Spatio-temporal Analysis of Traffic Accessibility in Cavite

Chrizzer Ann Rose L. Capalad [1], Kathryn Joie T. Mendoza [1], Carlyn Ann G. Ibañez [1], Bienvenido G. Carcellar III [1]

[1] Department of Geodetic Engineering, University of the Philippines Diliman, Philippines - clcapalad@up.edu.ph, ktmendoza1@up.edu.ph, cgibanez@up.edu.ph, bgcarcellar@up.edu.ph

Keywords: Traffic Accessibility, Spatio-temporal Analysis, Univariate Spatial Autocorrelation Analysis, Route Modification.

Abstract

Rapid urbanization in peri-urban provinces like Cavite has intensified pressure on transportation systems, leading to uneven traffic accessibility and growing spatial inequalities. As infrastructure development struggles to match population and economic growth, there is a need for spatially informed planning to ensure equitable mobility. This study presents a spatio-temporal analysis of traffic accessibility in Cavite's Districts 1 to 4 from 2013 to 2023. Using the Analytic Hierarchy Process (AHP), traffic accessibility was quantified across four dimensions: transport, space, system quality, and quality of service. Univariate Local Indicators of Spatial Association (LISA) identified spatial clusters of accessibility, revealing persistent disparities in urban centers such as Imus and Bacoor showed consistent improvements, while peripheral areas such as Cavite City, Rosario, and Noveleta remained underserved. Although accessibility scores rose due to infrastructure gains, a decline in 2023 was attributed to rising transport costs. To address this, six jeepney route adjustments and seven new transport stops were proposed in low-accessibility zones. Post-intervention analysis showed improved clustering, validating the strategy's impact. Thus, this study offers actionable insights for local governments and transport agencies and highlights the value of geospatial methods in supporting sustainable, inclusive urban mobility in fast-growing regions.

1. Introduction

1.1 Background of the Study

The global shift toward urban living has intensified focus on transportation systems in rapidly expanding urban and peri-urban environments (Gonçalves et al., 2017; Stanković et al., 2018). As development sprawls outward, existing networks strain to meet growing demands, leading to poor traffic accessibility, which is defined as the ease of reaching desired destinations (Litman, 2003). Effective accessibility depends on the spatial arrangement of residences, the location of services, and the infrastructure connecting them (Donges, 1999, cited in Stanković et al., 2018). When these components lag behind urban expansion, accessibility suffers, causing congestion, longer commutes, and unequal access to opportunities.

This issue is especially critical in fast-growing, under-resourced nations, where traffic accessibility is often overlooked in planning (Mortoja & Yigitcanlar, 2022). Peri-urban areas face acute neglect, as infrastructure fails to keep pace with settlement and economic activity (Ge et al., 2021). Consequently, accessibility becomes a pressing equity concern. Low- and middle-income peri-urban residents, frequently displaced by metropolitan costs, bear the heaviest commuting burdens yet benefit least from regional growth (Webster, 2002; İzgi, 2024; Bragais, 2022).

Inadequate planning results in disconnected roads and bottlenecks, worsening transport injustice. Outcomes include prolonged and expensive commutes for disadvantaged groups, limited access to education and healthcare, and increased exposure to traffic-related pollution (Stanković et al., 2018; Litman, 2024). This is particularly relevant in emerging peri-urban provinces like Cavite, where population growth and economic transformation pressure transportation networks (Japan International Cooperation Agency, 2012; Bragais, 2022). By framing Cavite's transport challenges within broader discussions of peri-urban exclusion and spatial inequality, this study moves beyond describing accessibility patterns. It instead diagnoses how uneven mobility arises amid rapid urbanization and identifies planning strategies for sustainable and equitable transport futures.

1.2 Objectives and Significance

The main objective of the study is to apply spatio-temporal analysis to examine traffic accessibility in Cavite in 2013, 2018, and 2023. Specifically, this study aims to:

1. Quantify the levels of traffic accessibility in Cavite using the Analytic Hierarchy Process (AHP);
2. Identify and analyze the spatio-temporal clusters of traffic accessibility in Cavite using univariate Local Indicators of Spatial Association (LISA); and
3. Propose route modifications that could improve traffic accessibility based on identified spatial patterns.

The significance of this research lies in its ability to provide evidence-based insights for transportation agencies such as the Department of Transportation (DOTr), Department of the Interior and Local Government (DILG), Land Transportation Franchising and Regulatory Board (LTFRB), and local governments in Cavite. By examining accessibility over time, the study highlights areas of congestion and inefficiency in the road network, thereby supporting informed decision-making in infrastructure planning, route optimization, and sustainable transport strategies. Beyond practical applications, the study contributes to the field of geomatics by showcasing how spatial analysis can be applied to urban planning. It also aligns with Sustainable Development Goal 11, particularly the promotion of inclusive, safe, resilient, and sustainable cities through improved mobility and connectivity.

2. Review of Related Literature

2.1 Traffic Accessibility

Traffic accessibility goes beyond mere traffic flow by integrating land use, travel behavior, and multimodal transport to evaluate how easily people can reach desired destinations

(Litman, 2003; Hansen, 1959; Van Wee, 2015). It plays a crucial role in identifying spatial inequities and fostering sustainable, inclusive urban development (Farrington & Farrington, 2005). While global approaches to measuring accessibility have evolved, from early spatial interaction models to modern reachability-based and multi-criteria methods, research specific to Cavite remains scarce. In the Philippines, studies have shown how access influences rural economies (Olsson, 2008), urban exclusion (Nogueira & Diaz, 2023), and land-use transitions (Verburg et al., 2004). Tools like the fuzzy AHP offer structured assessments, with Stanković et al. (2018) identifying 13 key criteria grouped into four main dimensions: transport, space, quality of service, and system quality. However, Cavite still lacks data-driven assessments of traffic accessibility that account for both spatial and temporal variations, underscoring the need for localized analysis to inform planning.

