Analyzing Urban Agglomeration Patterns and Economic Development in Metro Manila using Social Network Analysis

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Abstract

Metro Manila, the Philippines' largest urban agglomeration, illustrates the spatial clustering of economic activities typical of densely agglomerated regions. While core cities enjoy strong connectivity and agglomeration benefits, peripheral areas continue to experience marginalization, highlighting persistent uneven development. This study applies a gravity-based Social Network Analysis (SNA) to model intercity economic connections from 2015 to 2020, using entropy-weighted indicators and estimated transport distances to construct economic networks at three time points. The primary objective is to examine how the strength and structure of these connections have evolved and what they reveal about centralization, marginalization, and subgroup cohesion across cities. Findings confirm a strong and persistent core-periphery structure, with Makati, Manila, Pasay, and Quezon City consistently occupying dominant positions in the network. Fringe cities such as Marikina, Valenzuela, Muntinlupa and Pateros remained weakly integrated due to their peripheral location and limited connectivity to economic cores. In 2018, the network experienced a temporary decline in connectivity which is evident in lower density, efficiency, and centrality scores, before partially recovering in 2020. Central cities retained bridging roles, while others showed shifting positions over time. Cohesive subgroup analysis revealed strong intra-cluster ties but limited inter-cluster integration, reinforcing structural fragmentation. These demonstrate that proximity alone does not determine influence because functional roles, infrastructure, and institutional alignment are equally critical. Results also emphasize the need for proximity-responsive development, intercity collaboration, and investment in "bridge cities" to reduce spatial inequalities and enhance regional economic integration.

1. Introduction

Urban agglomerations refer to spatially dense and economically integrated clusters of cities that interact through infrastructure, transportation, and market flows (Fang and Yu, 2017). They drive over 80 percent of global GDP and accommodate much of the growing population (World Bank, 2017). However, their growth has also deepened inequalities in access to infrastructure, services, and opportunities (Obanan, 2021).

Uneven development in agglomerations often follows a core-periphery pattern, where core cities grow rapidly while peripheral ones lag behind (Klimczuk and Klimczuk-Kochańska, 2023). Myrdal (1957) and Krugman (1991) similarly argue that unchecked core expansion can entrench spatial inequality. In Metro Manila, prosperous areas coexist with underserved cities lacking adequate transport and housing (UN-Habitat, 2022). Addressing these disparities requires a thorough understanding on how cities interact and influence one another's development. Traditional approaches often analyze cities as isolated containers of growth, a view known as "spaces of places." However, this perspective overlooks the increasing interdependence between cities brought about by economic flows, technological exchange, and transportation linkages (Ter Wal and Boschma, 2009).

Social Network Analysis (SNA) and gravity models are increasingly used to examine these interactions to account for not only the city's internal assets but also by its relational position within the region. SNA quantifies the relative position and influence of cities in a network through centrality metrics (Tabassum et al., 2018). Gravity models estimate the economic connection strength between city pairs based on development potential and spatial accessibility. Together, these tools allow researchers to analyze urban systems as complex relational structures rather than isolated units. Recent studies using these approaches have revealed economic hierarchies, regional clusters, and spillover effects in various urban agglomerations (Huang et al., 2020). However, such analysis has yet to be explored in the Philippines.

Furthermore, while network participation is often associated with economic benefits, it does not guarantee equal development outcomes for all cities. Meeteren et al. (2016) and Glaeser et al. (2015) argue that the benefits of network integration vary widely depending on city role, institutional capacity, and regional context. These findings suggest that simply being connected is not enough to ensure shared growth and that network structure plays a critical role in shaping economic opportunity.

This study addresses the lack of attention to intercity economic interconnections in Metro Manila, where uneven development persists despite shared urban functions. To fill this gap, it applies gravity-based Social Network Analysis (SNA) to model and evaluate the structure of economic linkages among cities from 2015 to 2020. Using entropy-weighted economic indicators and estimated transportation distances, SNA constructs intercity networks across three time points to assess how connection strengths and city roles evolved. Centrality metrics and subgroup analysis are employed to uncover patterns of centralization, marginalization, and cohesion, thereby identifying key nodes, clusters, and weakly connected areas.

This paper aims to aid a data-driven, equitable regional planning by recognizing the dynamic economic relationships within Metro Manila's urban network. These insights support Sustainable Development Goals such as SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), and SDG 11 (Sustainable Cities and Communities), emphasizing balanced regional development and inclusive urban growth.

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However, the study makes several assumptions and have limitations. City-level indicators were used to represent economic development, assuming homogeneity within each city despite known intra-city disparities. Transportation distances were estimated using shortest-path algorithms under static travel time assumptions, with mall-to-mall routes serving as proxies for city centers and key origin-destination points. Additionally, the analysis also excluded interactions with cities outside Metro Manila, excluding spillover effects from surrounding provinces. Despite these constraints, the study offers a replicable framework for assessing regional economic connectivity using publicly available datasets and standardized methodologies. Its approach remains robust, reliable and comparable, given data limitations.

