EVALUATING THE TRANSIT-ORIENTED DEVELOPMENT POTENTIAL OF THE MRT-7 LINE IN METRO MANILA, PHILIPPINES

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Abstract

The worsening traffic congestion in Metro Manila highlights the need for well implemented and integrated public mass transport. This study demonstrates the application of the Extended-Node-Place Model as a means of characterizing and classifying the selected 10 stations of the Metro Rail Transit Line 7 (MRT-7) project in order to aid city and transportation planners to create, utilize or enhance the Transport-Oriented Development (TOD) attributes for each of the stations. With scores largely derived from geospatial processing using Geographic Information System (GIS), results show that three stations scored highly under Node and Place indices, one station is average across all three indices (i.e., Node, Place, and 'Orientedness'), one station is an unsustained node, while the rest have a variation of low-average-average result for the three indices. With these results, a diagnostic is produced that highlights areas of improvement and areas of strength. Planners can then provide measures based on desired outcomes for each index.

Keywords: Transport-Oriented Development, Geographic Information System, Urban Planning, MRT-7, Node-Place Model, Metro Manila

1. INTRODUCTION

The Philippines, with its rapidly growing population and urbanization, faces significant challenges in transportation and traffic management. Rather than providing convenient means of transportation, the current state of public transportation in the country is a challenge to negotiate within daily routines, hindering people from reaching their destinations efficiently. This issue hampers public access to essential services such as education, healthcare, and employment opportunities, especially in underserved areas where mass transit is limited.

Public transportation system holds a vital position in addressing the persistent issue of traffic congestion while offering accessible and affordable mobility to the general public. However, the sprawling area of Metro Manila is assessed to have the world's fifth worst transportation system encapsulating the challenges faced by commuters in the Philippines' capital region [13]. Furthermore, according to the 2019 Global Competitiveness Report, the Philippines has the lowest efficiency score among other Asian countries in terms of train services [11]. This can be traced to the piece-meal implementation of railway projects that has issues in integrating with other train lines and even other public transport modes [1].

The focus of the study is on the MRT-7 line, a significant infrastructure project in Metro Manila that is currently under construction. The MRT-7 line is a 23 kilometer-long rapid transit line with a total of 14 stations connecting the areas from North Avenue in Quezon City to San Jose del Monte, Bulacan [7] composed of a mix of elevated, at-ground, and underground segments. The project is designed to alleviate traffic congestion, reduce travel time, and provide a more efficient mode of transportation for commuters in densely populated areas of Quezon City, Caloocan City, and San Jose del Monte in Bulacan.

This study covers the first 10 stations along the MRT-7 line, these are: North Avenue, Quezon Memorial Circle, University Avenue, Tandang Sora, Don Antonio, Batasan, Manggahan, Doña Carmen, Regalado, and Mindanao Avenue stations (Figure 1). The remaining 4 stations from the Quirino Highway Station up to San Jose Del Monte are excluded from the analysis because the finalized locations have not been made publicly available as of the conduct of this study, and characterization of the last 4 station areas would not be as definite as the rest of the MRT-7 stations.

Fig. 1 MRT-7 railway alignment and the stations included in this study

The paper aims to determine the Transit-Oriented Development (TOD) characteristics of each station within the study area along the MRT-7 line. This involves evaluating various factors such as land use patterns, connectivity, accessibility, pedestrian infrastructure, and integration with other modes of transportation. By understanding the TOD characteristics of each station, a comprehensive analysis can be conducted to assess their impact on transit-oriented development in the area.

Additionally, the paper aims to develop a typology based on the TOD characteristics of each station. The typology will categorize the stations into different groups based on the level of their transit-orientedness by providing a structured framework for understanding the varying degrees of integration between transportation and land use at each station. By evaluating each station's TOD characteristics and their relative strengths and weaknesses, an assessment can be made regarding their contribution to sustainable urban development.

Furthermore, the developed TOD typology can be a valuable tool for policymakers, urban planners, and transportation authorities in making informed decisions regarding future development plans. The recommendations based on the findings and analysis of the study can be applied for future infrastructure and land use planning which can lead towards the improvement of the overall transportation system, urban planning, and a more efficient and sustainable urban environment for residents and commuters. Lastly, the study can analyze potential areas for job creation, increased property values, and business opportunities that can lead to economic benefits.

2. REVIEW OF RELATED LITERATURE

The literature reviewed in this study concerns works on TOD classification and characterization, and spatial analysis using Geographic Information System (GIS).
In many cities, a Transit-Oriented Development (TOD) strategy is considered a practical solution for tackling the challenges embedded in metro system construction by improving the interaction between transit and surrounding land use, as is the case of Shenzhen and Guangzhou cities in China [17].

A way to characterize train stations is the node-place model by Bertolini [2], as shown in Figure 2. Obtaining the performance of each station as a node and place based on a set of indicators, it is possible to evaluate their urban role. If the node and place role are equally strong, it is considered to be a balanced location. When both values are very high, a station finds itself in a "stress" situation. If both node and place index scores are low, the station is "dependent" on other areas. If one component is much stronger than the other, a station are considered either an "unbalanced node" or an "unbalanced place".

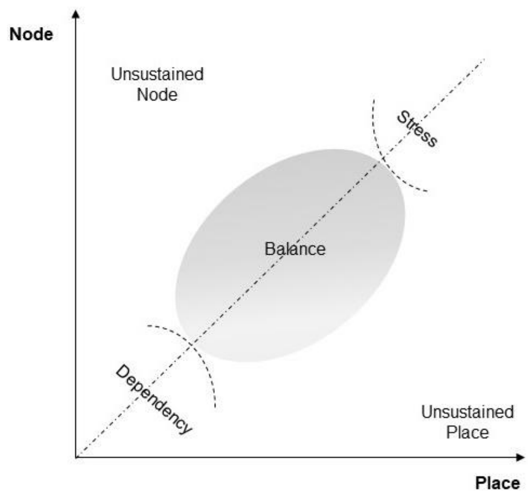

Fig. 2 The Node-Place model and Five Ideal-Typical Situations for a Location [2]

Lyu, et al. [5] used the Node-Place Model to generate a typology of Beijing metro station areas to provide urban planners and policymakers a summary of station area characteristics and more efficiently identify types of interventions to implement, as well as the allocation of resources. The addition of the 'oriented' index, thus 'extending' the node-place model, is a means of determining whether a station is a Transport-Adjacent or a Transport-Oriented development. The resulting modification to the node-place model for this study is later visualized in Figure 7.

