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All Roads Lead to Cubao: A Geospatial Centrality Analysis of Cubao as Metro Manila's Public Transportation Core

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Abstract

Metro Manila, one of Southeast Asia's most densely populated regions, faces persistent public transportation challenges. Transport hubs like Cubao, One Ayala Terminal, and the Parañaque Integrated Terminal Exchange (PITX) are vital in managing commuter flows across the metropolitan area and surrounding regions. However, there is limited spatial and network-based evidence on which among these hubs serves as the most central and accessible point in the broader transport network, creating a gap in transport planning. This study examines Cubao's role as a central transportation hub using network centrality analysis, focusing on betweenness and closeness, and compares it with the other hubs. Results reveal that Cubao exhibits the highest betweenness (0.475) and closeness centrality scores (1.018), indicating its position as the central and accessible node in the network. Hot spot analysis confirms that Quezon City, where Cubao is situated, is a highly dense residential area. Geographic distribution of urban facilities also shows that the chosen amenities cluster near Cubao and is located within the directional distribution ellipse. This proximity to key urban facilities, including its location as a high residential area, supports its function as a major attractor for commuters. Furthermore, the predicted trip volume highlights Cubao's high commuter flow compared to other hubs. The findings affirm Cubao's dominant role in Metro Manila's transport network and demonstrate the potential of centrality-based network analysis as a tool for urban transport planning. The methods can also be replicated to assess transportation hubs, guiding evidence-based accessibility, infrastructure, and transportation development across the area.

1. Introduction

Metro Manila, one of Southeast Asia's most densely populated regions, continues to face deep-rooted problems in public transportation. Known as one of the most congested places in the world, it ranked as the fifth-highest congestion level in 2024 (Lennefalk, J, n.d.). The lack of a reliable road network, as well as the increase in vehicle consumption adds to the already growing problem (Barry and Kaenzig, 2019). These transportation inefficiencies also take a toll on the economy. According to the Socioeconomic Planning Secretary Balisacan, citing JICA, traffic congestion results in losses of up to ₱2.4 billion per day, directly affecting labor productivity and income (Remo, 2013).

Amid these challenges, certain locations have emerged as pivotal points of convergence. One such area is Cubao in Quezon City, often humorously referred to as "the center of the universe", due to the high number of public trips bound for it, from both Metro Manila and rural provinces. Cubao's importance grew during Quezon City's tenure as the capital of the Philippines (1949-1976), developing into a commercial and transportation hub. Strategically located at the intersection of EDSA and Aurora Boulevard, it became a central stop in the transport network, hosting key city and provincial bus terminals.

Today, Cubao's high accessibility continues to attract varied economic activity, making it a key node in the transport network across Metro Manila and neighboring regions, such as Region III and IV-A. While several local studies have discussed Cubao's accessibility and functional importance (Orbon, 2014; Sy and Regidor, 2024), most have done so descriptively. In contrast, international research often employs network centrality analysis to validate transportation cores in urban areas, yet a similar analytical approach has not been applied to Cubao or any of the main transport hubs in the Metropolitan areas in the Philippines. There remains a gap in spatial and network-based research that quantitatively evaluates Cubao's centrality and the socioeconomic factors contributing to its prominence.

This study addresses that gap by examining Cubao's role as a central transport node using Network Centrality analysis, specifically through betweenness and closeness centrality. To provide comparative insights, emerging hubs such as PITX and One Ayala are also included in the analysis. Through GIS-based centrality analysis, this study explores Cubao's role in the transport network across Metro Manila, Region III, and IV-A. It tests the centrality of the hub and compares it with PITX and One Ayala to assess what factors make Cubao a transportation center. By combining insights from network connectivity, spatial relationships, urban facility distribution, and predicted trip volumes, this study also offers an established approach for assessing transport hubs beyond common perceptions. It enhances the understanding of how centrality interacts with key socioeconomic factors across space. It can guide planning decisions, promote more inclusive transport policies, and serve as a reference for identifying and evaluating other emerging transport centers in the Philippines.

Degree centrality, which was excluded in this study, measures a node's importance based on the number of its direct connections to other nodes. The Origin-Destination (OD) cost matrix analysis in this study assumed that all lines represented direct connections without accounting for the actual service route. All spatial data were also sourced from the QuickMapOSM plugin in QGIS, and actual trip volume data for public utility vehicles were not obtained. These limitations informed the scope of the study.

The paper is structured as follows. The second section discusses existing studies related to transportation centrality analysis. The next section discusses the methodology, followed by the final

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section for the findings of this paper and recommendations for future work.

2. Related Work

Network science focuses on understanding systems of connectivity across domains, involving two primary components: nodes (or vertices) and links (or edges), which represent agents and their interactions. These connections are not limited to physical links and can model a wide range of relationships, including social interactions and transportation routes (Marathe et al., 2013; Guo et al., 2019). In the context of spatial networks, Piovesana (2021) explains that establishing connections between distant nodes often incurs higher "wiring costs", making links between geographically closer nodes more likely. This spatial consideration makes such models effective for representing real-world systems, where geographic proximity significantly influences network structure.

The significance of the study is substantiated through multiple studies. A study done by Li et al. (2017) entitled "A Novel Analysis Method of Geographical Centrality Based on Space of Flows" claimed that geographic centrality can be analyzed and compared using spatial interaction data for regions with different conditions or stages. The study mentioned that a spatial unit's centrality may be determined by its own attributes and how far it is from other spatial units, which is referred to as the centrality derived from geographical proximity and attributes. Both short- and long-distance interactions were used in the paper. However, this study aims to use the shortest path distances to all nodes instead through Origin-Destination (OD) cost matrix.