2. Study Area and Data

2.1 Study Area

This study focuses on Metro Manila, which comprises of 16 cities and 1 municipality. It contributes to over a third of the Philippines' national GDP (Lambino, 2010.; Porio et al., 2019). As the most densely populated region in the country and the largest urban agglomeration, it plays a central role in shaping national development patterns (Diokno-Sicat, 2019). However, the coexistence of well-developed areas and extensive informal settlements in Metro Manila highlights significant socio-economic inequalities. These sharp contrasts between thriving urban centers and underdeveloped peripheral zones make it an ideal case for analyzing urban agglomeration and economic development. A map of Metro Manila is shown in Figure 1.

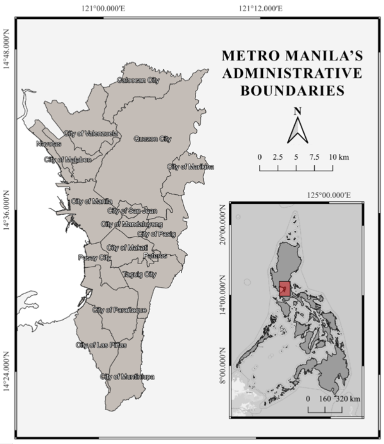

Figure 1. Map of Metro Manila.

2.2 Data Sets and Pre-processing

This study uses multiple datasets to model the strength of intercity economic connections of cities in Metro Manila for the years 2015, 2018, and 2020. These datasets include economic development indicators and transportation accessibility data, all processed using Google Earth Engine, QGIS, and Python to generate city-level metrics for use in a gravity model.

To evaluate the economic development, the study draws from the Cities and Municipalities Competitiveness Index (CMCI) compiled annually by the Department of Trade and Industry (2015-2020). While GDP is a standard measure of economic output, it often fails to capture local capacities, governance quality, and infrastructure readiness that influence a city's actual development potential. This is addressed by the index which includes a wide range of indicators reflecting economic dynamism, infrastructure capacity, and government efficiency. Complementing these are GHSL rasters for population (GHSL-POP) and built-up surfaces (GHSL-SMOD) as sourced from European Copernicus Commission (ECC), which were used to represent urban density and spatial development. Since GHSL data were only available for 2015 and 2020, 2018 values were interpolated. These indicators were entropy-weighted to reflect their relative importance and aggregated at the city level to serve as a proxy for development potential. A summary of these data, with their sources and use, is presented in Table 1.

Data	Source	Purpose
Local Economy Size	DTI	for economic vitality & scale
Local Economy Growth	DTI	for economic expansion
Productivity	DTI	for competitiveness
Employment Generation	DTI	for labor market vitality
Financial Deepening	DTI	for financial inclusivity
LGU Investment	DTI	for local development
Financial Technology Capacity	DTI	for financial modernization
Presence of Investment Promotion Unit	DTI	for ease of doing business and investor-friendliness
Information Technology Capacity	DTI	for technological growth and innovation
Capacity to Generate Local Resources	DTI	for measure of good fiscal management & independence
Education	DTI	for educational infrastructure
Health	DTI	for public health infrastructure
GHS-POP Data	ECC	for demographic size
GHS BUILT-S		for urban infrastructure

Table 1. Economic Development Quality Indicators

Meanwhile, transportation accessibility was modeled by estimating intercity transportation distance as the product of travel time and cost. Road and rail network data were obtained from OpenStreetMap and government agencies, covering major road classifications and the LRT-1, LRT-2, and MRT-3 lines. Jeepney and bus route data from OSM were used to restrict the network to public vehicle paths, while jeepney, bus, and taxi fare data from the LTFRB, along with train fare matrices from DOTr, LRMC, and LRTA, provided the basis for computing transportation costs between points. Travel time estimation incorporated maximum speed limits per road classification under Republic Act No. 4136 and DOTr guidelines, as well as train operational speeds. Field observations were also conducted to account for transfer waiting times, penalizing mode shifts in the network. Routing algorithms then integrated public and private transportation networks to compute the minimum travel time between cities. Multiplying the travel time by the corresponding fare estimates yielded the transportation distance, which served as the spatial impedance component in the gravity model.

3. Methodology

Figure 2 illustrates the research framework followed by the study which will be further discussed in the succeeding sections. It begins with the computation of economic development scores and transportation distances using CMCI, GHSL, and transportation datasets. These inputs inform a gravity model to estimate intercity economic connection strengths. The resulting matrix is filtered using the disparity method to retain significant ties. Finally, Social Network Analysis is applied to assess network structure, centrality, and regional clusters.

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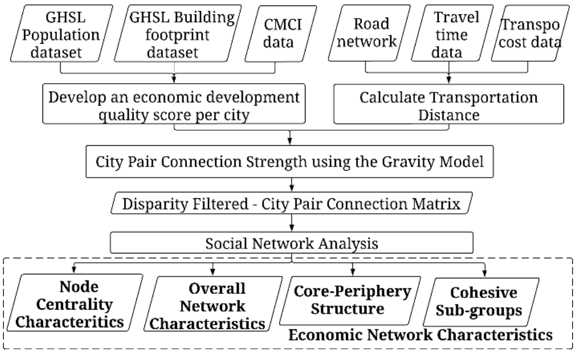

Figure 2. Research Framework.