2.2 Spatial Autocorrelation Analysis of Traffic Accessibility

Univariate LISA provides critical insight into how traffic accessibility varies across space by revealing localized patterns such as high-high (HH) clusters of high accessibility and low-low (LL) clusters of poor accessibility, thereby offering a finer resolution understanding than global statistics alone (Anselin, 1995). As shown in the study by Nie et al. (2015), spatial techniques such as the Network-constrained Getis-Ord Gi* (GLINCS) were applied to network-constrained data to detect statistically significant clusters of traffic incidents, validating the use of univariate LISA for identifying high-risk segments on urban roads. Similarly, Ge et al. (2021) underscored that spatial autocorrelation techniques effectively examined traffic accessibility within urban agglomerations, showing significant positive spatial dependence and highlighting the spatial spillover effects of accessibility across neighboring regions. These methods help planners prioritize transportation interventions and inform equitable infrastructure development by mapping accessibility disparities at granular levels.

2.3 Route Modification

Route modification has emerged as a crucial strategy in optimizing public transport efficiency, particularly in congested urban settings. Arcaño et al. (2023) employed data-driven simulations such as EMME and Origin-Destination (OD) matrices to assess transit route redesigns based on passenger demand, traffic patterns, and service classifications (e.g., Express, Local). The Department of Transportation (2017) has likewise pushed for route rationalization to reduce overlapping services and improve integration with mass transit systems. However, existing literature is largely focused on technical modeling, travel time reduction, and network restructuring, with limited attention to local implementation challenges. Belizario et al. (2017) noted that many drivers are unaware of the process of route modification and that institutional barriers, such as unclear LTFRB procedures, remain unaddressed. Moreover, studies rarely incorporate grassroots perspectives or analyze localized transport behaviors, especially within LGU-led planning. There is a notable gap in examining the spatial realities and institutional dynamics surrounding route changes at the community level, particularly in contexts where informal and formal transport modes coexist.

3. Methodology

3.1 Study Area

This study focuses on Districts 1 to 4 of Cavite, covering four component cities and three municipalities: Cavite City, excluding Corregidor Island, Bacoor, Imus, Dasmariñas, Kawit, Noveleta, and Rosario. These areas, classified as peri-urban zones (Webster, 2002), are situated along major transport corridors connected to Metro Manila and Laguna, making them critical to regional mobility. Spanning a total of 256.23 square kilometers or 17.96% of Cavite's land area (Cavite Ecological Profile, 2021), these districts have experienced rapid residential and commercial development as part of CALABARZON's Strategic Development Cluster 1 (Calabarzon RDC, 2023).

3.2 Flowchart

The study encompassed four phases, as seen in Figure 3.2, which include data collection, quantification of urbanization and traffic accessibility levels, spatiotemporal analysis, and route modification.

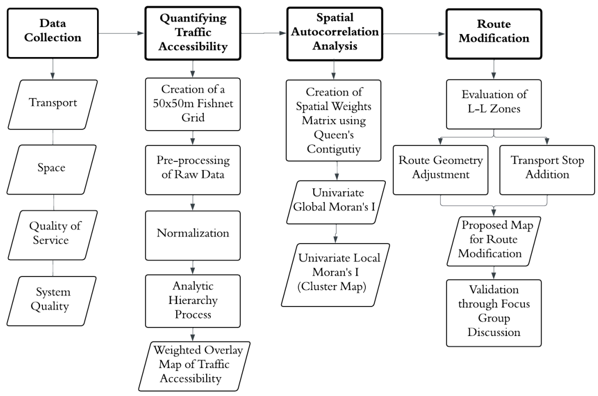

Figure 1. Flowchart of the study.

3.3 Quantifying Traffic Accessibility

In collecting data for traffic accessibility for the years 2013, 2018, and 2023, four groups were used to quantify the traffic accessibility levels in Districts 1-4 of Cavite, following the methodology outlined in the study by Stanković et al. (2018).

Indicator	Criteria	Specific Data	Source
Proximity and capacity-based weights of public transport lines	Transport	Excel and shapefile	LTFRB Region IV-A, OpenStreetMap Geofabrik
Proximity to connector roads	Space	Geopackage	OSMnx
Speed	Quality of Service	Geopackage	OSMnx
Proximity to nearest transport terminals and stops		Geopackage	OSMnx
Transport costs	System Quality	PDF File	LTFRB Region IV-A

Table 1. List of data for quantifying traffic accessibility

https://doi.org/10.5194/isprs-archives-XLVIII-5-W4-2025-55-2026

These four groups were transport, space, quality of service, and system quality, and for each group, the selected criteria were the proximity and capacity-based weights of public transport lines, proximity to connector roads, speed, and proximity to nearest transport terminals and stops, and transport costs, respectively. The table below summarizes the data used to quantify traffic accessibility levels and their data sources.

Traffic accessibility across Cavite's Districts 1–4 was quantified using multiple spatial indicators. Proximity to public transport lines, including jeepneys, buses, and UV Express, was measured by overlaying digitized routes onto a 50×50-meter grid in ArcGIS. Each grid cell's distance to the nearest line was weighted by passenger capacity and the number of authorized units, with shorter distances to high-capacity routes yielding higher accessibility scores. Similarly, travel speed was incorporated by classifying roads by type and assigning greater influence to higher-speed classes. Cells nearer to faster roadways received better scores after normalization and inversion.

