the Downtown Cebu City. *Asian Transport Studies*, Vol. 8, 2022, 100059.

Duncan, M., Winkler, E., Sugiyama, T., Cerin, E. duToit, L., Leslie, E., Owen, N. (2010) Relationships of Land Use Mix with Walking for Transport: Do Land Uses and Geographical Scale Matter? *Journal of Urban Health*. 2010 Sep; 87(5):782-95.

Ewing, R., Sabouri, S., Park, K., Lyons, T., & Tian, G. (2019) Key Enhancements to the WFRC/MAG Four-Step Travel Demand Model. NITC-RR-1086. Portland, OR: Transportation Research and Education Center (TREC). **https://dx.doi.org/10.15760/trec.246**

Krambeck, H. (2006) Walkability Index 2006: Pilot Survey Implementation Guide. Prepared for the World Bank.

Litman, T. (2007) Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior. Victoria Transport Policy Institute.

Manaugh, K. and Kreider, T. (2013) What is Mixed Use? Presenting an Interaction Method for Measuring Land Use Mix. *The Journal of Transport and Land Use*, Vol. 6 no. 1, pp. 63-72.

Mavoa, S. et al. (2018) Identifying Appropriate Land-use Mix Measures for Use in a National Walkability Index. *The Journal of Transport and Land Use*, Vol. 11 no. 1, pp. 681-700.

Planades (2020) Consulting Services for the Economic Impact of Pedestrianization of an Urban Space in Metro Cebu, Final Report. Prepared for NEDA Region 7.

Regidor, J, (2007) Development of Philippine Trip Generation Rates. *Proceedings of the Eastern Asia Society for Transportation Studies*, Vol. 6.

Saelens, B. and Handy, S. (2008) Built Environment Correlates of Walking: A Review. *Med Sci Sports Exerc*. 2008 July; 40(7 Suppl): S550–S566.

Speck, J. (2013) Walkable City: How Downtown Can Save America, One Step at a Time. New York: Farrar, Straus and Giroux.