In the case of Hefei City where population is reportedly increasing at a rapid pace, Transit Oriented Development along the city's railway lines is evaluated in order to efficiently allocate resources. The silhouette method was combined with the node-place model in order to identify which of the 77 TODs were unbalanced and in need of development efforts in order to achieve a more balanced state [16].

Vecchio [14] explores the urban role of railway stations in Santiago, analyzing the relationship that active stations establish with the metropolitan mobility system, and with their immediate urban surroundings. The paper evaluates the Metrotren-Nos suburban train stations by applying the node-place model, that examines each one based on its role as a node – that is to say, how many destinations it can reach – and as a place – considering the diversity and intensity of activities that take place in its surroundings.

Beyond the node-place model, there is a range of other approaches that investigate spatial and TOD characteristics of train stations. A few examples are to be briefly discussed in this literature review. Sakanishi [10] is one such example that uses a different method to spatially analyze railways and station areas. To identify factors in the declining rail service demand in the Osaka Metropolitan area, small-area statistics or a 1x1km grid was used to enable characterization of areas both near and away stations. In contrast, studies that use the node-place model typically applies a buffer around a train station and limits the scope of analysis to only within the immediate vicinity of stations. Sakanishi's findings indicate that changes in economic activities and locations have more to do with the decreased rail service demand over slow population growth. Employment opportunities became more decentralized, reducing need for rail travel and encouraging car and bicycle use.

Galelo, et al. [4] analyzed spatial characteristics of train stations of the Azambuja train line based on the definition and variables of TOD in their literature review furthered by conducting a correlation amongst their selected variables. Their findings showed a weaking correlation between population and train connections over time amidst a lack in TOD strategies from either local or national government.

GIS and spatial multi-criteria assessment (SMCA) were combined by Singh et al [12] to measure TOD levels in the Arnhem Nijmegen City Region. The push for TOD in the City Region is aimed at inducing a modal shift from car to public transit as car use was observed to be increasing for longer trips. A potential TOD Index was obtained that showed that urban areas having higher index values and identified "hot spots" or areas of high index values that are 800m away from a train connection.

TOD evaluation on the Ankeng Line in New Taipei City used the fuzzy Delphi method to select an evaluation criteria followed by a fuzzy analytic network process (FANP) to set weights for the established criteria. GIS was then used to conduct analysis of each station area based on the previously obtained weighted evaluation criteria, resulting in a classification for each station of the railway line [15].

There are several studies concerning railways and rail station area spatial analysis in Metro Manila. Damian and Mabazza [3] investigated the parallel evolution of Manila City's settlements and the tranvia street car system covering the period between 1895 and 1945. Their study utilized GIS and graph-theoretic analysis that revealed a correlation between district population and built-up areas. Pacheco-Raguz's [6] analysis of the Light Rail Transit Line-1 (LRT-1) looks into the impact of the railway line on land values, land uses, and population densities. Using GIS, the study covered a 2000m buffer around an LRT-1 station to cover both adjacent and relatively distant areas. The study [6] identified only residential land values being consistently influenced by accessibility and distance brought about by the construction of the LRT-1

3. METHODOLOGY

3.1 Identification of Indicators and Data Collection

Based on existing literature [2,5], indicators pertaining to node, place, and 'orientedness' were selected in order to assess each of the ten MRT-7 stations in the study area as potential sites for TOD. The selection of indicators was based on the availability and reliability of secondary data sources. The study used open data sources including Points of Interests (POIs) and other shapefiles extracted from OpenStreetMap and information from government websites (Figure 3).

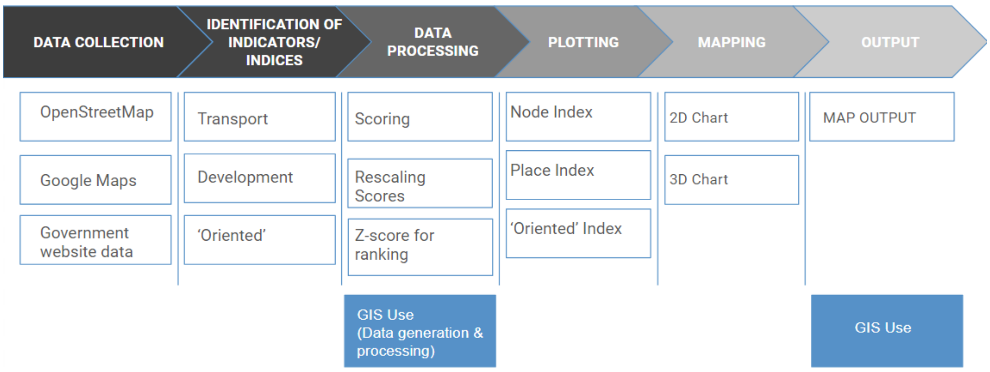

Fig. 3 Methodological Framework

3.2 Node indicator data

Selected indicators pertaining to a transit-oriented development's node characteristics include:

a) public transport count which refers to the number of jeeps and buses that ply alongside station area
b) distance to central business districts which is quantified by the geographic

distance of identified central business districts from each of the MRT-7 stations
c) travel time to central business districts
d) number of bus stops within the catchment area established within a 700 meter buffer, and
e) bike path length within 2 kilometers around each of the stations.

3.3 Place indicator data

In order to calculate for the stations' respective place index scores, the study utilized available data on:

a) working-age population
b) number of commercial facilities with area sizes of 1,000 square meters and over
c) number of green or open spaces
d) number of public facilities such as hospitals, schools, public markets, and churches
e) retail and services establishments
f) size and density of residential areas within the buffer zone, and
g) land use mix.