3.1 Computation of Inputs for Gravity Model

The gravity model in this study uses two primary variables which are the economic development score and the transportation distance between cities. Economic Development Indicators include population values from GHSL-POP and built-up surface data from GHSL-SMOD. Since these were only available for 2015 and 2020, values for 2018 were estimated using interpolation. A logistic growth model was used for population, while linear interpolation was applied for built-up surfaces. The choice of the logistic model was informed by its strong fit to historical population trends observed across Southeast Asian countries, including the Philippines, where urban growth often follows nonlinear patterns due to saturation factors. After interpolation, zonal statistics were used to extract city-level totals from the GHSL rasters. These were then combined with CMCI data and were subjected to entropy weighting to determine their relative contribution based on dispersion of values rather than subjective assessment, limiting bias. The final entropy-weighted score represents each city's overall development score.

Transportation distance was computed as the product of estimated travel time and travel cost between city pairs. Travel time was based on the road and rail network using data from OpenStreetMap and government sources. This included road classifications, train routes, maximum speed limits, operational speeds, and waiting times. Travel costs were estimated using fare matrices from the LTFRB and railway agencies. The combination of these variables provided a realistic measure of the spatial accessibility of each city in the agglomeration.

3.2 Economic Connection Strength Using Gravity Model

A gravity model is used to estimate the economic connection strength between each pair of cities in Metro Manila. The model is widely used in spatial economic analysis to reflect how the interaction between two locations is influenced by their economic weight and spatial separation (Zipf, 1946; Jin et al., 2018). The gravity model used in this study incorporates both the economic development scores of the cities and the transportation distance between them, allowing the analysis to capture both development capacity and intercity accessibility. The economic connection strength between cities (C_{ij}) is calculated using the following gravity model equation:

$$C_{ij} = k \, \frac{E_i \times E_j}{{TD_{ij}}^{n}}, \quad (1)$$

where Ei and Ej = econ development scores of cities i and j
TD_{ij} = transportation distance between the two cities
n = distance decay parameter, set to 2
k = modified gravitational coefficient

The transportation distance TD_{ij} is computed as the geometric mean of travel time and travel cost:

$$TD_{ij} = \sqrt{TT_{ij} \cdot TC_{ij}} \quad (2)$$

where TT_{ij} = estimated travel time between cities
TC_{ij} = estimated travel cost between cities

The coefficient k_{ij} is derived to account for the asymmetry in intercity influence:

$$k_{ij} = \frac{E_i}{E_i + E_j} \quad (3)$$

This means that a city with a higher development score exerts greater influence in the directional economic connection, which supports the assumption of a directed network structure. A complete matrix of economic connection strengths was generated for all city pairs, resulting in an asymmetric matrix where the strength from city i to city j may differ from the reverse.

After calculating the connection strengths, the study applied a thresholding method to remove statistically insignificant ties from the matrix. This step is essential because using all weighted connections in the network would result in a fully dense matrix, which may obscure the actual structure and lead to misleading Social Network Analysis (SNA) outcomes. To identify significant connections, the disparity filter method was used. This method evaluates the significance of each edge weight based on a null hypothesis that assumes uniform distribution of weights across the edges of each node (Serrano et al., 2009; Truică et al., 2018). It also ensures that the analysis retains a core subset of significant edges, while maintaining the overall network structure, and allows for the identification of key connections without excluding smaller nodes that contribute to the complexity of the urban network. The disparity filter uses the following equation for each edge:

$$\alpha_{ij} = 1 - k_i - 1 \int_0^{p_{ij}} (1-x)^{k_i - 2} dx \quad (4)$$

where k_i = degree of node i,
p_{ij} = normalized weight of edge between nodes i and j,
α_{ij} = statistical significance of edge's weight (p-value)

Edges with $\alpha_{ij} < \alpha$ (where α is the significance threshold) are considered statistically significant and are preserved in the network. This study adopts a significance threshold of $\alpha = 0.20$, consistent with recommendations by Serrano et al. (2009) and Fang et al. (2022), who found that thresholds in the range of 0.05 to 0.20 effective in preserving important multiscale connections while filtering out noise. The resulting filtered network preserves the essential economic structure of Metro Manila and serves as the foundation for the subsequent analysis.

3.3 Social Network Analysis

This study applied Social Network Analysis (SNA) to examine the economic network structure of Metro Manila. Using economic connection strength derived from the gravity model, the analysis was implemented in UCINET to explore the structure, centrality, and cohesiveness of intercity economic ties. Cities were treated as nodes and their economic connections as weighted, directed edges. The goal of SNA was to identify economic drivers, peripheral cities, key intermediaries, and cohesive city clusters to better understand the spatial organization and economic interdependencies in the region.

3.3.1 Overall Network Characteristics: To analyze Metro Manila's overall network structure, this study calculated the overall network metrics. These metrics include network's density, correlation degree, level, and efficiency which was adopted from Wang et al. (2021) to assess the network's robustness and connectivity.