Network Centrality is one of the most widely used metrics in social network analysis, measuring the importance of a node in terms of connectivity or the flow of information within a network. Closeness centrality reflects how efficiently a node can interact with all other nodes in the network, and can be measured by taking the inverse of the average distance or the set impedance between nodes (Scheurer, 2006). In contrast, betweenness centrality measures how often a node lies on the shortest path between pairs of nodes. A high betweenness score indicates a node's potential to control or influence the flow within the network (EMBL-EBI, n.d.). This study evaluates whether Cubao is both central to and between other terminals—indicating its influence over the overall movement of actors within the road network.

A study by Haznagy et al. (2015) named "Complex network analysis of public transportation networks: A comprehensive study" also discussed the use of network analysis and two important parameters that were chosen to be included in the study: closeness and betweenness. The paper used both unweighted and weighted networks in order to determine which nodes sought out to be of highest importance by being a central node, while this study achieves to display the importance of the three different nodes by their connection with all other nodes instead of assigning weights and comparing each of them.

Another notable study that mirrors the project was done by Wang et al. (2020) entitled "Analysing the spatial configuration of urban bus networks based on the geospatial network analysis method". This also utilized the nodes involved in the study done through network analysis and they determined that accurate spatial configuration analysis is important to improve the attractiveness of transportation networks for current and future users. The findings mentioned that human bus travel demands may also be predicted through this. Predicted trip volume for people going in and out of Cubao will be analyzed to determine the demands of the transportation network in the city, solidifying the claims of the study. This serves as a valuable indicator to identify which hubs are likely to experience the highest traffic.

The growth of population may entail more problems within the transportation industry of a country, and this may be observed in the Philippines. Increased fuel consumption, as well as a surge in traffic density are some of the problems brought upon by this phenomenon (Perez et al., 2021). Understanding the relationship between population and transportation is crucial in creating decisions and strategies to improve transit hubs.

In 2020, Pham et al. published a study that made use of multiple centrality methods in order to outline a proper flow for disaster preparedness in the Philippines. The study incorporated various ways to encapsulate the characteristics of how certain actors relate to each other and their effect in the overall resilience patterns of the country. The paper mainly focused on surveying people from different parts of the country, all with diverse backgrounds. The main objective of the study was to create a well-represented network of people who work together to ensure that the country is well-equipped in case of disasters. One of the key actors types the study included were brokers, and they analyzed their connection with betweenness centrality. Brokers had ties with other actors and classes, such as professional and economic groups, which entails connection with central actors. This led to the decision of using betweenness as a metric to determine how well-linked the brokers were. Similar to the methods done by Pham et al. (2020), this study aims to use centrality methods (specifically, betweenness and closeness) to establish and govern network relationships in Cubao and other terminals – bounding their connections with values that described the actual centrality of Cubao in the transportation landscape.

Metro Manila is known to have the highest urban density in the world, leading to its limitations in handling traffic. One of its greatest contributors is the high number of commercial facilities, such as shopping malls and business areas (Boquet, 2013). Another factor is the amount of bus terminals in Cubao, which provides transportation to different parts of the country, but also adds to its growing traffic volume. The study further noted that finding solutions for the congestion of traffic in Metro Manila would not be an easy process. This study utilizes urban facilities and bus terminals within the area of interest to ascertain whether or not transportation converges in Cubao and if it truly is a focal point in the transportation scene in the Philippines.

Based on prior studies that applied network and spatial analysis in urban contexts, this research seeks to address a critical gap in the formal geospatial assessment of Cubao's transport centrality. Through multiple methods corroborated by various studies about centrality and the transportation networks of the Philippines, this study's primary goal is to establish Cubao's position in the conveyance local of the country.

3. Methodology

Figure 1 illustrates the geospatial framework employed in this study. The framework is divided into two primary phases: data collection and data processing. The data collection phase involves the acquisition of key datasets required for spatial analysis. The data processing phase encompasses the application of various spatial analytical methods such as network centrality analysis, spatial distribution assessment of urban facilities, hot spot analysis, and predicted trip volume calculation using the

gravity model. Each stage in the workflow represents detailed procedures and decisions essential for the analyses in this study.

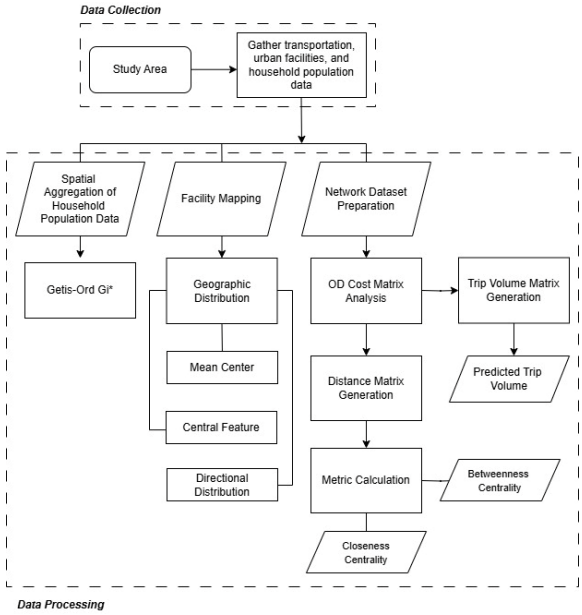


Figure 1. Overall Methodology of the Study.