The analysis also integrated structural and economic factors. Betweenness centrality which was evaluated in OSMnx, identified key connector roads, with grid cells near central segments receiving stronger accessibility values. Proximity to transport terminals and stops was calculated, where closer distances directly improved scores. Finally, affordability was captured using LTFRB fare data, and each cell's distance to the lowest-cost route was weighted inversely, prioritizing access to affordable transport. All measures were normalized and inverted to ensure consistency, with shorter distances and lower costs contributing to higher overall accessibility.

3.4 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was applied to determine the relative importance of factors influencing traffic accessibility. Following Saaty's (1987) recommendation, nine experts were consulted including officials from Local Government Units (LGU) traffic management departments, the Department of Public Works and Highways (DPWH), the Land Transportation Franchising and Regulatory Board (LTFRB), and the National Center for Transportation Studies (NCTS), to conduct pairwise comparisons. An odd number of respondents was chosen to minimize ties and ensure clearer consensus. Experts were briefed through in-person meetings, printed guides, and email clarifications. Pairwise comparison matrices from all experts were aggregated using the geometric mean method (Forman & Peniwati, 1998). Matrices were normalized, and factor weights were derived. Consistency was checked using λmax, Consistency Index (CI), and Consistency Ratio (CR). A consistency ratio of 0.03557 was calculated. Thus, the CR < 0.10 was satisfied. Shown below are the computed weights for traffic accessibility based on the results of the Analytic Hierarchy Process (AHP).

Rank	Criteria	Weights
1	Proximity and capacity-based weights of public transport lines	0.379138
2	Proximity to nearest transport terminals and stops	0.203582
3	Proximity to connector roads	0.195609
4	Transport cost	0.148353
5	Speed	0.073319

Table 1. Weights for quantifying traffic accessibility

The findings highlight that public transport accessibility and proximity to terminals/connector roads are the most critical factors. The results align with international studies such as the study from Skankovic et al. (2018), reinforcing the universality of proximity and network integration as core drivers of traffic accessibility. The consistency of responses reflects the strong contextual relevance of the chosen criteria, grounded in Cavite's local mobility realities and validated through consultation with key agencies.

3.5 Univariate Spatial Autocorrelation Analysis of Traffic Accessibility

This study employed univariate spatial autocorrelation to analyze the distribution patterns of traffic accessibility within Districts 1–4 of Cavite for the years 2013, 2018, and 2023. Using GeoDa software, Global and Local Moran's I indices were computed to determine whether traffic accessibility values exhibited clustering, dispersion, or randomness across the study area. A 50×50 meter fishnet grid was used as the spatial unit, and spatial weights were defined using Queen's contiguity to account for both edge- and corner-based neighbors. The Global Moran's I analysis utilized 999 permutations to generate pseudo p-values and z-scores, providing statistical validation of the observed spatial patterns. Values near +1 indicated clustered high or low accessibility scores, while values near –1 suggested dispersion, and values close to 0 reflected random spatial distribution. Local Moran's I analysis (LISA) was then conducted to identify significant spatial clusters, including High-High (HH), Low-Low (LL), and potential spatial outliers such as High-Low (HL) and Low-High (LH).

3.6 Route Modification

The final phase of the study focused on applying route modification strategies to areas identified as Low Traffic Accessibility - Low Urbanization (L-L) zones in the 2023 univariate spatial analysis. These zones, characterized by spatial isolation and weak transport connectivity, were prioritized due to the persistent underserved areas. Two practical strategies were employed: Route Geometry Adjustment and Transport Stop Addition. These strategies were selected to address accessibility gaps in L-L zones without proposing new infrastructure, instead working within the limitations of the existing road network. The approach ensured that only current roads and transport systems were used, excluding planned infrastructure due to the absence of consistent provincial data.

3.6.1 Route Geometry Adjustment: To adjust existing route geometries in L-L zones, ArcGIS Network Analyst's Route Tool was used to simulate and assess modifications. This included extending or adjusting existing public transport routes, particularly for jeepneys, to underserved areas where no active lines were available. The road network was prepared using 2023 spatial data, and impedance values were calculated based on the formula:

$$Travel\ Time = \frac{Distance}{Speed} \quad (1)$$

Speed classifications used were from the study of Vergara et al. (2019). Travel time was used as the impedance factor to reflect both the cost-efficiency and time sensitivity of commuters. Routes were designed to remain within the 35-kilometer maximum set by DOTr Department Order No. 2023-022 for Public Utility Jeepneys (PUJs). Only routes that met this regulation were extended or modified, with 1 to 2 stops proposed per adjustment based on stakeholder feedback. U-turns at junctions were restricted in the analysis for realism.

3.6.2 Transport Stop Addition: In L-L zones where route adjustment was not feasible, either due to capacity constraints or redundancy, additional transport stops were proposed. These zones were identified as already traversed by high-frequency public transport vehicles but lacking formal stops. Following the guidelines from Regidor et al. (2018), stops were positioned at least 30 meters from intersections for safety. A buffer was created around intersections in ArcGIS, and proposed stops were manually placed within this buffer. Visual verification was conducted using Google Earth and Street View to ensure adequate space and feasibility for new stops in each proposed location.