3.4 "Oriented" indicator data

To generate scores for each of the stations' orientedness index, the study assigned indicators based on:

a) number of cul-de-sacs within buffer zones
b) number of intersections within buffer zones
c) average block size within buffer zones
d) sidewalks and bikeways characterized by their length
e) average distance of each of the stations to commercial areas and identified places with job opportunities
f) total length of bikeways within two kilometers of each of the stations
g) average distance of each of the stations to residential areas
h) average walking distance from station to a block.

3.5 Data Processing

Open-source data and shapefiles from reliable secondary sources were utilized with further geoprocessing work done in ArcGIS and QGIS to calculate and refine indicator data (Table 1). The values obtained for each station area is then rescaled from zero to one [5, 8], with zero being the lowest desirable score and one being the highest. Two equations were used, taken from Lyu et al [5]:

$$X_{index} = \left(X - Min(X)\right) / \left(Max(X) - Min(X)\right) \qquad (1)$$

$$X_{index} = \left(Max(X) - X\right) / \left(Max(X) - Min(X)\right) \qquad (2)$$

Use of Equation (1) was for indicators where high numerical values are desirable such as the number of other public transport modes and stations, working population, and land use mix within 700m of a station. Equation (1) assigns the value zero to those with the lowest numerical value while 1 is assigned to the highest numerical value. Equation (2) was used for indicators where lower numerical values are desirable, such as distance and travel time to places from a station. Thus, 0 is assigned to the highest numerical values (e.g., longer travel times) while 1 is assigned to the lowest numerical value.

Each station was then given an average score based on the rescaled zero to one range for each indicator per index. With an average score obtained for each station, these averages per index was then standardized further with a z-score [8,9] shown in Tables 2 to 4. These standardized scores allow the visualization of a station's performance relative to another based on "the number of standard deviations an observation is" [9] with respect to the mean.

Indicators	PT Count	Average distance of station to CBD	Average travel time to a CBD	Number of Bus stops	Total bike path length within 2km around station	Total Working Population	Number of Commercial Facilities (1,000 m^2 sq.m.)	Number of Green Space	Number of Public Facilities	Number of neighborhood retail and service	Residents -Within the Buffer	Land Use Mix Index	Number of dead-ends / cul-de-sacs	Number of intersections	Block size	Road - Sidewalk Total (km)	Bike lane length in station area total (km)	Average distance of station to commercial area	Average distance of station to residence area	Average walking to from station to a block
Station	(T1)	(T2)	(T3)	(T4)	(T5)	(D1)	(D2)	(D3)	(D4)	(D5)	(D6)	(D7)	(O1)	(O2)	(O3)	(O4)	(O5)	(O6)	(O7)	(O8)
Batasan	65	11.666	46.63	11	14.433	32122	1	1	11	26	47749	0.149	64	270	1.25	11.363	5.013	366.62	515.14	13.98
Dona Carmen	53	13.503	53.97	1	13.318	35432	5	5	11	16	57097	0.097	30	148	1.75	5.794	3.948	331.99	531.02	14.35
Don Antonio	62	10.727	42.87	6	19.037	29825	7	0	4	45	43559	0.228	59	123	1.96	6.787	4.333	441.26	551.87	14.9
Manggahan	60	12.967	51.83	5	14.588	54201	2	0	10	13	39290	0.153	92	423	1.95	11.567	5.494	595.24	546.01	15.13
Mindanao Avenue	56	16.243	64.92	3	9.247	4455	6	3	10	46	6676	0.652	17	101	1.76	13.163	2.323	461.87	594.62	15.27
North Avenue	68	8.096	32.36	19	45.402	22903	5	5	10	35	39290	0.688	18	84	2.05	19.46	4.279	470.98	574.32	15.45
Quezon Memorial Circle	75	7.501	29.98	9	52.526	14728	3	8	12	31	19551	0.997	11	16	7.6	20.28	8.949	640.42	681.13	17.02
Regalado	53	13.443	53.73	7	9.747	18215	5	9	12	22	30108	0.12	22	159	1.14	9.418	2.93	406.33	524.91	14.36
Tandang Sora	67	8.894	35.55	23	30.832	19264	7	5	11	43	27247	0.721	31	104	2.28	15.87	8.18	357.7	518.91	13.12
University Avenue	73	7.811	31.22	10	41.961	16481	3	2	9	23	22993	0.858	19	40	4.33	15.895	6.239	399.55	517.72	14.39

Table 1 TOD Indices Scores

Node Indicators / Station	PT Count (T1)	Average distance of station to CBD (T2)	Average travel time to a CBD (T3)	Number of Bus stops (T4)	Total bike path length within 2km around station (T5)	Average of Station Node indicators	Z- Score
Batasan	0.545	0.524	0.523	0.455	0.120	0.433	-0.150
Dona Carmen	0.000	0.313	0.313	0.000	0.094	0.144	-1.112
Don Antonio	0.409	0.631	0.631	0.227	0.226	0.425	-0.178
Manggahan	0.318	0.375	0.375	0.182	0.123	0.275	-0.678
Mindanao Avenue	0.136	0.000	0.000	0.091	0.000	0.045	-1.441
North Avenue	0.682	0.932	0.932	0.818	0.835	0.840	1.203
Quezon Memorial Circle	1.000	1.000	1.000	0.364	1.000	0.873	1.312
Regalado	0.000	0.320	0.320	0.273	0.012	0.185	-0.977
Tandang Sora	0.636	0.841	0.841	1.000	0.499	0.763	0.948
University Avenue	0.909	0.965	0.965	0.409	0.756	0.801	1.072
Overall average of all 10 stations node indicators: 0.478 Standard Deviation (STDEV.P): 0.300							