This study employed a network- and centrality-based approach to analyze the spatial connectivity of key public transport terminals within Metro Manila and adjacent regions. A network dataset was created using bus routes as edges, with geodesic length (in meters) set as the impedance. Transportation nodes were represented by the mean centers of terminals and stations in each municipality or city, which were snapped to the nearest network edge to ensure spatial connectivity. This allowed for accurate modeling of travel paths within the transport network.

An Origin-Destination (O-D) Cost Matrix analysis was then performed to compute the shortest path distances between all node pairs, with particular focus on three key hubs: Cubao, One Ayala, and PITX. The output, which contained pairwise distance values, was used to manually construct a square, symmetric matrix that served as the input for the centrality.

To evaluate the strategic importance of the three hubs, the matrix was filtered to include only connections involving Cubao, One Ayala, or PITX. Paths without direct or indirect links to these terminals were set to zero to ensure that the analysis reflected actual functional connectivity. This refined matrix was used as the input for subsequent centrality measures. Centrality metrics were calculated using UCINET based on the filtered matrix.

Betweenness centrality measured how often each hub appeared on the shortest paths between other nodes (Freeman, 1977), while closeness centrality assessed the average distance from each hub to all others (Freeman, 1979). Cubao's centrality scores were then compared to those of One Ayala and PITX to assess its role as a transportation core within the regional network.

For closeness centrality, a score approaching unity (i.e., a normalized value close to 1) suggests that a node is, on average, near all other nodes in the network. As the average distance from the node to others decreases, the closeness centrality increases, indicating higher accessibility and connectivity (Freeman, 1979). For betweenness, a score near unity implies that a node frequently lies along the shortest paths (geodesics) between other pairs of nodes. This suggests a high probability of that node serving as a critical intermediary in the flow of movement across the network (Freeman, 1977).

To provide a deeper understanding of why key transportation hubs like Cubao obtained their centrality scores, additional spatial analyses were conducted to explore factors influencing movement toward or across these hubs. First, a hot spot analysis (Getis-Ord Gi*) was performed using normalized household population density data per city or municipality. This helped identify statistically significant clusters of high population concentration, giving insights into potential sources of travel demand toward the hub. Data obtained for household populations were also complete for all municipalities involved in the study, hence it was used as the baseline for the analysis. This contrasts with the household population data for barangays which have unavailable statistics for the chosen areas.

In addition, urban facilities—including malls, hotels, and art spaces—were mapped across the study area and analyzed using spatial statistical tools such as central feature, mean center, and directional distribution. These analyses assessed the spatial distribution and clustering of amenities in proximity to the key hubs, which helps explain their attraction as transit destinations.

Lastly, trip volume flows toward Cubao, One Ayala, and PITX were modeled by generating flow lines based on an origin-destination matrix linking municipal nodes to the three hubs. Municipal-level population data were spatially joined to the flow lines and predicted trip volumes were calculated using a gravity model from Equation 1, which considers both the population sizes of origin and destination areas and the inverse square of the distance between them. These flows were then visualized using graduated symbology to highlight the intensity and direction of movement, further illustrating the key hubs' functional importance and connectivity within the regional transportation network. Given that this analysis also used municipal-level population data, it consequently produced inter-municipal trips.

$$p_{ij} = p_i p_j d_{ij}^{-2}, \quad (1)$$

where p_{ij} = Predicted Trip Volume
p_i = Population of Origin
p_j = Population of Destination
d_{ij} = Length of Flow Line

4. Results

After the processing of the datasets, the results were derived from the analyses done such as transportation network centrality analysis, spatial hotspot analysis, geographic distribution, and predicted trip volume. This section summarizes the results found for each analysis.

Transportation Hub	Betweenness Score
Cubao	0.475
One Ayala Terminal	0.063
PITX	0.277

Table 1. Betweenness Centrality Score of the Key Transport Hubs in Metro Manila.

Table 1 presents the normalized betweenness centrality scores derived from the topological network analysis. Among the three major transportation hubs, Cubao recorded the highest betweenness score at 0.475, indicating its position as the most critical node in the system. While One Ayala and PITX also

registered notable betweenness scores, reflecting their tactical locations in Makati and Parañaque, were not as central as Cubao. This suggests that a significant portion of the shortest paths in the network pass through Cubao.

Additionally, Figure 2a illustrates the UCINET-generated network topology, where node sizes are proportional to betweenness centrality values. The figure highlights Cubao as the most prominent node, indicating that it is not only highly connected but also strategically positioned to facilitate transfers between many origin-destination pairs. PITX and One Ayala follow in importance, serving as significant intermediaries within the regional public transport system. In this network, thicker edges represent greater distances between nodes. The radial layout further emphasizes how numerous cities and municipalities across Regions III and IV-A depend on a small number of central terminals to access the broader transport network.

Table 2 presents the results of the normalized closeness centrality analysis, computed via UCINET software. The analysis reveals a clear centrality hierarchy among the transportation hubs: Cubao ranks highest with a score of 1.018, followed by PITX with 0.864 and One Ayala with 0.704. These values indicate that Cubao has the shortest average network distance to all other terminals.

Transportation Hub	Closeness Score
Cubao	1.018
One Ayala Terminal	0.704
PITX	0.864

Table 2. Closeness Centrality Score of the Key Transport Hubs in Metro Manila.

Using the same network, Figure 2b visualizes the closeness centrality scores using an inverse node sizing convention—smaller nodes represent higher closeness values, given that more central nodes have smaller cumulative distances to all others. As such, Cubao appears as the smallest node in the map, reaffirming its central role in terms of proximity and accessibility within the transportation system. Its compact node size indicates that it requires fewer steps to reach any other node, making it the most efficient location for minimizing travel time across the network. PITX and One Ayala, while still important, appear slightly larger, denoting relatively longer travel paths on average.