3.6.3 Validation: Validation of proposed modifications was conducted in two ways: stakeholder consultation and technical analysis. Outputs were reviewed in a Focus Group Discussion (FGD) with the Provincial Engineering Office, Road Safety Division, and LTFRB Region IV-A. Maps of traffic accessibility and the L-L zones were presented alongside the proposed adjustments, and stakeholders confirmed whether these matched observed realities. Additionally, validation forms were distributed to local government units (LGUs) in Districts 1–4 to collect municipal-level feedback. Lastly, spatial autocorrelation was recalculated after integrating the modifications to assess whether L-L zones transitioned to improved categories, specifically from Low-Low (L-L) to High-High (H-H), indicating better alignment between service availability and transport demand.

4. Results and Discussion

4.1 Quantified Traffic Accessibility

4.1.1 Proximity and Capacity-Based Weights of Public Transport Lines: From 2013 to 2023, public transport accessibility in Cavite's Districts 1 to 4 showed significant overall improvement, with accessibility scores rising from a mean of 0.62 in 2013 to 0.85 in 2023. The accessibility maps reveal that central urban areas like Dasmariñas, Imus, and Bacoor experienced the most progress, becoming key nodes in the transport network due to increased route density and higher-capacity services. In contrast, coastal and peripheral municipalities such as Rosario, Kawit, Noveleta, and Cavite City, while showing some gains, remained at moderate levels of accessibility and failed to match the progress seen in core cities. This highlights a growing spatial disparity, where improvements were concentrated in urban centers, leaving outlying areas relatively underserved despite a decade of network expansion.

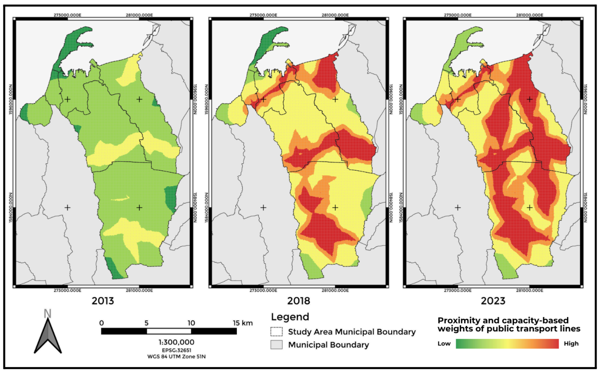

Figure 2. Accessibility map of public transport lines based on proximity and capacity weights.

4.1.2 Proximity to Connector Roads: From 2013 to 2023, road accessibility in Cavite showed a gradual yet meaningful evolution in network connectivity. In 2013, high-centrality zones were concentrated in northern municipalities like Imus, Kawit, and parts of Rosario and Noveleta, while areas like Dasmariñas and Bacoor had low accessibility. By 2018, despite some infrastructure projects, the overall improvement was modest, with a rise in minimum centrality but a slight drop in the mean, indicating localized benefits without major network-wide changes. By 2023, the road network exhibited a more connected structure, with an increased mean centrality and broader high-accessibility zones, especially in eastern Bacoor and central Dasmariñas. However, some earlier high-centrality areas like Kawit and Noveleta showed slight declines, suggesting a redistribution of connectivity.

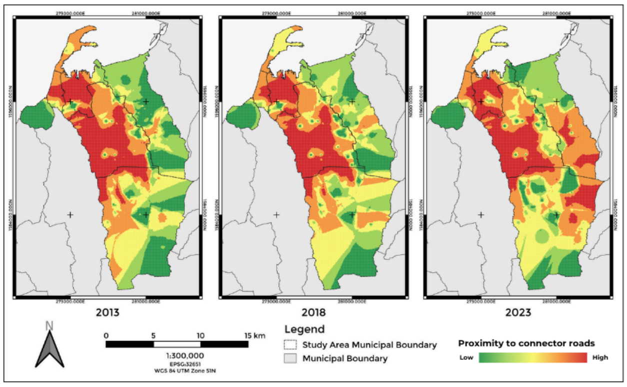

Figure 3. Accessibility map based on proximity to connector roads.

4.1.3 Speed: From 2013 to 2023, speed-based accessibility across Cavite's Districts 1–4 remained largely stable, with only slight improvements observed over time as average scores rose marginally from 0.8588 in 2013 to 0.8625 in 2023. This consistency reflects the relatively unchanged road network and the use of fixed speed weights assigned to different road classifications. High accessibility was consistently seen in Bacoor, Imus, Dasmariñas, and Kawit due to their proximity to major high-speed roads like Aguinaldo Highway and Daang Hari Road. In contrast, municipalities such as Rosario, Noveleta, and northern Imus showed moderate accessibility due to reliance on a mix of slower secondary and residential roads, while Cavite City persistently recorded the lowest scores, indicating limited access to high-speed corridors.

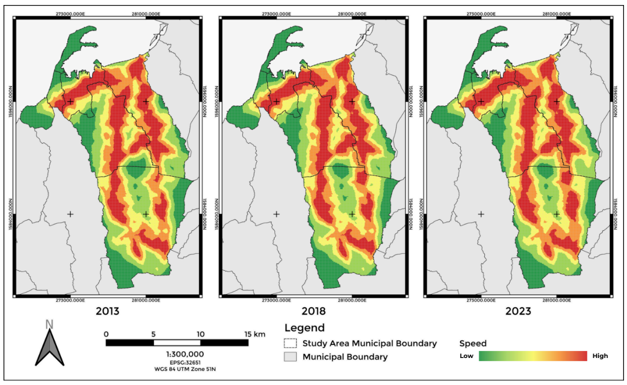

Figure 4. Accessibility maps based on speed.