Table 2 Z-scores for the Node index

Place Indicators / **Station**	Total Working Population (D1)	Number of Commercial Facilities (1,000 m^2 (D2)	Number of Green Space (D3)	Number of Public Facilities (D4)	Number of neighborhood retail and service (D5)	Residents Within the Buffer (D6)	Land Use Mix Index (D7)	Average of Station Place Indicators	Z-score
Batasan	0.556	0.000	0.111	0.875	0.394	0.815	0.058	0.401	-1.197
Dona Carmen	0.623	0.667	0.556	0.875	0.091	1.000	0.000	0.544	0.315
Don Antonio	0.510	1.000	0.000	0.000	0.970	0.732	0.146	0.480	-0.369
Manggahan	1.000	0.167	0.000	0.750	0.000	0.647	0.063	0.375	-1.472
Mindanao Avenue	0.000	0.833	0.333	0.750	1.000	0.000	0.617	0.505	-0.103
North Avenue	0.371	0.667	0.556	0.750	0.667	0.647	0.657	0.616	1.074
Quezon Memorial	0.207	0.333	0.889	1.000	0.545	0.255	1.000	0.604	0.946
Regalado	0.277	0.667	1.000	1.000	0.273	0.465	0.025	0.529	0.157
Tandang Sora	0.298	1.000	0.556	0.875	0.909	0.408	0.694	0.677	1.716
University Avenue	0.242	0.333	0.222	0.625	0.303	0.324	0.846	0.414	-1.067
Overall average of all 10 stations node indicators: 0.515									
Standard Deviation (STDEV.P): 0.095									

Table 3 Z-scores for Place index

` **Oriented' Indicators**	Number of dead-ends / cul-de-sacs	Number of intersections	Block size	Road - Sidewalk Total (km)	Bike lane length in station area total (km)	Average distance of station to commercial area	Average distance of station to residence area	Average walking to from station to a block	Average of Station Oriented Indicators	Z-score
Station	(O1)	(O2)	(O3)	(O4)	(O5)	(O6)	(O7)	(O8)		
Batasan	0.346	0.624	0.983	0.384	0.406	0.888	1.000	0.779	0.676	0.871
Dona Carmen	0.765	0.324	0.906	0.000	0.245	1.000	0.904	0.685	0.604	0.198
Don Antonio	0.407	0.263	0.873	0.069	0.303	0.646	0.779	0.544	0.485	-0.899
Manggahan	0.000	1.000	0.876	0.399	0.479	0.146	0.814	0.485	0.525	-0.535
Mindanao Avenue	0.926	0.209	0.904	0.509	0.000	0.579	0.521	0.449	0.512	-0.653
North Avenue	0.914	0.167	0.859	0.943	0.295	0.549	0.643	0.403	0.597	0.132
Quezon Memorial Circle	1.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.375	-1.924
Regalado	0.864	0.351	1.000	0.250	0.092	0.759	0.941	0.682	0.617	0.325
Tandang Sora	0.753	0.216	0.824	0.696	0.884	0.917	0.977	1.000	0.783	1.863
University Avenue	0.901	0.059	0.507	0.697	0.591	0.781	0.984	0.674	0.649	0.621
Overall average of all 10 stations node indicators: 0.582										
Standard Deviation (STDEV.P): 0.108										

Table 4 Z-scores for 'Oriented' index

3.6 Limitations of Data Collection Method

There were several limitations encountered during the data gathering process of the study. Data gathering was restricted to the information and public documents readily available on the Internet. This reliance on existing data sources may have limited the depth and comprehensiveness of the information collected. The pandemic also posed limitations on data gathering efforts for primary data. The restrictions, safety measures and procedures to access certain data sources, and to conduct interviews and fieldwork would entail applications for approval that would consume a significant amount of time for data collection, processing, and analysis. As a result, the study relied heavily on secondary data sources which affected the selection of indicators for the study.

4. FINDINGS & ANALYSIS

4.1 Findings

The Node and Place chart in Figure 4 shows roughly two groups, one characterized by high Node and Place indices composed of North Avenue, Quezon Memorial Circle, and Tandang Sora stations, and the other group of average node and low place index consisting of Doña Carmen, Mindanao Avenue, and Regalado Stations. The rest are somewhat dispersed along the "unbalanced node" area of the graph.

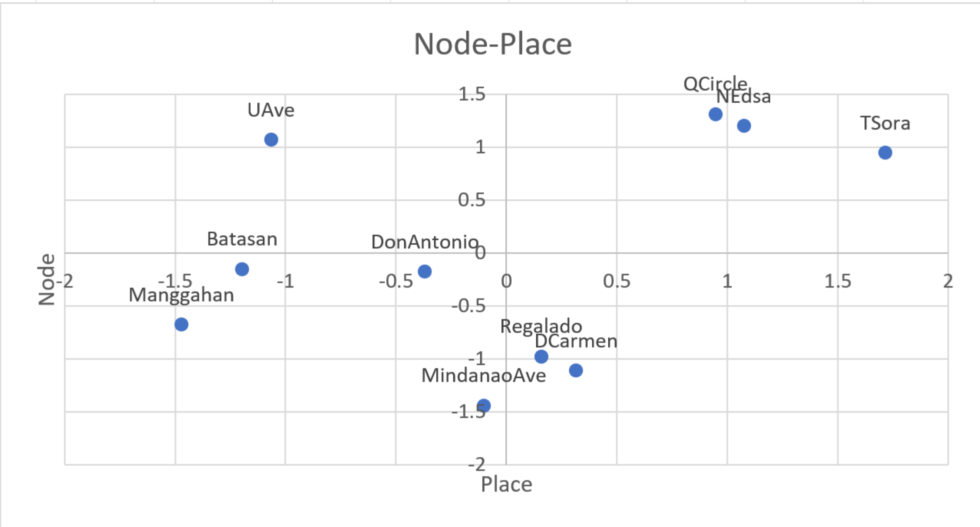

Fig. 4 Plotted Node-Place Indices

"Oriented" index points to Tandang Sora and Batasan stations as areas with good indicators while Quezon Memorial Circle has the lowest-scoring indicators. The rest of the stations have average values (i.e., within one standard deviation)