Metric	Description	Effect on Variable
Network Density	Ratio of existing to possible ties	Higher values suggest an integrated economy
Correlation Degree	Availability of alternative paths	Higher values indicate network stability
Network Level	Extent of network hierarchy	Higher values imply few central cities
Network Efficiency	Redundancy of economic exchanges	Higher values indicate optimized interactions

Table 2. Overall Network Characteristics

Network Density measures the overall connectivity between cities in the network. Higher values imply a more integrated economy enabling frequent city interactions. Network Correlation Degree measures vulnerability and assesses the alternative routes that facilitate exchange between city A and B. Network level reflects the hierarchy of cities in the region. A high level indicates dominance by central cities, while a lower level suggests balanced development. Lastly, Network Efficiency measures the redundancy of connections. An efficient network suggests that exchanges are facilitated through fewer paths.

3.3.2 Core-periphery Structure Analysis: The core-periphery structure analysis was conducted to understand the hierarchical organization of Metro Manila's economic network. The study used UCINET's categorical core-periphery function to identify core and peripheral cities based on their positions and connectivity within the network. The algorithm fits the network to an ideal model where core cities are densely interconnected, while peripheral cities have fewer or weaker ties. The results reveal which cities act as central economic drivers, facilitating flows of people, information, and resources, and which remain more isolated. This analysis allows the study to assess Metro Manila's internal economic hierarchy, identify growth centers, and recognize areas needing stronger integration.

3.3.3 Nodal Centrality Characteristics: To understand the roles of cities (nodes) in the network, the nodal centrality characteristics, as adopted from Wang et al. (2021) and Jin et al. (2018) was analyzed.

Metric	Description	Effect on Variable
Degree Centrality	Measures direct connections	Higher values imply greater network influence
Betweenness Centrality	Assesses bridges or connectors	Higher values indicate importance for stability
Closeness Centrality	Evaluates accessibility	Higher values suggest strategic positioning

Table 3. Node Centrality Characteristics

Degree centrality measures the magnitude of a city's direct connections with others. A higher degree suggests a more central role. This can be divided into in-degree, which captures incoming connections, reflecting a city's capacity to attract economic interactions, and out-degree, which reflects outgoing links and shows a city's ability to initiate exchanges. Betweenness centrality reflects a city's role as an intermediary in the network. It is based on how frequently a city lies on the shortest paths between others. Cities with high betweenness serve as vital bridges, and their disruption can lead to network disruption. Lastly, closeness centrality measures how close a city is to others based on the shortest paths. It indicates how easily a city can access others and how well-positioned it is within the network.

3.3.4 Cohesive Subgroup Analysis: This analysis identifies clusters of cities in Metro Manila's economic network that interact frequently and strongly. This reveals patterns of cooperation or competition among cities with relationships ranging from strong to weak or positive to negative (Jin et al., 2018). Using UCINET's CONCOR (CONvergence of iterated CORrelations) developed by Breiger et al. (1975), the network is partitioned into cohesive subgroups. This operation iteratively calculates the correlations of the matrix row and columns to determine the cohesive subgroup or the cities which share similar patterns with their intercity economic ties. This reveals the relative strength and relationship type between and within subgroups which can be used to determine each city cluster's economic role in the network.

4. Results and Discussion

4.1 Economic Development Scores

To assess intercity economic connectivity within Metro Manila, the study computed entropy-weighted economic development scores for each city using CMCI indicators, population data, and built-up surface data. Table 4 presents the computed scores from 2015 to 2020, while Figure 3 provides a corresponding map to visualize changes in a city's economic development over time.

City	2015	2018	2020
Caloocan	34.8605*	18.4682	18.3353
Las Pinas	14.7653	12.8453	17.9546
Makati	54.8907*	30.1183*	35.7191*
Malabon	10.6458	13.1027	11.0695
Mandaluyong	30.1331*	20.7961	16.4364
Manila	53.6753*	34.7126*	43.0677*
Marikina	19.6243	13.2204	5.4646
Muntinlupa	27.8253	16.4507	21.2535
Navotas	9.8089	20.4853	9.6747
Paranaque	39.6256*	21.5970	24.1684
Pasay	26.3050	45.6479*	59.1544*
Pasig	31.7030*	25.4203*	25.4301*
Pateros	13.1615	3.94334	10.0321
Quezon City	56.0498*	43.0698*	84.8441*
San Juan	14.4484	12.9179	8.7925
Taguig	19.6721	27.5167*	9.8941
Valenzuela	30.1824*	18.3077	17.2595
Average	28.6692	22.2718	24.6206

**Above Average scores per year*

Table 4. Economic Development Scores

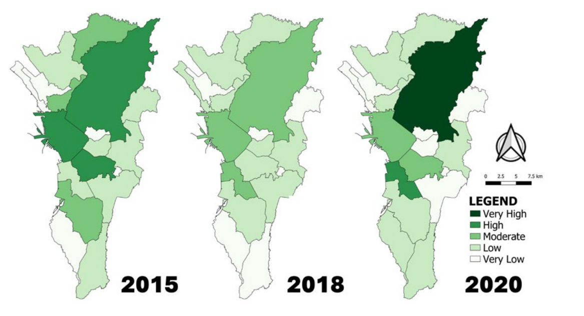

Figure 3. Economic Development Scores

From 2015 to 2020, Metro Manila's economic development scores revealed growing disparities among cities. In 2015, 8 out of 17 cities scored above the regional average, led by Quezon City, Makati, and Manila. By 2018, the average score dropped significantly, with only 6 cities performing above average. The downward trend continued into 2020, where only 5 cities, Makati, Manila, Pasay, Pasig, and Quezon City, remained above the average, despite a slight regional recovery. Using these scores, the gravity model calculated the economic connection strength between cities. The resulting directed and weighted matrix was filtered using the disparity filter method, preserving statistically significant ties, which retained meaningful intercity links while removing noise and redundancy.

