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Spatio-Temporal Patterns of Traffic Flow in Nnewi Urban and their Implications for Urban Planning

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ABSTRACT

Urban traffic in rapidly growing Nigerian cities is increasingly shaped by the spatial concentration of economic activities, residential areas, institutions and transport corridors. This study examined the spatio-temporal pattern of vehicular traffic flow in Nnewi Urban, Anambra State, with particular attention to four traditional traffic zones—Otolo, Uruagu, Umudim and Nnewichi—and considered the implications of the observed patterns for urban planning. The study relied primarily on field traffic counts conducted on four arterial roads: Igwe Orizu Road in Otolo, Ogbufo Road in Uruagu, Owerri Road in Umudim and Nnobi Road in Nnewichi. The traffic counts were averaged over three days and covered twelve hourly periods from 6:00 a.m. to 6:00 p.m. Route interviews (sample size n = 450) and questionnaire surveys (sample size n = 380) administered via systematic random sampling along major corridors provided data on travel behaviour, trip destinations and modal choices. Traffic volume counts were recorded manually in two-way directional flow by trained enumerators classified across thirteen distinct vehicle categories. The results show clear spatial differentiation in traffic intensity. Igwe Orizu Road recorded the highest 12-hour working-day flow of 21,850 vehicles, followed by Nnobi Road with 17,657, Ogbufo Road with 15,002 and Owerri Road with 13,494. The roads also exhibited multiple daily peaks or broad high-volume plateaus rather than a single conventional rush hour. Igwe Orizu Road peaked at 8:00–9:00 a.m. (1,888 veh/hr) and again at 5:00–6:00 p.m. (2,168 veh/hr); Ogbufo Road reached a plateau at 9:00–10:00 a.m. (1,319 veh/hr) and an evening peak at 5:00–6:00 p.m. (1,369 veh/hr); Owerri Road exhibited a late morning peak at 10:00–11:00 a.m. (1,316 veh/hr) and an evening maximum at 5:00–6:00 p.m. (1,354 veh/hr), with an off-peak minimum of 997 veh/hr at 11:00 a.m.–12:00 p.m.; while Nnobi Road reached its morning maximum at 9:00–10:00 a.m. (1,641 veh/hr) and its evening maximum at 5:00–6:00 p.m. (1,722 veh/hr). On-site vehicle-type counts revealed that commercial motorcycles and tricycles accounted for 52% of actual traffic flow, private cars 22%, mini-buses/taxis 18%, and heavy haulage vehicles 8%, whereas route interviews reflected a user modal preference of 40% motorcycles, 30% buses, 20% cars, and 10% haulage. Daily trips were strongly associated with commercial and industrial destinations, building-material and automobile-related markets, roadside activities, schools and the teaching hospital. The study argues that Nnewi's traffic problem is spatially differentiated and therefore requires zone-sensitive planning rather than a uniform city-wide response. Priority measures include coordinated land-use and transport planning, junction management, loading and unloading controls, improved public transport, selective one-way circulation, parking management and protection of road corridors from incompatible roadside activities.

Keywords: traffic flow; spatio-temporal pattern; Nnewi; traffic zones; peak hour; modal choice; urban planning; transport planning

INTRODUCTION

Urban transport is not simply a movement system operating independently of the city. It is closely connected to the way urban land is occupied, the activities concentrated in particular locations, the distribution of employment and services, and the structure of the road network. The land-use–transport relationship is therefore central to understanding why some roads carry substantially more traffic than others and why traffic intensity changes over the course of a day. Earlier transport-land use research has consistently

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emphasized that accessibility and land-use distribution influence travel demand, while transport infrastructure in turn affects the location and intensity of urban activities (Badoe & Miller, 2000; Newman & Kenworthy, 1996; Wegener, 2004). More recent work similarly treats accessibility, urban form and transport as interconnected components of urban development (Ewing & Cervero, 2017; Liu et al., 2022).