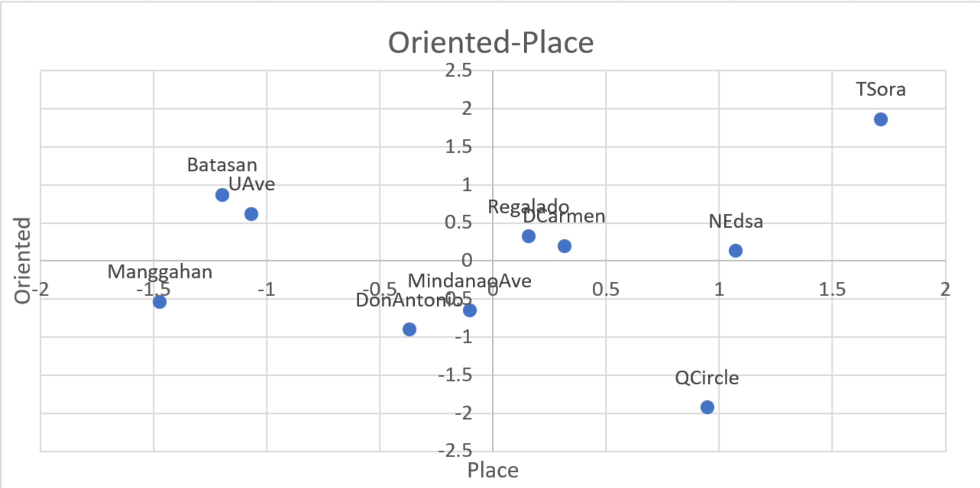

Fig. 5 Plotted 'Oriented' and Place Indices

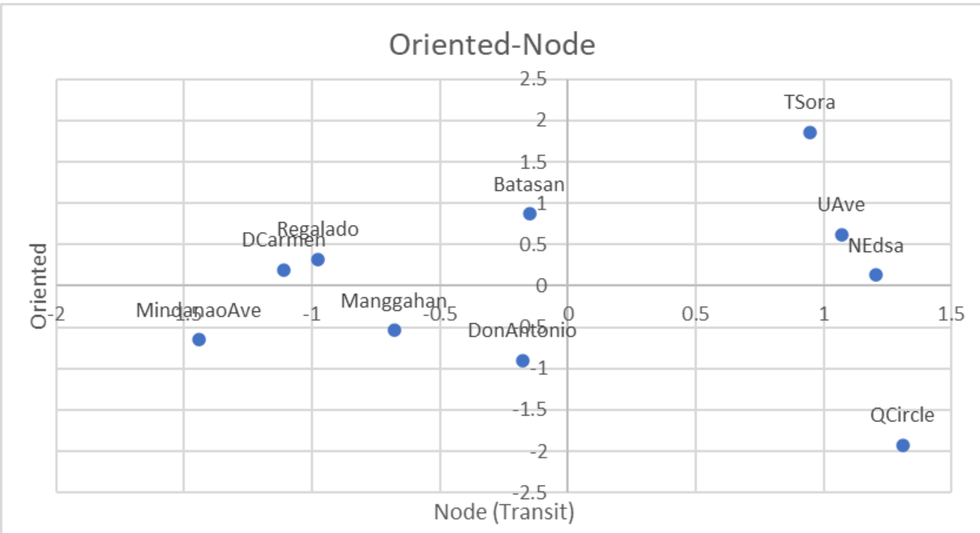

Fig. 6 Plotted 'Oriented' and Node Indices

The final output for this process is a three-dimensional graph with the Place index on the x-axis (parallel to the red cutting plane), Node index on the y-axis (parallel to the green cutting plane) and the "Oriented" index on the z-axis (Figure 7).

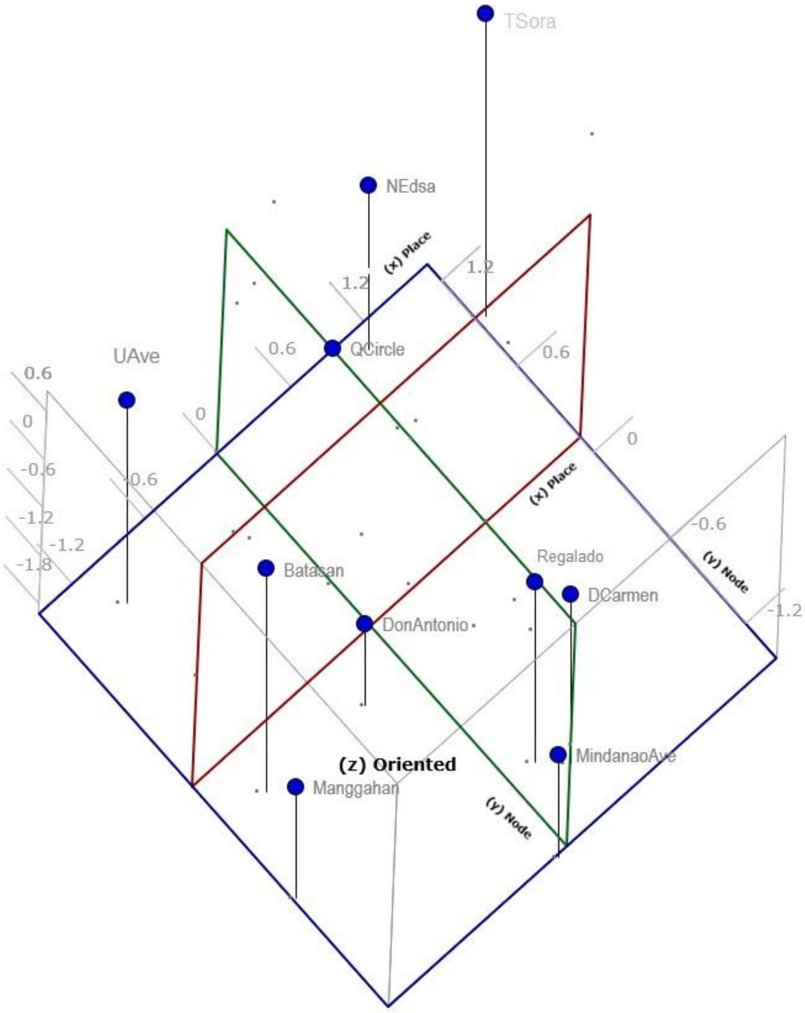

Fig. 7 3D Plot for all 3 Indices

4.2 Analysis

Based from the findings of the study, the 10 stations of the MRT-7 line can be generalized into the following:

Group 1: High Node and Place index
Group 2: Average Node index, low Place index, and average Oriented index
Group 3: Low Node index, average Place and Oriented index
Group 4: Average Node, Place, and Oriented index
Group 5: High Node index, low Place index, average Oriented index

Group	Sub-group	Indices			Stations
		Node (Transit)	Place (Development)	"Oriented"	
1	A	High	High	High	Tandang Sora
	B	High	High	Average	North Avenue
	C	High	High	Low	Quezon Memorial Circle
2		Average	Low	Average	Batasan, Manggahan
3		Low	Average	Average	Doña Carmen, Regalado, Mindanao Avenue
4		Average	Average	Average	Don Antonio
5		High	Low	Average	University Avenue

Table 5 Summary of Findings

Group 1 features good Node and Place characteristics indicating that there is "intensity and diversity of transportation modes" [2] and as a place, it is host to a variety of activities facilitating "physical human interaction" [2]. Station areas with high Node and Place index scores are defined by Bertolini [2] as "stressed" where there is a "great chance of conflicts between multiple, extensive claims on a limited space". These areas need to balance "intensity of land use" as well as a responsive transportation system to maintain intense use.

The three stations differ in their 'Oriented' scores. Tandang Sora station scored well in distance-related indicators (i.e., being closer to places of interest) and in bike and pedestrian lengths compared to the other stations. On the other end, Quezon Memorial Circle station has the lowest score. This can be explained by the physical layout around the station being largely limited by the land use, block arrangement, and street network. North Avenue station has an average score, positioned between the two aforementioned stations.

Given a low score on the 'Oriented' index, Quezon Memorial Circle station has characteristics of a Transit-Adjacent Development (TAD) rather than a TOD in that transport and place activities develop independent of each other rather than being coordinated. To redress this poor performance, improvements to Quezon Memorial Circle station may be in creating more direct and comfortable pedestrian corridors connecting to points of interest.

Group 2 are stations with average Node and 'Oriented' indices and low Place index. According to the Node- Place model, Batasan and Manggahan stations are referred to as "unsustained nodes" in which "transportation facilities are relatively much more developed than urban activities" [2], where the Node index is higher than the Place index. An average 'Oriented' index points to features around that station area that are encouraging for TOD.

Possible interventions within Group 2 station areas are measures that improve place features that promote increased activities, either or both in intensity and diversity, and that these areas are easily accessible from the MRT-7 stations to capitalize on the 'Oriented' features.

Group 3 stations of Doña Carmen, Mindanao Avenue, and Regalado are the opposite of Group 2 where the Place index is higher than the Node index. These stations are referred to as "unsustained places" and feature a decent level of activities and places of interest but having weak public transportation characteristics. As with most of the MRT-7 stations, Group 3 stations have average 'Oriented' index scores.

A possible explanation for good place features is that activities are patronized by and reliant on local residents, thus minimizing the need to expand transportation services. Only when these activities begin to attract more customers outside the station area are interventions to be acted upon public transportation arrangements, leading to a more balanced situation between place and node. The average 'Oriented' score implies that these areas are reasonably navigable on foot or on active transport.

Don Antonio station is in its own unique category. Group 4 is characterized by an average performance in all three indices. This indicates a balance of transportation services with surrounding activities and complemented by decent 'Oriented' features. It is not yet at a level of competition for limited space nor is the area in need for more transportation options.

Despite being referred to as a 'balanced' station, this does not imply that the area has already maximized its potential or that further improvements cannot be made to the area. The status of a station is subject to change because the extended Node-Place model is not static. Any changes in the level of transportation services, variety of activities, or active transport features may change or enhance the 'balanced' status of Don Antonio station.

Group 5 refers to an example of an extreme unsustained node. The University Avenue station rates highly in the Node index but low in the Place index with the station area having an average 'Oriented' index.

This outcome may be partly explained by the presence of several transport modes that stop within the vicinity of Philippine Coconut Authority (PHILCOA) for the Node index, while Place index may be attributable to the station area including lands under the University of the Philippines (UP) which limits the diversity of land uses, such as dense residential zones. The current placement of University Avenue station on the enhanced Node- Place model is appropriate, reflecting that it is a transportation stop and transfer point to other destinations, particularly UP.

Interventions may be limited, given the nature of allowing more UP spaces being opened to commercial, office, and private residential use is politically contentious. Redressing the imbalance may be in the form of intensifying land uses outside university grounds to provide additional residential and office units, and commercial spaces in pursuit of TOD.

These groupings have been mapped in Figure 8 and show that Group 1 stations are towards the southern end of the line close to busy areas while stations that are unsustained Node and unsustained Places (Group 2 and 3) tend to be at the northern end where there are more residential areas.

A limitation in the application of the extended Node-Place model in this study is that the scoring is based on the relative performance of each station to others within the same line. The methods in classifying spatial attributes within station areas would also have considerable implications in the ranking of one station relative to another.

To illustrate the drawback of relative scoring of stations to one another, an example would be that a future operational MRT-7 North Avenue station would be a 'stressed' point as part of an interchange with future LRT-1, MRT-3, and Metro Manila Subway operations. This scenario would result in high Node and Place indices relative to other MRT-7 stations. However, if one were to put data in a dummy station with characteristics similar to that of Tokyo Station in Japan, then the North Avenue station may give a different result, possibly more 'balanced'. Results of the extended Node-Place model are applicable only within the sampled railway line or network within a particular locale.