The clustering of household populations can be visualized through Figure 3. Since only one attribute was analyzed, the sum, average, minimum, and maximum values for the dataset were identical. Consequently, only the maximum density values were visualized on the resulting map.

Observing the result of the analysis, areas in the National Capital Region, as well as neighbouring areas situated in Regions III and IV-A, were shown to be hot spots with 99% confidence. Specifically, the analysis revealed that Quezon City, where Cubao is located, had one of the highest population densities, with a value of 18,163.673. The hot spot map highlighted Quezon City as a statistically significant high-density cluster.

This pattern shows the dense urban concentration surrounding the wider NCR, indicating that population density and residential clustering are predominantly confined within the metropolitan limits. The absence of notable clustering in the adjacent areas likely reflects lower population densities, or distinct urban growth patterns, reinforcing Cubao as a key focal point.

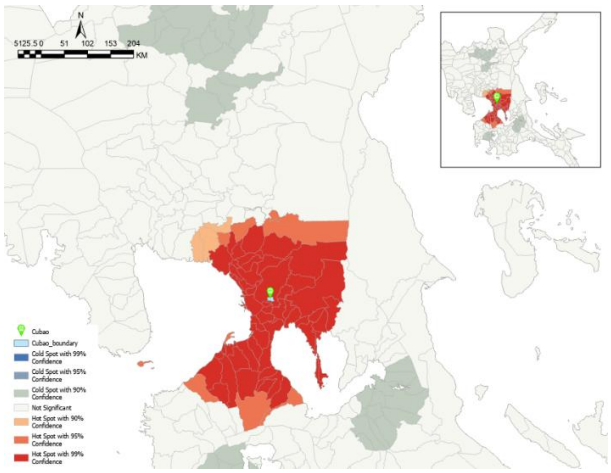
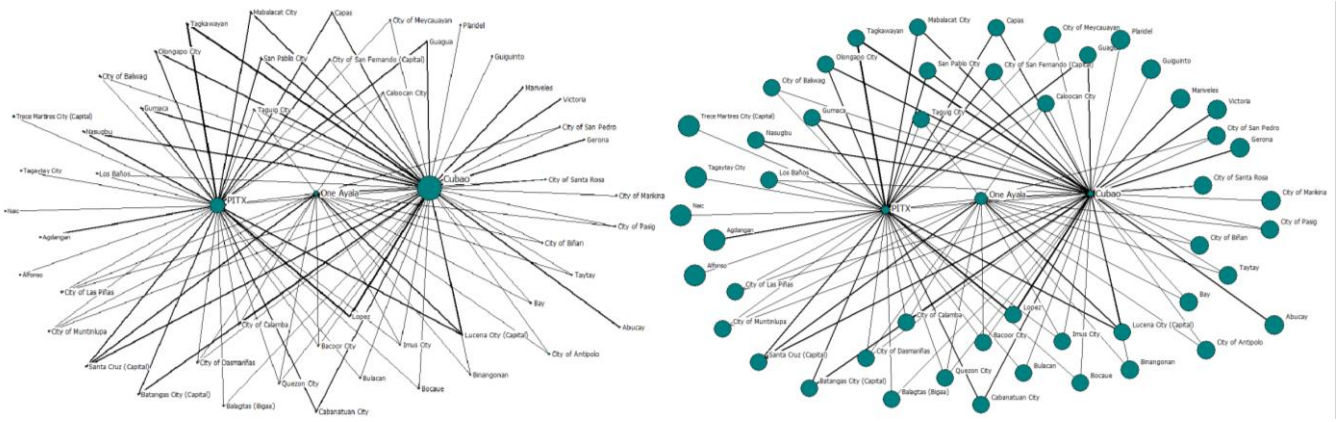


Figure 3. Hot Spot Analysis of Household Population Density Across the Municipalities of Region III, IV-A, and NCR.

Figure 4 displays the central feature, mean center, and directional distribution of each of the urban facilities such as malls, hotels, and art spaces. The analysis revealed that these facilities are not exclusively clustered in Cubao, Quezon City, but are widely distributed across Metro Manila, the National Capital Region.



(a) (b)

Figure 2. Topological Representation of Betweenness Centrality (a) and Closeness Centrality (b) of Key Transport Hubs and Other Terminals.

Importantly, Cubao lies within this ellipse, indicating that the transport hub falls inside the broader area where most urban facilities are concentrated.

The directional distribution, represented by the ellipse, showed the general orientation and spread of these facilities. The distribution is primarily aligned toward the northwest, indicating a spatial pattern or axis of urban growth and facility development extending from Cubao in that direction. This orientation suggests that a large share of commercial establishments, hotels, and art spaces are situated or expanding along this axis, likely corresponding to key transportation routes, economic hubs, or densely populated areas as the location corresponds to the metropolitan area. Additionally, the differing sizes of the ellipses for malls, hotels, and art spaces reflect variations in their spatial dispersion, with some being more widely spread out while others remain more concentrated. Importantly, Cubao lies within this ellipse, indicating that the transport hub falls inside the broader area where most urban facilities are concentrated.