4.2 Social Network Analysis

An important aspect of the analysis is the production of an effective visualization to examine intercity economic ties. UCINET was used to highlight relational similarities, where edge thickness indicates the strength of economic relationships. Green lines represent reciprocated ties, whereas black lines denote one-sided connections. This was then mapped spatially in Figure 4 to show the geographic proximity of the cities to one another within the economic network.

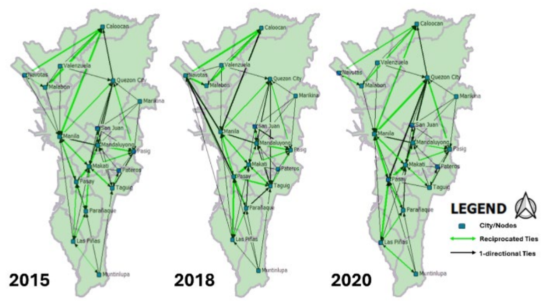

Figure 4. Map of Intercity Pair Connections

It can be observed that across all years, Makati, Manila, and Pasay consistently emerged as central hubs with strong mutual ties, underscoring their critical role in the regional economy. Quezon City, despite having numerous links, exhibited weaker inbound ties. In 2018, the network flattened as high-performing cities weakened, narrowing the gap in connection strengths. By 2020, some cities recovered, most notably Quezon City. However, peripheral areas such as Marikina, Pateros, San Juan, and Navotas remained weakly connected or isolated. Overall, the network map confirms that stronger ties clustered among neighboring and centrally located cities, while peripheral ones either maintained thin connections or exhibited one-way relationships. This reveals structural disparities and a centralized economic pattern.

4.2.1 Overall Network Characteristics: Metro Manila's economic network from 2015 to 2020 was analyzed using the metrics in Table 5 to collectively assess the system's connectivity, stability, optimization, and hierarchical structure.

Overall Network Characteristics	2015	2018	2020
Network Density	0.25	0.257	0.243
Network Correlation Degree	0.882	0.654	0.882
Network Efficiency	0.504	0.428	0.493
Network Level	0.588	0.514	0.576

Table 5. Overall Network Characteristics

From 2015 to 2020, Metro Manila's economic network exhibited low but stable density, where only a quarter of potential inter-city ties were active, reflecting limited network integration. The network correlation degree dropped sharply in 2018 compared to 2015 and 2020, suggesting that while more links were present in 2018, the network was functionally weaker and more vulnerable. This is likely due to weakened tie intensity and reduced coherence in economic interactions. The network efficiency also showed similar patterns. The decline, despite an increase in tie quantity, reinforces the idea that structural redundancy did not translate into functional strength because connections existed but lacked coordination and is not optimized. Lastly, network level values hovered between 0.514 and 0.588, showing central dominance of core cities but not extremely monopolizing the network. Overall, the network was moderately centralized and resilient but vulnerable to disruptions when economic ties weaken, Therefore, it's the quality, not quantity, of connections that drives the robustness and stability of a network.

4.2.2 Core-Periphery: The core-periphery analysis revealed shifting roles among Metro Manila cities between 2015 and 2020 as shown in Figure 5. Core cities act as economic hubs, while peripheral ones rely more on these cores for interaction.

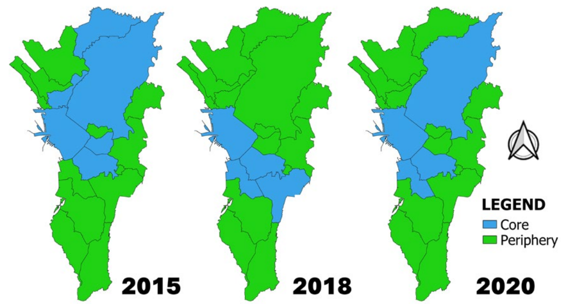

Figure 5. Core-Periphery Maps of Cities in Metro Manila

In 2015, the core group included Caloocan, Makati, Mandaluyong, Manila, and Quezon City. By 2018, the core group shifted to Makati, Manila, Pasay, and Taguig, with Quezon City, Caloocan, and Mandaluyong losing their dominant status. Quezon City had a high economic score but with weaker structural integration. It had stronger outbound ties than inbound ones, indicating economic activity that was outwardly directed but less reinforced by surrounding cities. This shift suggests a semi-peripheral role, where it was still influential but less embedded in reciprocal economic flows.