4.1.4 Proximity to Transport Terminals and Stops: From 2013 to 2023, the spatial accessibility of transport terminals and stops in Cavite's Districts 1–4 showed gradual improvement, with the mean accessibility score increasing from approximately 0.73 in 2013 to 0.78 in 2023. This upward trend reflects the steady addition of new terminals and stops, particularly in major urban centers like Bacoor, Imus, and Dasmariñas, where transport demand is highest. Notable facilities such as the Vista Mall terminals, NoMo, and Vermosa were introduced during this period, enhancing accessibility in key areas. Meanwhile, municipalities like Kawit, Noveleta, Rosario, and Cavite City had fewer terminals, proportionate to their lower transport route density. Overall, the spatial distribution remained relatively balanced, aligning with the structure of the public transport network in each locality.

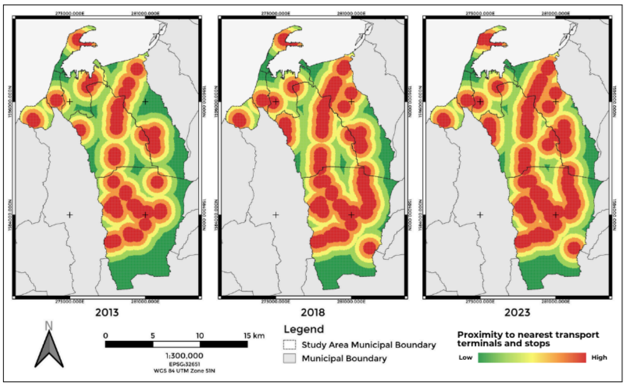

Figure 5. Accessibility maps based on transport terminals and stops.

4.1.5 Transport Costs: From 2013 to 2023, transport cost accessibility across Cavite's municipalities declined significantly due to rising public transport fares. In 2013, municipalities like Bacoor, Imus, Dasmariñas, and Rosario exhibited high accessibility, as reflected by lower fares and broader transport coverage. However, areas such as Cavite City, Kawit, and Noveleta showed lower accessibility despite low fares, largely due to limited transport line availability. By 2018, the mean accessibility score dropped from 0.7867 to 0.7105 as fare increases across all modes reduced affordability. The trend continued in 2023, with the mean score falling further to 0.52, indicating a sharp decline in accessibility largely influenced by fare inflation and the socioeconomic effects of the COVID-19 pandemic.

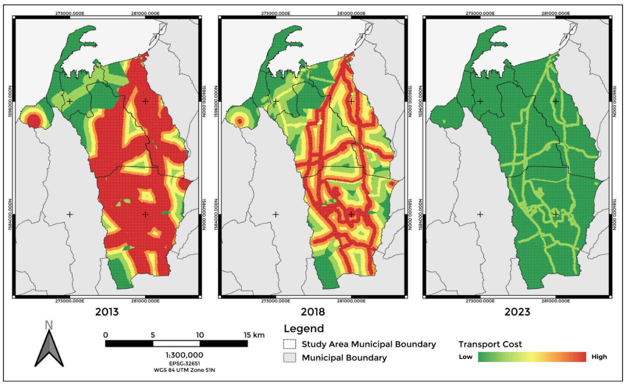

Figure 6. Accessibility maps based on transport cost.

4.1.6 Traffic Accessibility Levels: From 2013 to 2023, traffic accessibility across Cavite's Districts 1–4 showed a general upward trend, with municipalities like Imus, Bacoor, and Kawit demonstrating consistent improvement due to expanding public transport routes, more terminals, and enhanced connector roads. Imus remained the most accessible municipality throughout the decade, while Bacoor and Kawit transitioned from moderate to high accessibility. Dasmariñas showed uneven development, with improvements in the north but stagnation in the south. However, despite these infrastructure gains, municipalities like Cavite City, Noveleta, and Rosario continued to exhibit low to moderate accessibility. The overall mean accessibility rose from 0.6296 in 2013 to 0.6983 in 2018, but declined slightly to 0.6929 by 2023. A sensitivity analysis revealed that this decline was driven solely by increasing transport costs, which negatively impacted the overall accessibility score, while all other factors continued to contribute positively. This underscores that infrastructure alone cannot sustain accessibility if rising fares make public transport economically unreachable for many commuters.

Validation from focus group discussions and planning documents confirmed this trend, noting that fare inflation, which was exacerbated by the COVID-19 pandemic, fuel price hikes, and the replacement of traditional jeepneys with more expensive modern PUJs, significantly reduced affordability and accessibility. While initiatives like the Public Utility Vehicle Modernization Program (PUVMP) improved transport quality and capacity, they also led to fare increases, especially on routes previously served by cheaper PUJs. Local experts from LTFRB and the Provincial Planning Office emphasized that affordability has become the primary barrier to mobility, particularly in southern Cavite, where rising operational costs and fare adjustments placed a burden on lower-income commuters. Additionally, overlapping transport stops and rising private vehicle use further strained the network, revealing that without cost regulation and equitable fare structures, accessibility gains from infrastructure will remain uneven and unsustainable.

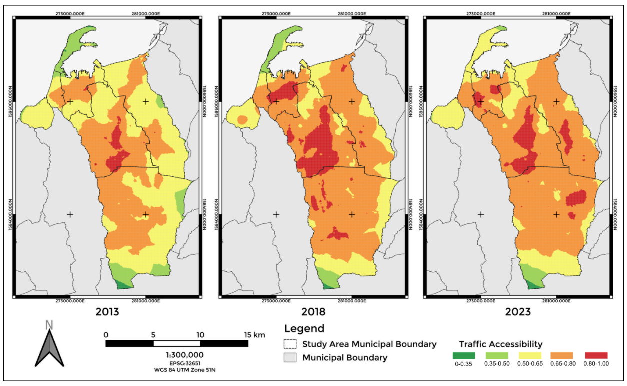

Figure 6. Map of quantified traffic accessibility levels.