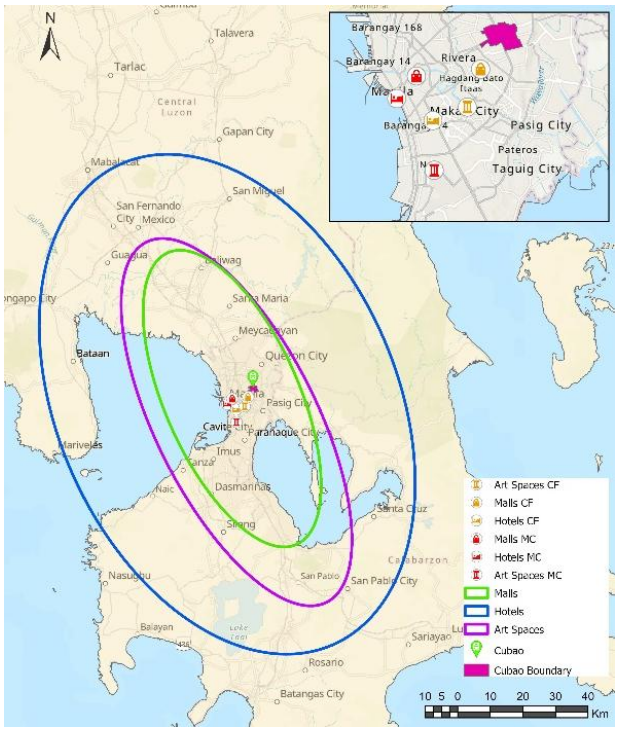


Figure 4. Central Feature, Mean Center, and Directional Distribution of Urban Facilities.

This study estimated trip volumes to three major transport hubs—Cubao, One Ayala, and PITX—by applying the gravity model to an origin-destination (OD) matrix, using total population as a proxy for spatial interaction. The model considered both the population sizes of origin and destination areas and the inverse square of the distance between them.

Figure 5 illustrates the resulting flow patterns, revealing that the four highest predicted trip volumes are directed toward Cubao. These results are presented in increasing gradient of flow lines, clearly demonstrating Cubao's dominance in anticipated commuter movement. Additionally, flow lines with higher predicted trip volumes are concentrated near the hubs, while lighter-colored lines, representing lower predicted trip values, primarily originate from more distant regions traveling toward the hubs.

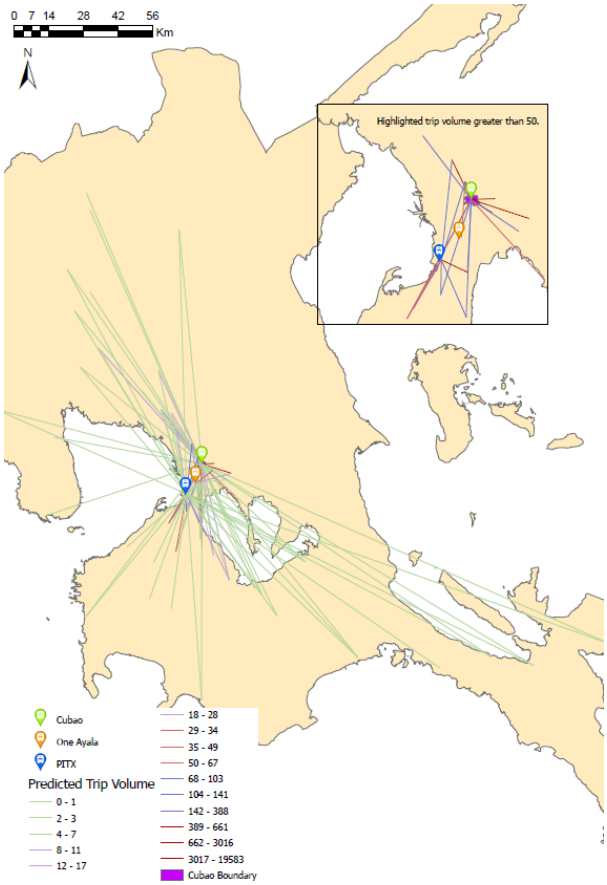


Figure 5. Predicted Trip Volume Across the Study Area to the Transport Hubs.

Figure 6 illustrates the summary of predicted trip volumes for each transport hub. Based on the gravity model, Cubao is projected to accommodate approximately 28,500 trips, far exceeding the volumes for the other hubs. PITX ranks second, with an estimated 1,700 trips, while One Ayala registers the lowest predicted flow at around 210 trips. These findings suggest that Cubao is expected to handle the greatest trip volume, reinforcing its role as the central transportation hub in the study area. Since Cubao is expected to have the greatest predicted trip volume, it is inferred that it exhibits a strong degree of accessibility and connectivity for the whole population.

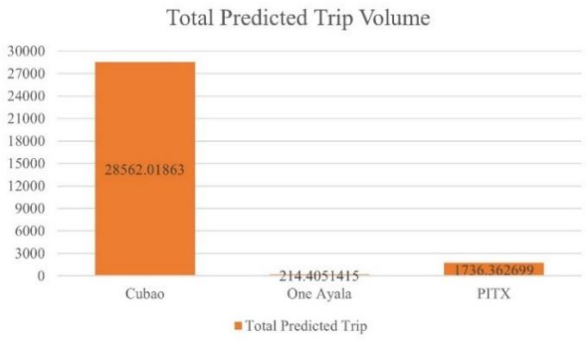


Figure 6. Total Predicted Trip Volume Across the Study to the Transport Hubs.