In 2020, core cities are Makati, Manila, Pasay and Quezon City with Taguig losing core status. Caloocan and Mandaluyong also remained peripheral, likely due to Caloocan's fragmented northern location and Mandaluyong's limited space for expansion, coupled with competition from dominant neighboring cities. Overall, the pattern shows that proximity to existing cores helps cities rise in influence. However, this proximity alone is not enough to maintain core status without ongoing integration and support. While Makati and Manila remained stable cores, the shifting roles of cities like Taguig and Quezon City reflect the fluid nature of urban economic influence in the agglomeration.

4.2.3 Nodal Centrality Characteristics: Centrality measures reflect how cities initiate, receive, or mediate economic flows, offering a multi-dimensional view of their accessibility, influence, and integration in the region. These values are meaningful only in comparison with other cities within the same network. To ensure consistency across years, this study classified cities as having high or low centrality considering the average scores across all periods.

4.2.3.1 Degree Centrality: Out-degree (out-going ties) reflects a city's role in initiating economic exchanges, while in-degree (in-going ties) captures its capacity to attract inflows.

Cities can be broadly grouped into four categories based on whether they score high or low on each measure. These are central hubs (high in both), receivers (high in-degree, low out-degree), disseminators (low in-degree, high out-degree), and peripheral cities (low in both). Figure 6 presents the bivariate map of degree centrality for the years 2015, 2018, and 2020.

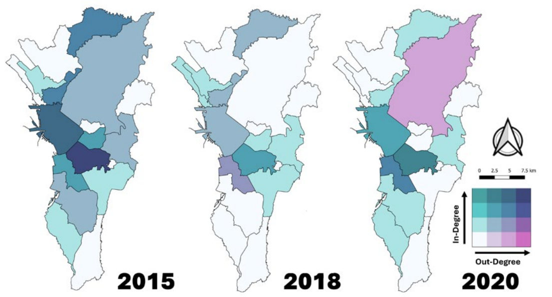

Figure 6. Degree Centrality of Cities in Metro Manila

In 2015, Makati and Manila were the most central cities, both sending and receiving significant economic flows. Caloocan and Pasig also demonstrated balanced roles, though at lower magnitudes. Meanwhile Marikina, Muntinlupa, and Valenzuela showed minimal connectivity. By 2018, the network weakened. Central cities declined in both in-degree and out-degree, and peripheral cities remained isolated. While Pasay is the top sender of flows, overall, the differences between cities became less pronounced, suggesting a less cohesive regional structure that year. In 2020, centrality patterns re-concentrated with Pasay, Makati, and Manila regaining strong in- and out-degree scores and reinforcing their dominance in the network.

Quezon City rose with its out-degree but remained weak in attracting inflows, suggesting it contributed more than it received. This asymmetry may stem from its links to less influential neighbors. Patterns of low out and in-degree values are also observed in cities on the edges of Metro Manila aligning with the concept of peripheral economies supplying core regions without proportional gain. This asymmetry, where stronger cities consolidate influence while fringe areas remain dependent and less integrated shows signs of regional inequality. Overall, the bivariate maps show a stable divide between a few dominant cores and many peripheral cities. Despite some shifts, Metro Manila's network remains spatially and functionally imbalanced.

4.2.3.2 Closeness Centrality: These metric measures how accessible a city is within the economic network, both in terms of how efficiently it can reach others (out-closeness) and how easily it can be reached (in-closeness). Cities that are strong in both tend to be central gateways, while those low in both are typically peripheral and less integrated. Figure 7 visualizes these relationships across Metro Manila through 2015, 2018, and 2020.

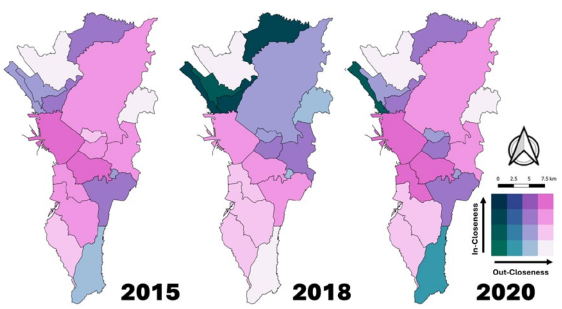

Figure 7. Closeness Centrality of Cities in Metro Manila

The network reveals a stable spatial structure from 2015 to 2020 with core cities like Makati and Manila consistently exhibit high values in both in-closeness and out-closeness. This shows their role as central hubs with strong reciprocal connectivity due to their strategic position. Meanwhile, peripheral cities such as Valenzuela, Muntinlupa, and Marikina consistently had low in-closeness scores, meaning they were harder to access but their moderate out-closeness values suggest they could still reach other cities efficiently. This indicates a one-way interaction where they act more as contributors than recipients in the network.

Quezon City recorded strong closeness scores by 2020, supported by its large size and central location surrounded by a lot of cities. However, while its in-closeness was high, its in-degree was low. This contrast highlights that closeness measures the ease of access through the entire network, not just direct inflows since its incoming ties are from economically weaker cities, which lowers its degree score despite its strong positional advantage. San Juan and Pateros also recorded moderate to high out-closeness values but remained low in in-closeness. Their adjacency to multiple cities allows them to reach others efficiently, yet their limited economic scale may hinder their accessibility.