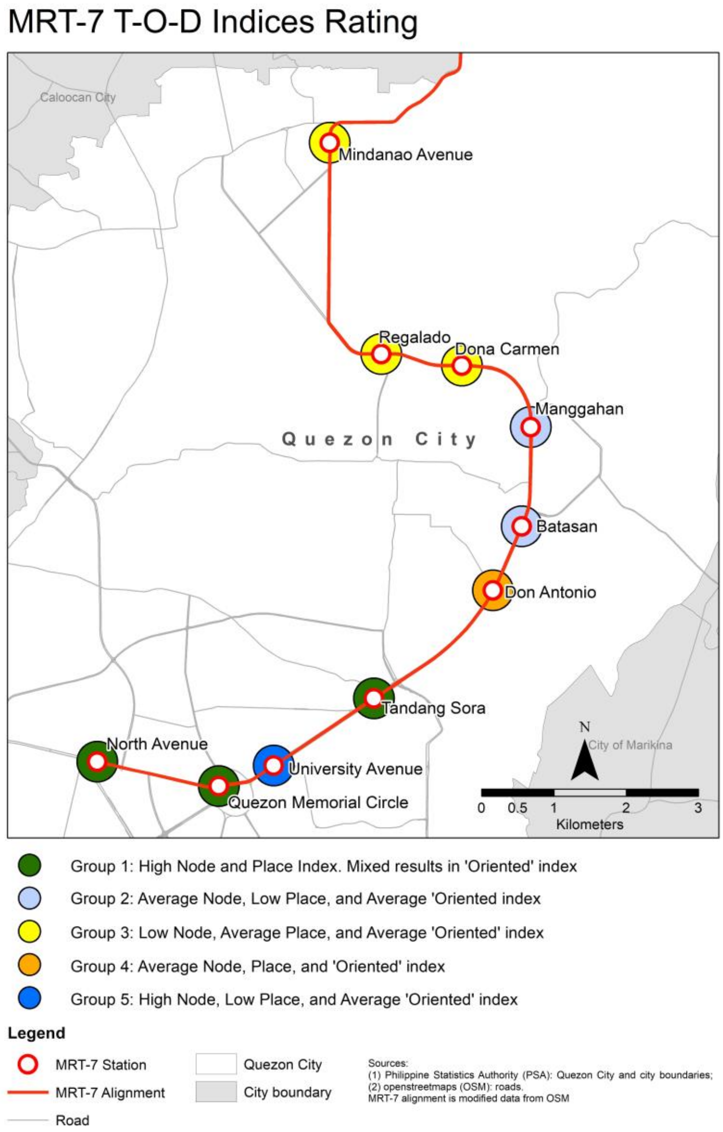

Fig. 8 MRT-7 TOD Indices Rating

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Public transportation in the Philippines faces significant challenges, including traffic congestion and limited access to basic services in underserved areas. The study used the Extended Node-Place Model to assess the MRT-7 railway stations based on the developed Transit-Oriented Development (TOD) indices. The findings revealed that the ten selected stations exhibited a variety of outcomes, highlighting the diverse characteristics and performances of each station.

The application of the Extended Node-Place Model showcased its effectiveness in producing a typology of the transportation stations and providing a diagnostic of their performance in comparison to one another. This model serves as a valuable tool for transportation and city planners as it enables them to analyze and classify stations based on desired outcomes for each index. With accurate and updated information, planners can tailor specific interventions and strategies to improve the performance of individual stations and enhance the overall transit-oriented development within the system. The Extended Node-Place Model's flexibility and systematic classification methodology make it adaptable to different geographic contexts, making it applicable not only to the MRT-7 line but also to other transportation systems in the Philippines or even other countries. By utilizing this model, policymakers and planners can make informed decisions and implement targeted interventions that address the specific challenges and opportunities presented by different transportation stations.

The utilization of the Extended Node-Place Model in this paper has provided valuable insights into the performance and characteristics of the MRT-7 rail stations. This model can be used to improve land use planning and infrastructure around each station which can lead to transit-oriented development, sustainable urban development, and economic benefits.

5.2 Recommendations

Future studies and research on Transit-Oriented Development should diversify data sources and utilize primary data collection methods when possible. Different sets of indicators can also be used specifically for the geographic context of the chosen study area for more accurate findings and analysis.

Incorporating a pedestrian service area (such as in Figure 9) may also be helpful in the TOD typology analysis and decision-making process of TOD implementation whereby the visualization of these areas may better pinpoint priority locations for investment or intervention.

Statements and Declarations

Rosemarie Goltiao is employed by the private proponent of the MRT-7 project as this study was conducted. However, this research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The authors declare that they have no conflict of interest.

Figure 7 was generated using the 'Excel 3D Scatter Plot' programmed by Gabor Doka. https://www.doka.ch/Excel3Dscatterplot.htm