5. Discussion

Cubao is home to numerous inter-city and inter-provincial transport terminals, making it a major nexus for regional mobility. It serves as a convergence point for commuters

traveling across Metro Manila, as well as to and from Regions III and IV-A, supporting a wide range of daily travel demands. Due to this unique role, Cubao has humorously earned the title "all roads lead to Cubao," reflecting its reputation as the de facto center of transportation activity in the metropolis. This central role is not new, as its prominence began to take shape as early as the mid-20th century, when Cubao developed into a commercial and transit hub during Quezon City's tenure as the national capital. Its early development allowed major road construction and urban expansion to center around it, making it a natural node for both public infrastructure and private settlement (Quezon City Government, n.d.).

The high betweenness score of Cubao reinforces its function as a key intermediary within the transportation network. This can be attributed to its strategic geographic location at the convergence of two major metropolitan corridors, EDSA (North-South) and Aurora Boulevard (East-West). These thoroughfares are heavily utilized by both public and private transport daily (Orbon, 2014), naturally elevating Cubao's centrality in the network. Cubao functions as a multidirectional transfer point, offering connectivity via both bus and rail systems, which enhances its role as a central access node for inter-city and inter-regional mobility (Japan International Cooperation Agency [JICA], 1985).

In comparison, One Ayala (which began operations in 2022) and PITX (opened in 2018) also serve as important hubs due to their locations in Makati—the country's financial center (Ti, 2021) and Parañaque—a highly urbanized city (Rappler, 2024). However, their relatively lower betweenness scores reflect not only differences in geographic positioning but also in connectivity across cardinal directions. Unlike Cubao, whose development began earlier, these newer hubs are responses to recent urban decentralization efforts.

Similarly, Cubao's high closeness score reflects its central geographic location within Metro Manila and its transport-oriented development, both of which have strengthened its role as a primary access point in the region. Unlike One Ayala and PITX, which serve more specialized or regional commuting roles, Cubao offers consistently shorter and more direct connections to a greater number of terminals across Metro Manila, Region III, and Region IV-A. This reflects a continuity of its role since its early days as a hub for provincial bus lines, when it first became a gateway between the capital and surrounding provinces.

As illustrated in Figures 2a and 2b, Cubao is strategically positioned to support both inter- and intra-regional mobility, with direct connections to key terminals. Its high closeness value highlights efficient reachability, making it an ideal origin or destination for commuters moving across multiple urban and suburban areas. In contrast, One Ayala and PITX, while still important, exhibit lower closeness scores due to their more peripheral positions in the network. Their access paths involve greater cumulative distances, reinforcing Cubao's status as the most accessible and interconnected transport hub.

In addition to network centrality, the identification of Quezon City—particularly Cubao—as a hot spot for household population density further supports its central role in regional mobility. High population density reflects a substantial residential base, which generates strong travel demand both to and from the area. This demographic concentration naturally contributes to Cubao's elevated centrality scores, as dense populations tend to produce higher volumes of trip generation and attraction. Such a pattern is consistent with the centrality results from the network analysis, indicating that Cubao's geographic position and demographic profile work in tandem to reinforce its role as a major transportation hub. The large residential population in and around Cubao increases the likelihood of its inclusion in optimal travel routes across the network. A comparable use of hot spot analysis is found in a study by Lieberman et al. (2023), in which they found that hot spot zones also corresponded to high levels of activity and interaction. Similarly, the high-density hot spots surrounding Cubao suggest it is a core zone of movement and connectivity, further validating its role as a key transportation hub.

Moreover, although Cubao is not the precise center of urban facility clustering, its inclusion within the primary distribution area suggests a strong functional integration with key commercial and recreational nodes. This spatial alignment explains why Cubao continues to attract high volumes of commuters and visitors, as it is well-positioned amidst the densest concentration of malls, hotels, and art spaces in Metro Manila. This pattern has roots in its historic transformation into a premier commercial district, anchored by developments such as the Araneta Center, which have long drawn both economic activity and commuter flows.

This proximity enhances Cubao's role not only as a transportation hub, but also as a commercial and cultural destination. Facilities such as Gateway Mall, Farmers Market, and the Araneta City complex bolster Cubao's identity as a key urban center. Additionally, its connectivity is anchored by the presence of MRT-3, LRT-2, and numerous bus and jeepney terminals (Medina, 2023). The concentration of urban amenities around Cubao, combined with robust transportation infrastructure, reinforces its centrality in both functional and spatial terms within Metro Manila's urban fabric.

Cubao's dominance in predicted trip volumes also strongly supports its position as the primary transportation hub in the network. Its significantly higher trip volume, which have an approximate value of 28,500 predicted trips, can be attributed to its geographic location within one of Metro Manila's most densely populated areas. The district's accessibility, as demonstrated through the gravity model, reinforces its importance in the regional transport system, particularly for daily commuters. These findings align with the concept of network centrality as a function of accessibility (Tenzin et al., 2019), further validating earlier betweenness and closeness centrality results that identified Cubao as the most critical node.

In conclusion, the trip volume model not only confirms Cubao's functional centrality but also highlights its operational capacity to accommodate substantial commuter flows, an outcome shaped by decades of prior development that positioned Cubao at the core of Metro Manila's early road network. For transportation planning, these results suggest both opportunities and challenges: the heavy reliance on Cubao could lead to congestion and inefficiencies, but it also identifies strategic points where decentralization efforts or optimization of secondary hubs (e.g., PITX, One Ayala) could redistribute travel demand. Such interventions could improve traffic flow, enhance commuter convenience, and build resilience in the transport system.

6. Conclusions and Recommendations

In a country where public transportation remains a significant challenge, transport hubs play a vital role in organizing mobility and facilitating efficient transfers. This study assessed three

major hubs—Cubao, One Ayala, and PITX—using multiple geospatial methods to determine whether Cubao serves as the primary convergence point in Metro Manila's transportation network.