Cities near Metro Manila's geographic center consistently scored higher in both closeness measures supporting how physical proximity to major hubs improves network accessibility. In contrast, peripheral cities remained less connected due to distance and infrastructure gaps. This reflects how development tends to correlate negatively with distance from core areas. Although some fringe areas showed improvements in out-closeness, the lack of mutual accessibility prevents full integration. These spatial inequalities remained consistent over time, with darker clusters in the bivariate maps reinforcing the concentration of access in the center of Metro Manila.

4.2.3.3 Betweenness Centrality: Betweenness centrality captures the intermediary role of cities in facilitating economic flows between other cities. Cities with high betweenness do not need to be the most connected but serve as key bridges in the network. Figure 8 maps the betweenness values of Metro Manila's cities for 2015, 2018, and 2020.

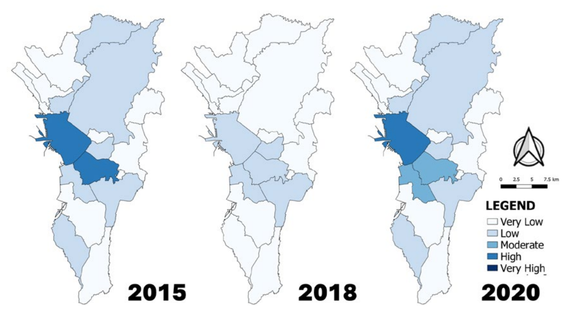

Figure 8. Betweenness Centrality of Cities in Metro Manila

In 2015, Manila and Makati held the highest betweenness, serving as key intermediaries. Cities like Pasay, Mandaluyong, Quezon City, Taguig, Las Piñas, and Caloocan played moderate roles, while Marikina, Muntinlupa, Valenzuela, and Navotas had very low scores, reflecting peripheral positions. By 2018, betweenness dropped sharply across all cities. Manila and Makati lost dominance, suggesting a shift to a more decentralized network with alternative paths. Most cities had very low values, with only Pasay and Taguig maintaining moderate roles. This indicates a flatter, less centralized structure.

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In 2020, Manila and Makati regained their intermediary importance, with Pasay also rising to a more central role. These cities, located near major corridors and transport links, re-established themselves as critical access points. Quezon City, despite its high degree and closeness centralities, consistently recorded low betweenness. This suggests that while it's well-connected and accessible, it's not typically on the shortest routes between other city pairs. Overall, Metro Manila's network reveals moderate centralization. While Manila, Makati, and Pasay act as key bridges, no city monopolizes intermediary control. These highlight potential for further decentralization by enhancing the connectivity roles of peripheral cities.

4.2.4 Network Stability: In 2018, a disruption to Manila's stable economic trajectory was observed. During this time, a decline in the overall economic development scores among consistent economic hubs like Makati, Mandaluyong, Manila, and Caloocan was observed, recording weaker centrality scores. The 2018 drop in the correlation degree and network efficiency supports the disruption in the network structure.

This coincides with the decline in the gross domestic product's (GDP) growth to 6.2%, lower than the 6.7% growth in 2017. Foreign direct investments (FDI), a vital driver of economic growth and intercity economic flows, dropped by nearly 4.5% to $9.8 billion in 2018, resulting in a limited and less robust economic network, as demonstrated by reduced centrality scores (Valencia, 2019). Although cities like Pasay, Taguig, and Navotas exhibited a modest increase in their scores, their growth failed to compensate for the weakening ties in the core, reflecting a shifting economic network. The results indicate 2018 was not only a period of economic decline, but rather a period of economic reconfiguration.

4.2.5 Cohesive Subgroup Analysis: Cohesive subgroups identified using the CONCOR method reveal clusters of cities with similar economic ties in Metro Manila's economic network. The subgroup labels (e.g., I, II, III) are arbitrary and do not imply any order, ranking, or level of importance. Figure 9 presents the groupings, highlighting stronger internal subgroup ties, as compared to external ties among subgroups.

Some city groupings remained consistent across 2015, 2018, and 2020. Quezon City, Pasig, and Mandaluyong often clustered together, reflecting their strong economic ties, central location, and similar mixed-use functions. Their high internal densities support this stable relationship. Caloocan, Malabon, and Navotas also repeatedly clustered together. Their consistently high internal density values suggest strong localized interactions, even with weak ties to core cities. Meanwhile, Manila, Las Piñas, and Parañaque often grouped as another stable cluster, though density dropped in 2018 when some cities shifted out, possibly due to limited direct access routes.