4.2 Univariate Spatial Autocorrelation Analysis of Traffic Accessibility

The results of the univariate Global Moran's I analysis for traffic accessibility in Cavite's Districts 1–4 indicate consistently strong spatial autocorrelation across the years, with values of 0.994 in 2013, 0.995 in 2018, and 0.994 in 2023. These near-maximum Moran's I values suggest that traffic accessibility scores are highly clustered spatially, meaning that areas with similar accessibility levels, whether high or low, are located near each other rather than being randomly distributed.

https://doi.org/10.5194/isprs-archives-XLVIII-5-W4-2025-55-2026

To identify specific hotspots of traffic accessibility, the Univariate Local Moran's I cluster maps for the years 2013, 2018, and 2023 were used to examine the spatial patterns across selected municipalities in Cavite. As seen in Figure 7, these maps reveal how accessibility is spatially clustered over time, with validation from the corresponding significance maps in Figure 8 confirming the statistical strength of the results based on 999 permutations and a pseudo p-value of 0.001.

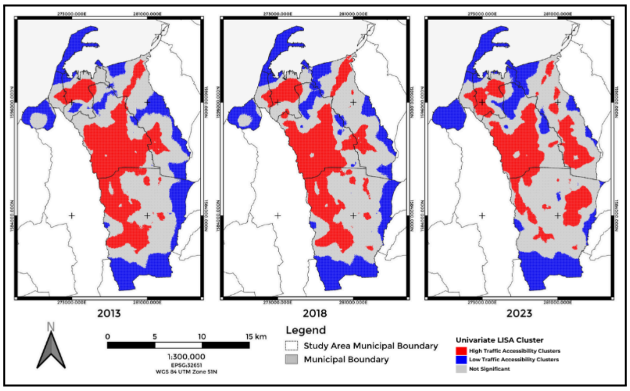

Figure 7. Univariate LISA cluster map.

The maps consistently show High-High clusters of traffic accessibility in areas where similarly high values surround high accessibility zones are concentrated in Imus, Bacoor, Dasmariñas, and parts of Kawit. These municipalities serve as major urban centers with dense road networks, numerous public transport lines, and well-distributed terminals and stops, collectively enhancing traffic accessibility. Their strategic location near Metro Manila and continued infrastructure investments further reinforce their strong accessibility performance over the decade.

In contrast, Low-Low clusters are consistently found in the northern coastal areas such as Cavite City, Noveleta, Rosario, and portions of Kawit, as well as in the southern peripheral zones of Dasmariñas. These areas exhibit low traffic accessibility values surrounded by similarly low-scoring areas. In Rosario, for instance, urbanization is evident due to the Cavite Economic Zone and high population densities. However, the municipality lacks internal transport coverage, and most public transport routes bypass it. Similarly, Cavite City has limited public transport integration despite its urban character, with only a few jeepney routes and most buses bypassing the city center. These patterns suggest that while infrastructure in key zones has improved, certain areas remain underserved, reinforcing persistent accessibility gaps.

Interestingly, some peripheral barangays of Dasmariñas showed transitions from Low-Low in 2013 to Non-significant or even emerging High-High by 2023. This pattern reflects localized improvements brought about by the expansion of connector roads and increased penetration of public transport lines. However, these improvements were uneven and insufficient to shift the municipality as a whole into a consistently high-accessibility cluster. Instead, they point to the beginnings of change that may require further investments to consolidate gains in accessibility. First, LL to HH shifts, such as in Kawit, demonstrate how targeted infrastructure, such as new roads, terminals, and expanded service coverage, can alter spatial accessibility patterns, pulling previously peripheral municipalities into the core accessibility network. Furthermore, persistent LL clusters such as Rosario and Cavite City highlight the limitations of urbanization without corresponding transport integration. Dense populations and economic growth alone do not guarantee improved accessibility when networks bypass localities. Finally, partial transitions, as in parts of Dasmariñas, show the uneven spatial impacts of infrastructure projects, where improvements may concentrate in certain barangays but not extend across the entire municipality.

Overall, the maps from 2013 to 2023 indicate that while accessibility has improved in core urban municipalities, spatial disparities remain, particularly in areas where transport networks and service coverage have not expanded in line with regional growth.

4.3 Route Modification

In the final phase of the study, route modification strategies were implemented. Given that rising transport costs were the only factor negatively influencing accessibility, the modifications focused exclusively on jeepneys, which are the most affordable mode of public transport in the Philippines. This decision was made to ensure that route improvements would not increase the financial burden on commuters, especially in low- to middle-income areas.

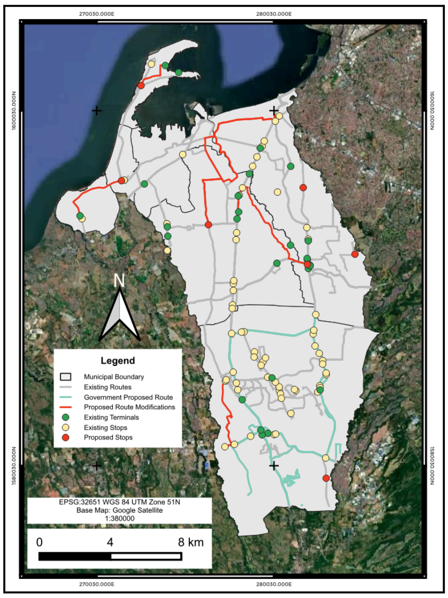

Figure 8. Proposed Route Map

In Figure 8, six new jeepney routes were proposed using existing infrastructure and travel-time impedance analysis. These include strategic connections such as SM Rosario to Manila-Cavite Road via Marseilla Road, Robinsons Imus to Molino via Buhay na Tubig Road, Governor's Drive to Don Placido Campos Avenue, and multiple alignments between St. Dominic and Patindig Araw Road. Another route loops through Cavite City's interior neighborhoods, improving service coverage for dense residential areas that were previously underserved.