Network Centrality Analysis revealed that Cubao holds the highest betweenness centrality score and highest closeness centrality score. These results affirm Cubao's role as a strategic connector supporting inter- and intra-regional mobility across Metro Manila, Region III, and Region IV-A. The hot spot analysis identified Quezon City, where Cubao is located, as a major population density cluster, which implies high travel demand – reinforcing Cubao's role as both a residential and transportation center. While urban facilities like malls, hotels, and art spaces are generally distributed around Metro Manila rather than centered in Cubao, the hub still lies within the directional distribution ellipse. This proximity to a dense concentration of key establishments enhances its attractiveness as a commuter and visitor destination. The combination of transport access and commercial relevance solidifies Cubao's dual function as both a mobility node and a commercial center.

Predicted trip volumes show Cubao as the leading hub with approximately 28,500 estimated trips—far exceeding PITX and One Ayala. This confirms Cubao's operational capacity to handle large commuter flows and highlights its strong spatial interaction with surrounding municipalities. These results are consistent with the centrality scores, reinforcing Cubao's accessibility and strategic location within the network.

However, the interpretation of these findings must account for the study's inherent limitations. The network topology, centrality measures, and directional distribution are based only on data from NCR, Region III, and Region IV-A. This geographic scope inherently centers Cubao within the analysis and may not represent alternative mobility patterns outside these regions. The ellipses' orientation also follows the natural extent and structure of Metro Manila's Road network, which means that the spatial trends observed are shaped partly by the dataset boundaries rather than solely by transportation dynamics. As such, the conclusions drawn are most applicable within this regional context.

From a transportation planning perspective, the results have practical implications. Cubao's dominance in connectivity and predicted trips highlights both its strength as a hub and its vulnerability to congestion. Planners could use these findings to: (1) explore strategies for decentralizing commuter flows by enhancing connectivity of secondary hubs like PITX and One Ayala, (2) prioritize infrastructure upgrades in and around Cubao to manage high passenger volumes efficiently, and (3) leverage Cubao's accessibility to support transit-oriented development that balances mobility needs with urban livability. By applying centrality-based analysis to other hubs, decision-makers can also identify locations with untapped potential to absorb more demand, improving the overall network performance.

The study also aligns with real-world indicators. Quezon City has been recognized as the top-performing city in terms of local revenue generation, largely due to property, business, and recreation taxes. This financial performance may be partially driven by the concentration of movement and activity around Cubao, providing real-world validation of the transport trends observed in the study. In December 2024, the Philippine Statistics Authority released the Provincial Products Account detailing the top contributors to the country's economy. Quezon City was deemed as number one, with the largest share in the country in 2023, at six percent. Supporting this, an article published by The Philippine Star stated that the Commission on Audit also released their Annual Financial Report for 2023 and Quezon City was the top runner. The commission mentioned that the total assets were based on the local government unit's total cash value, alongside its cash equivalent and receivables. They also accounted for the city's properties, plants, and equipment.

Overall, this study combined network analysis, clustering, and spatial modeling to assess the centrality of Cubao and tested the well-known urban expression that "all roads lead to Cubao." The findings not only support this notion but also emphasize the broader implications for mobility management, hub optimization, and equitable accessibility in Metro Manila's complex transport landscape. These results also demonstrate the potential of centrality-based network analysis as a powerful tool for identifying functionally critical nodes like Cubao. This method supports evidence-based infrastructure and transportation decisions and can be replicated in other urban areas.

Degree centrality was excluded from the centrality analyses because it depends largely on the actual count of direct links a node has with others which may not bring relevant conclusions given that betweenness and closeness were already done. Moreover, the Origin-Destination (OD) cost matrix used in this study worked under the assumption that all OD lines were direct and valid connections, which may not always align with real-world dynamics, road conditions, or route availability. The study also encountered data limitations since all spatial data were obtained through the QuickMapOSM plugin in QGIS, which may not reflect the most locally updated data. In addition, actual trip volume data for public utility vehicles (PUVs) were unavailable due to restricted access to datasets. These limitations affected how detailed and accurate the network analysis could be, especially in understanding each node and how they connect in real-world situations.

To strengthen future analyses, incorporating degree centrality could further validate and solidify the argument regarding Cubao's centrality by quantifying the number of direct connections the hub has within the network. Obtaining actual trip data from public utility vehicles would also improve the accuracy of predicted flows, ensuring that models reflect real commuter behavior rather than purely population-based estimates. Expanding the study to include additional regions could test whether Cubao's dominance persists at a broader geographic scale or whether other hubs emerge as central. For future research, it is recommended to consider these factors to provide additional insights into the connectivity of transport hubs.

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References

Barry, J., Kaenzig, R., 2019. Bus Case Study for Highly Congested Orbital Route in Manila. Changing Transport. https://changing-transport.org/publications/bus-case-study-manila/ (16 May 2025).

Boquet, Y., 2013. Battling Congestion in Manila: The Edsa Problem. *Transport and Communications Bulletin for Asia and the Pacific*. 82, 45-59.

Del Prado, D., 2024. Quezon City Has the Largest Share to Philippine Economy; Three Economies Record Trillion Pesos GDP in 2023. Philippine Statistics Authority. psa.gov.ph/content/quezon-city-has-largest-share-philippine-economy-three-economies-record-trillion-pesos-gdp (8 July 2025).