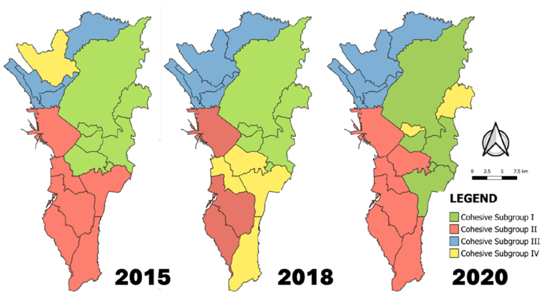

Figure 9. Cohesive Subgroups of Cities in Metro Manila

Key core cities like Manila, Pasay, and Makati shifted subgroup memberships over time. This reflects evolving economic roles rather than fragmentation. For instance, Manila's governance and education focus, Pasay's growth in logistics and tourism, and Makati's business dominance suggest functional diversification. Across all years, strong internal ties within subgroups were more common than links between subgroups. This pattern reflects fragmentation and supports the core-periphery structure seen in earlier results. Lastly, subgroup formation largely aligns with geographic proximity. Neighboring cities frequently grouped together, likely due to shared infrastructure and urban functions. Even when clusters changed, cities often shifted into groups containing nearby counterparts, highlighting the influence of spatial adjacency in economic interactions in the network.

5. Conclusion and Recommendations

Metro Manila's economic growth has long been marked by spatial disparities, with central cities accumulating more opportunities while peripheral areas lag behind. Understanding the structure and evolution of these intercity connections is crucial for addressing persistent inequality and uneven development across the region. To address this, the study used a network-based approach, combining entropy-weighted economic indicators and a gravity model, to analyze how cities in Metro Manila are economically connected from 2015 to 2020. Social Network Analysis (SNA) revealed a persistent core-periphery pattern, where economic influence remained concentrated in cities like Makati, Manila, Pasay, and Quezon City. Peripheral cities showed weaker integration, partly due to geographic distance and lower accessibility to core hubs.

From 2015 to 2018, network efficiency declined despite more connections, indicating that proximity alone was not enough without strong coordination. The rise of cities like Pasay and Taguig (with closer ties to growing business districts) and the demotion of Quezon City and Caloocan reflect a reconfiguration of roles influenced by shifting locational advantages. 2020, the network showed signs of recovery; however, peripheral cities such as Marikina, Valenzuela, and Muntinlupa remained weakly integrated, highlighting how geographic distance and limited connectivity continue to hinder their influence within the region. Centrality analysis showed that Makati and Manila remained highly connected and well-positioned as bridges due to their central location. Some despite being geographically near core areas, lacked connectivity, reinforcing how spatial proximity must be matched by strategic planning and infrastructure. Lastly, the cohesive subgroup analysis highlighted how nearby cities maintained stable internal ties, while core cities diversified and fragmented. Overall, the network remained moderately dense, with fragmentation and weak interconnectivity, particularly across long distances. Still, the moderate level of hierarchy suggests that improvements in peripheral cities' connectivity and infrastructure can meaningfully reduce disparities and promote a more balanced regional growth.

To address the persistent core-periphery divide, this study recommends several interventions. First, improving connectivity between core and fringe cities is essential. This can be achieved through expanding rail networks, implementing Bus Rapid Transit (BRT) systems, and reducing travel times along short but underserved routes. Second, a dedicated regional coordination platform should be established. A Metro Manila council focused on regional economic planning can help manage intercity disparities and align development based on each city's location and functional role. Third, bridge cities that serve as intermediaries between the core and peripheries must be strategically located. These are peripheries nearby core cities that are either receivers or disseminators and are accessible or can access other cities easily, such as Pasig, Parañaque, and Caloocan. These cities should be supported through targeted infrastructure projects and inter-LGU partnerships to enable more effective economic interactions between more isolated peripheries and cores to facilitate balanced regional growth.

Fourth, marginalized but geographically close cities like Navotas, Marikina, and Pateros require tailored support. Investments in climate-resilient infrastructure, small business development, and workforce training can help these cities convert proximity into meaningful participation in the regional economy. Finally, aligning transit-oriented development (TOD) and corridor projects with spatial patterns will help bridge physical and economic gaps. Prioritizing developments near major transport lines or between economic clusters ensures that proximity is matched with accessibility and opportunity.

It is recommended for future studies to adopt improvements in data quality and availability particularly consistent, long-term, and disaggregated datasets that allow for annual and subregional analysis. While this study used optimal travel times based on routing algorithms, actual intercity travel times would better reflect accessibility and should be incorporated once available. Similarly, integrating trip generation and attraction data could provide a more accurate measure of functional economic ties beyond structural proximity.

The use of the CMCI and population satellite data was practical for measuring development, but future work could benefit from incorporating direct financial indicators like subnational GDP and population data. Moreover, employing weighting methods that require expert opinions from LGUs and urban planners can improve the selection of relevant factors. To validate and contextualize the results, it would also be beneficial to facilitate focused group discussions or LGU consultations discussing the implications and accuracy of the obtained results. Extending the study period and spatial coverage to include neighbouring provinces such as Bulacan, Cavite, Laguna, and Rizal, or even comparing patterns with other urban regions like Metro Cebu and Metro Davao, could also contextualize Metro Manila's development within broader national trends. Lastly, district-level analysis within NCR, especially in spatially diverse cities like Quezon City, could help uncover intra-city disparities and reveal more nuanced patterns of agglomeration and spatial inequality.

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