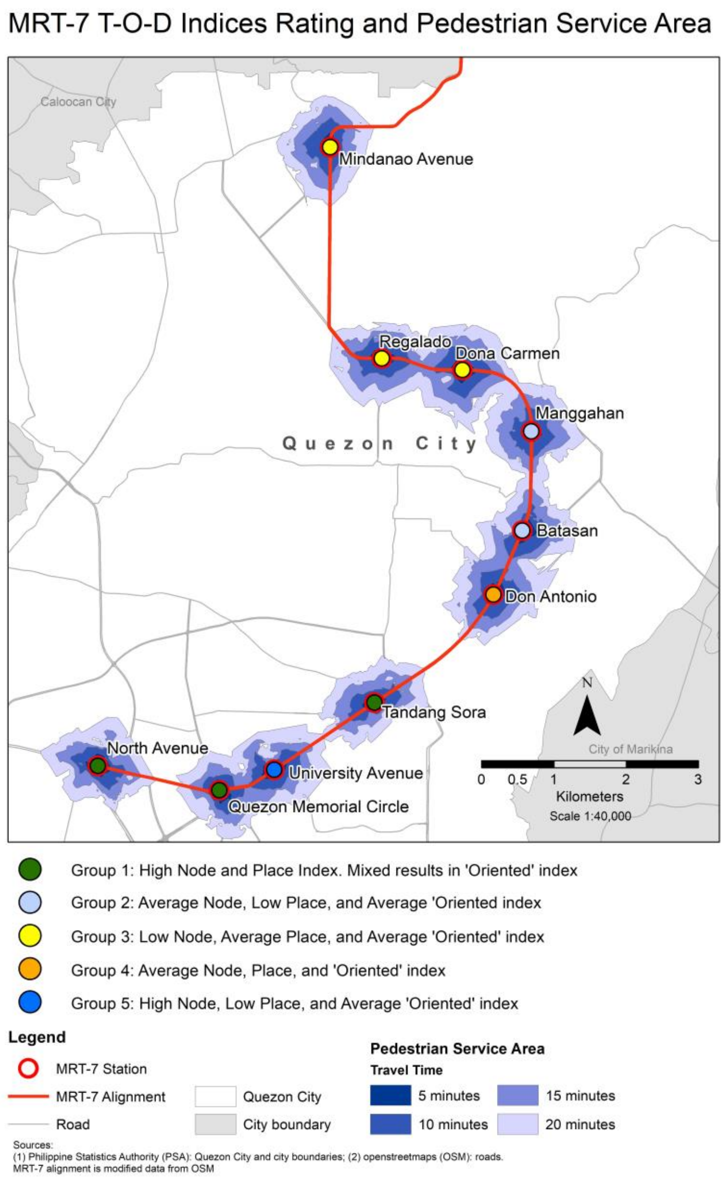

Fig. 9 MRT-7 TOD Indices Rating and Pedestrian Service Area

REFERENCES

[1] ALMEC Corporation. (2014) "Roadmap for transport infrastructure development for Metro Manila and its surrounding areas (Region III & Region IV-A) – Final report". Japan International Cooperation Agency, & National Economic Development Authority. https://neda.gov.ph/wp-content/uploads/2015/03/FR-MAIN-TEXT.-12149605_01.pdf
[2] Bertolini L (1999) "Spatial development patterns and public transport: the application of an analytical model in the Netherlands". Planning practice and research, 14(2), 199-210. https://doi.org/10.1080/02697459915724
[3] Damian JC, Mabazza DL (2017) "Historical Transport Network: Mapping Manila's Settlements and Railway Systems (1895-1945) Using Geographic Information Systems and Graph Theoretic Analysis". Conference paper. 6th Asian Network for GIS-based Historical Studies (ANGIS) International Conference. https://riles.upd.edu.ph/wp-content/uploads/2018/02/016-ANGIS-2017-Historical-Transport-Network_-Damian-Mabazza.pdf
[4] Galelo A, Ribeiro A, Martinez LM (2014) "Measuring and evaluating the impacts of TOD measures–Searching for evidence of TOD characteristics in Azambuja Train Line". Procedia-Social and Behavioral Sciences 111, 899-908. https://doi.org/10.1016/j.sbspro.2014.01.124
[5] Lyu G, Bertolini L, Pfeffer K (2016) "Developing a TOD typology for Beijing metro station areas". Journal of Transport Geography, 55, 40-50. https://doi.org/10.1016/j.jtrangeo.2016.07.002
[6] Pacheco-Raguz JF (2010) "Assessing the impacts of Light Rail Transit on urban land in Manila". Journal of Transport and Land Use 3(1), 113-138. https://doi.org/10.5198/jtlu.v3i1.13
[7] Public-Private Partnership Center. (n.d.) "MRT line 7". Retrieved September 6, 2023., from https://ppp.gov.ph/ppp_projects/mrt-line-7/
[8] Reusser DE, Loukopoulos P, Stauffacher M, Scholz RW (2008) "Classifying railway stations for sustainable transitions–balancing node and place functions". Journal of transport geography, 16(3), 191-202. https://doi.org/10.1016/j.jtrangeo.2007.05.004
[9] Sanders J (2015) "Linking station node-and place functions to traffic flow: a case study of the Tokyu Den-En Toshi line in Tokyo, Japan". Master's thesis, University of Twente. https://essay.utwente.nl/67082/
[10] Sakanishi A (2006) "Commuting patterns in the Osaka Metropolitan Area: A GIS-based analysis of commuter rail passengers". In Review of Urban & Regional Development Studies: Journal of the Applied Regional Science Conference (Vol. 18, No. 1, pp. 41-59). Melbourne, Australia: Blackwell Publishing Asia. https://doi.org/10.1111/j.1467-940X.2006.00106.x
[11] Schwab K (2019) "The global competitiveness report 2019". World Economic Forum. https://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf
[12] Singh YJ, Fard P, Zuidgeest M, Brussel M, van Maarseveen M (2014) "Measuring transit oriented development: a spatial multi criteria assessment approach for the City Region Arnhem and Nijmegen". Journal of Transport Geography 35, 130-143. https://doi.org/10.1016/j.jtrangeo.2014.01.014
[13] Thibault G, de Clerq M, Brandt F, Nienhaus A, Bayen A, Cartigny L, ElAsmar E, Hoh WL, Ibarra A, Irwin D, Jaworska K, Kleinman D, Marangu N, Mbatudde F, Mincer J, Moffett S, Reid L, Parab S, Shaw S, Slimani A, Talaj W, Woo L (2023) "Urban

mobility readiness index 2022 report". Oliver Wyman Forum. https://www.oliverwymanforum.com/content/dam/oliver-wyman/ow-forum/template-scripts/urban-mobility-index/PDF/Mobility-Index-Report.pdf
[14] Vecchio G (2021) "Train stations as nodes and places: the potential of trains for transit-oriented urban development in Santiago, Chile". Revista Urbano No. 43 Page 84-95. https://www.scielo.cl/pdf/urbano/v24n43/en_0718-3607-urbano-24-43-84.pdf
[15] Wey WM, Zhang H, Chang YJ (2016) "Alternative transit-oriented development evaluation in sustainable built environment planning". Habitat International 55, 109-123. https://doi.org/10.1016/j.habitatint.2016.03.003
[16] Wu W, Divigalpitiya P (2022) "Assessment of accessibility and activity intensity to identify future development priority TODs in Hefei City". Land, 11(9), 1590. https://doi.org/10.3390/land11091590
[17] Yang Y, Zhong C, Gao QL (2022) "An extended node-place model for comparative studies of transit-oriented development". Transportation Research Part D: Transport and Environment, 113, 103514. https://doi.org/10.1016/j.trd.2022.103514