EMBL-EBI, n.d. Betweenness centrality | Network analysis of protein interaction data. European Molecular Biology Laboratory. ebi.ac.uk/training/online/courses/network-analysis-of-protein-interaction-data-an-introduction/building-and-analysing-ppins/topological-ppin-analysis/betweenness-centrality/ (16 May 2025).

Freeman, L. C. 1977. A set of measures of centrality based on betweenness. *Sociometry*, 40(1), 35. doi.org/10.2307/3033543.

Freeman, L. C. 1979. Centrality in social networks conceptual clarification. *Social Networks*, 1(3), 215–239. doi.org/10.1016/0378-8733(78)90021-7.

Guo, W., Toader, B., Feier, R., Mosquera, G., Ying, F., Oh, S., Price-Williams, M., Krupp, A., 2019. Global air transport complex network: multi-scale analysis. *SN Applied Sciences*, 1(680). doi.org/10.1007/s42452-019-0702-2.

Haznagy, A., Fi, I., London, A., Nemeth, T., 2015. Complex network analysis of Public Transportation Networks: A comprehensive study. *2015 International Conference on Models and Technologies for Intelligent Transportation Systems* (MT-ITS), 371–378. doi.org/10.1109/mtits.2015.7223282.

Japan International Cooperation Agency, 1985. The Metro Manila transportation planning study: Phase II final report. openjicareport.jica.go.jp/pdf/10304855_01.pdf (1 August 2025).

Lennefalk, J., n.d. Revamping Philippine connectivity and public transport. Business Sweden. business-sweden.com/sv/insikter/focusasia-2024/100-affarsmojligheter-asien/2024/transportation-manila/ (16 May 2025).

Li, J., Qian, J., Liu, Y., 2017. A novel analysis method of geographical centrality based on space of flows. *ISPRS International Journal of Geo-Information*, 6(5), 153. doi.org/10.3390/ijgi6050153.

Lieberman, B., Kong, J., Gusinow, R., Asgary, A., Bragazzi, N., Choma, J., Dahbi, S., Hayashi, K., Kar, D., Kawonga, M., Mbada, M., Monnakgotla, K., Orbinski, J., Ruan, X., Stevenson, F., Wu, J., Mellado, B., 2023. Big data- and artificial intelligence-based hot-spot analysis of covid-19: Gauteng, South Africa, as a case study. *BMC Medical Informatics and Decision Making*, 23(1). doi.org/10.1186/s12911-023-02098-3.

Marathe, A., Zhengzheng, P., Apolloni, A., 2013. Analysis of friendship network and its role in explaining obesity. *ACM transactions on intelligent systems and technology*, 4(3), 1–21. doi.org/ 10.1145/2483669.2483689.

Marcelo, E., 2024. Quezon City still Philippine's richest LGU. The Philippine Star. philstar.com/nation/2024/12/05/2405075/quezon-city-still-philippines-richest-lgu (8 July 2025).

Medina, M., 2023. Cubao: The country's pioneer in commercial center operations. Inquirer. business.inquirer.net/424157/cubao-the-countrys-pioneer-in-commercial-center-operations (16 May 2025).

Orbon, G., 2014. Ecosystem of a Transport Hub: Analysis on the Urban Development of Cubao, Metro Manila. *Asian Urban Places*, 286-296.

Perez, R. E., Ng, A. C. L., Tiglao, N. C. C., 2021. Enhancing policy capacity through Co-design: the case of local public transportation in the Philippines. *Policy Design and Practice*, 5(1), 103–121. doi.org/10.1080/25741292.2021.1930689.

Pham, P., Bollettino, V., Vinck, P., Marnicio, A., Manzanero, L., Toldo, M., Dickinson, R., Smart, A., Bloom, E. 2020. Network Analysis of Actors Working to Support Disaster Preparedness and Resilience in the Philippines. Harvard Humanitarian Initiative.

Piovesana, A., 2021. An introduction to spatial networks: network generating models. ime.unicamp.br/~mac/db/2021-1S-165023.pdf

Quezon City Government., n.d. History. https://quezoncity.gov.ph/about-the-city-government/history/ (8 July 2025).

Rappler, 2024. Parañaque City. *Rappler*. https://www.rappler.com/philippines/metro-manila/l93828499-ncr-paranaque-city/ (16 May 2025).

Remo, M., 2013. 'Traffic costs P2.4B daily. Inquirer. business.inquirer.net/130649/traffic-costs-p2-4b-daily (16 May 2025).

Scheurer, J., Porta, S., 2006. Centrality and connectivity in public transport networks and their significance for transport sustainability in cities. *Australian Housing and Urban Research Institute.*

Sy, C., Regidor, J. R., n.d. An Assessment of the Effectiveness of the Quezon City Bus Service based on Users' Satisfaction. ncts.upd.edu.ph/tssp/wp-content/uploads/2024/12/TSSP-2024-31-Revised-Paper.pdf.

Tenzin, N., Jayasinghe, A., Abenayake, C., 2019. Road Network Centrality based Model to Simulate Population Distribution. *Journal of the Eastern Asia Society for Transportation Studies 13*, 1194–1215. doi.org/10.11175/easts.13.1194.

Ti, W., Jr., 2021. Makati. Inquirer Business. INQUIRER.net. https://business.inquirer.net/332590/makati (16 May 2025).

Wang, Y., Deng, Y., Ren, F., Zhu, R., Wang, P., Du, T., Du, Q., 2020. Analysing the spatial configuration of urban bus networks based on the Geospatial Network Analysis Method. *Cities*, 96, 102406. doi.org/10.1016/j.cities.2019.102406.