To complement these proposed routes, seven new jeepney stops were introduced, following Regidor et al.'s 30-meter-from-intersection guideline for safety and flow management. These stops were strategically placed in areas such as Paliparan-Silang Road in Dasmariñas, Gawaran Avenue and Molino Road in Bacoor, Marseilla in Noveleta, Daang Hari in Bacoor, NIA Road in Imus, and J. Felipe Boulevard in Cavite City. Each stop was intended to serve areas with high commuter demand but lacking designated transport points, thereby

https://doi.org/10.5194/isprs-archives-XLVIII-5-W4-2025-55-2026

reducing reliance on informal loading practices. Together, the new routes and stops aim to enhance connectivity, reduce travel time, and ensure more equitable transport access across rapidly urbanizing municipalities, particularly in areas where accessibility has lagged behind urban growth.

To further validate the effectiveness of the proposed route modifications, a follow-up univariate Local Moran's I analysis was conducted after integrating the new routes and stops. The results showed a slight but meaningful improvement in spatial clustering patterns, with the persistence of high-high clusters expanding into areas that were previously categorized as low-low zones. This shift indicates a positive spatial response, where the intervention helped improve traffic accessibility in previously underserved locations.

Cluster Type	Before Modification (2023)	After Modification (2023)	Change
High-High (HH)	2,900 grids	4,012 grids	+1,112
Low-Low (LL)	2,637 grids	1,642 grids	–995
Not Significant (NS)	4,619 grids	4,502 grids	–117
Total	10,156 grids	10,156 grids	-

Table 2. Changes in LISA cluster classification before and after route modifications

5. Conclusion and Recommendations

5.1 Conclusion

From 2013 to 2023, traffic accessibility in Cavite's Districts 1–4 improved overall, driven by increased proximity to public transport lines, better distribution of terminals and stops, and a more connected road network. Urban municipalities like Imus, Bacoor, and Dasmariñas consistently scored high due to their dense transport infrastructure and proximity to major corridors. However, coastal and peripheral areas such as Cavite City, Rosario, and Noveleta continued to experience limited accessibility due to sparse route coverage and slower road classifications. While infrastructure investments generally enhanced accessibility, a noticeable decline in 2023 was attributed solely to rising transport costs, as confirmed by sensitivity analysis. This highlights that despite physical network improvements, fare inflation which was exacerbated by the COVID-19 pandemic and modernization programs, undermined affordability and accessibility, especially for lower-income commuters.

Spatial autocorrelation analysis confirmed these patterns, with univariate Global Moran's I values remaining consistently high (0.994–0.995), indicating strong spatial clustering of accessibility over time. High-High clusters were concentrated in well-connected municipalities like Imus, Bacoor, and Dasmariñas, while Low-Low clusters persisted in underserved zones such as Cavite City, Rosario, and southern Dasmariñas. To address these gaps, route modification strategies were introduced, focusing exclusively on jeepneys as the most cost-effective mode. Six new routes and seven new transport stops were proposed using existing infrastructure, guided by travel-time analysis and strategic stop placement. A follow-up spatial analysis after these interventions revealed a notable improvement in clustering, with some previously low-accessibility areas transitioning to higher cluster groupings. This validates that the proposed modifications not only expanded coverage but also helped realign public transport access with areas of high urban demand, contributing to a more equitable and efficient transport system.

5.2 Recommendations

While the current study provides a foundational analysis of traffic accessibility in Cavite, it acknowledges several limitations and recommends key enhancements for future research. Notably, non-fixed route transport modes such as tricycles, taxis, and app-based services like Grab and Angkas were excluded from the analysis, along with real-time traffic congestion data. Future studies should incorporate congestion metrics and detailed travel time components, including walking, waiting, in-vehicle, and transfer times, to offer a more realistic and commuter-centered accessibility assessment. Integrating public transport timetables and the number of operational units per route would also improve accuracy in measuring service capacity and availability. Additionally, expanding the geographic scope to include the broader MUCEP region and considering upcoming infrastructure projects would help contextualize accessibility within interprovincial commuting patterns. Finally, extending the study period to 30 years would allow for a more comprehensive understanding of long-term urbanization and mobility trends, enhancing the strategic value of accessibility planning.

References

Anselin, L., 1995. Local indicators of spatial association—LISA. *Geographical Analysis,* 27(2). dces.webhosting.cals.wisc.edu/wp-content/uploads/sites/128/2013/08/W4_Anselin1995.pdf (23 August 2025).

Arcaño, A., De Guzman, K.K., Sales, R.D., Tan, J.T., Lucas, K.J., & Fillone, A., 2023. Proposed improvement of the public transport service routes in Northern Iloilo, Region VI, Philippines. [Thesis, De La Salle University, Manila]. ncts.upd.edu.ph/tssp/wp-content/uploads/2023/01/TSSP2022_03-1.pdf (23 August 2025).

Belizario, M.C., Paz, G.C.D., & Regidor, J.R., 2017. A study on the potential for rationalizing road public transport services with respect to a rail transit line extension. *Eastern Asia Society for Transportation Studies*, 2017. doi.org/10.11175/easts.12.1383.

Bragais, M.A.B., 2022. The impacts of rapid urbanization in the rural-urban fringe area: the case in the Province of Cavite, Philippines. hdl.handle.net/11250/3059182 (23 August 2025).

Cavite Ecological Profile, 2021. cavite.gov.ph/home/wp-content/uploads/2023/02/CEP2021_FINAL.pdf (23 August 2025).

Cavite Ecological Profile, 2023. Provincial Planning and Development Office (PPDO) Cavite.

Department of Transportation, Department of the Interior and Local Government, & Land Transportation Franchising and Regulatory Board, 2017. Local public transport route plan manual (Vol. 1). Department of the Interior and Local Government. dilg.gov.ph/PDF_File/reports_resources/dilg-reports-resources-2017112_2cf0f97098.pdf (23 August 2025).

Farrington, J., & Farrington, C., 2004. Rural accessibility, social inclusion and social justice: towards conceptualisation. *Journal* *of Transport Geography,* 13(1), 1–12. doi.org/10.1016/j.jtrangeo.2004.10.002.

Forman, E., & Peniwati, K., 1998. Aggregating individual judgments and priorities with the analytic hierarchy process. *European Journal of Operational Research,* 108(1), 165–169. doi.org/10.1016/s0377-2217(97)00244-0.

Ge, F., Chen, W., Zeng, Y., & Li, J., 2021. The nexus between urbanization and traffic accessibility in the Middle Reaches of the Yangtze River Urban Agglomerations, China. *International Journal of Environmental Research and Public Health,* 18(7). doi.org/10.3390/ijerph18073828.

Gonçalves, J., Gomes, M., & Ezequiel, S., 2017. Defining mobility patterns in peri-urban areas: a contribution for spatial and transport planning policy. *Case Studies on Transport Policy,* 5(4), 643–655. doi.org/10.1016/j.cstp.2017.07.009.

Hansen, W. G., 1959. How accessibility shapes land use. *Journal of the American Institute of Planners,* 25(2), 73–76. doi.org/10.1080/01944365908978307.

İzgi, B. D., 2024. Quantitative analysis of peri-urbanization—Developing a peri-urban index for medium-sized cities using the analytic hierarchy process—A case study of Yozgat, Turkey. *Sustainability,* 16(14), 6002. doi.org/10.3390/su16146002.

Japan International Cooperation Agency, 2012. Chapter 4—Traffic study. In Preparatory survey for expressway projects in mega Manila region, Cavite–Laguna expressway project (Laguna section) final report. openjicareport.jica.go.jp/pdf/12113262_02.pdf (23 August 2025).

Litman, T., 2003. Measuring transportation: Traffic, mobility and accessibility. *ITE Journal,* 73(10), 28-32. citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=a084703ad74f513743d8be26b02b4492ea3d1c23 (23 August 2025).

Litman, T., 2024. Evaluating accessibility for transport planning. Victoria Transport Policy Institute. www.vtpi.org (23 August 2025).

Mortoja, M.G., Yigitcanlar, T., 2022. Factors influencing peri-urban growth: Empirical evidence from the Dhaka and Brisbane regions. *Remote Sensing Applications: Society and Environment,* 26, 100762. doi.org/10.1016/j.rsase.2022.100762

Nie, K., Wang, Z., Du, Q., Ren, F., Tian, Q., 2015. A network-constrained integrated method for detecting spatial cluster and risk location of traffic crash: A case study from Wuhan, China. *Sustainability,* 7(3), 2662-2677.

Nogueira, A.C.C.S., Diaz, C.E.D., 2023. Evaluating public transport accessibility and walkability in Pasig City (Philippines) and their correlation to socioeconomic factors at the Barangay level. *Asian Transport Studies,* 9, 100117. doi.org/10.1016/j.eastsj.2023.100117

Olsson, J., 2008. Improved road accessibility and indirect development effects: evidence from rural Philippines. *Journal of Transport Geography,* 17(6), 476–483. doi.org/10.1016/j.jtrangeo.2008.09.001

Province of Cavite, n.d. cavite.gov.ph/home/ (23 August 2025).

Regidor, J.R., Ieda, H., Sigua, R., 2018. Traffic Problems at Jeepney Stops and Proposals for the Development of a Better Jeepney Stop Policy. National Center for Transportation Studies. ncts.upd.edu.ph/tssp/wp-content/uploads/2018/08/Regidor96.pdf (23 August 2025).

Saaty, R., 1987. The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling,* 9(3–5), 161–176. doi.org/10.1016/0270-0255(87)90473-8

Stanković, M., Gladović, P., Popović, V., Lukovac, V., 2018. Selection criteria and assessment of the impact of traffic accessibility on the development of suburbs. *Sustainability,* 10(6), 1977. doi.org/10.3390/su10061977

Van Wee, B., 2015. Accessible accessibility research challenges. *Journal of Transport Geography,* 51, 9–16. doi.org/10.1016/j.jtrangeo.2015.10.018

Verburg, P.H., Overmars, K.P., Witte, N., 2004. Accessibility and land‐use patterns at the forest fringe in the northeastern part of the Philippines. *Geographical Journal,* 170(3), 238–255. doi.org/10.1111/j.0016-7398.2004.00123.x

Vergara, K.A., Sanchez, J., Bautista, E.L., 2019. Site selection for new point to point (P2P) bus endpoints and routes in Metro Manila, Philippines. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.,* XLII-4/W16, 659–666. doi.org/10.5194/isprs-archives-XLII-4-W16-659-2019

Webster, D., 2002. On the edge: Shaping the future of peri-urban East Asia. citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=55e8f06b80e28ac57d7f81cce615558939bbe22e (23 August 2025).