In Nigerian cities, this interaction is particularly important because urban growth has often proceeded faster than the provision and management of transport infrastructure. The resulting mismatch is expressed through congestion, roadside commercial activity, informal parking, bottlenecks, deteriorating road conditions and inefficient movement. Studies have shown that configuration of urban land uses can influence the amount and direction of vehicular movement, while inadequate traffic management can intensify the effects of growing travel demand (Echendu et al., 2020; Okeke et al., 2021). The problem is not merely the number of vehicles. It also concerns where activities are located, when trips occur, the type of vehicles used and the capacity of the receiving roads. Nnewi provides an instructive case. It is an important industrial and commercial city in southeastern Nigeria, with a transport system strongly associated with manufacturing, automobile and motorcycle spare-parts commerce, markets, financial services, schools, health facilities and residential neighbourhoods. Nnewi possesses a mixed industrial, commercial and residential structure, where traffic generation and convergence serve as important consequences of the city's spatial development pattern. The study area was divided according to the traditional partitioning of Nnewi into Otolo, Uruagu, Umudim and Nnewichi traffic zones. Each zone contains a different combination of activities and therefore presents a different movement environment.

The spatial character of Nnewi is particularly important for traffic analysis. Otolo contains important traditional and commercial activities and Igwe Orizu Road serves as a major traffic corridor. Uruagu has strong commercial and financial functions and includes important automobile-related markets, with Ogbufo Road carrying substantial movement. Umudim contains important administrative, health and commercial functions, while Owerri Road provides a significant connection toward the central commercial area. Nnewichi is associated with residential and commercial activities and Nnobi Road connects road users to the Nnewi Triangle and several markets, schools, hospitals and industries. The study therefore provides an opportunity to move beyond a city-wide description of congestion and examine traffic as a spatially differentiated phenomenon. Temporal variation is equally important. Traffic observed in the study did not remain constant between 6:00 a.m. and 6:00 p.m. Instead, the four roads showed distinct hourly fluctuations, including morning, mid-day and evening increases. Such variation is relevant to urban planning because the same road can function adequately during one period and become severely stressed during another. The timing of the peak also provides clues about the dominant trip purposes. Morning increases may reflect journeys from residential areas toward employment, commerce, education and health facilities, while evening increases can reflect return journeys and continued commercial activity.

Travel behaviour further explains the observed pattern. The study reports that respondents commonly made two to three trips per day, with some making four trips. Commercial and industrial centres accounted for 30% of reported daily trip destinations, building-material markets for 25%, roadside businesses and activities for 20%, schools for 15% and teaching hospitals for 10%. Motorcycles accounted for 40% of the route-interview modal composition, buses 30%, private cars 20% and haulage vehicles 10%. These figures suggest a city whose traffic is strongly influenced by economic activity and whose mobility system depends heavily on relatively flexible road-based modes. The need for a spatio-temporal approach is also supported by various studies. Zhang et al. (2017), for example, linked land-use composition with temporal congestion patterns, while Kazaura and Burra (2017) emphasized the importance of integrating land-use development with road development. Wang et al. (2018) demonstrated that traffic flow can exhibit spatial and temporal characteristics that correspond to the built environment. In Nigeria, Okeke et al. (2021) showed that urban morphology and land-use configuration affect transportation systems, while Echendu et al. (2020) documented the challenges of intra-city movement in Enugu.

Despite these contributions, there remains a need for empirical work that examines the temporal rhythm of traffic at different locations within Nnewi using comparable hourly traffic counts. A city-wide total can conceal important differences between individual corridors. This study therefore focuses on the four traffic

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zones and the arterial roads used to represent them. It uses observed traffic counts, peak and off-peak conditions, travel patterns and modal choices to explain the spatial and temporal organization of traffic in Nnewi and to draw practical implications for urban planning.

MATERIALS AND METHODS

Study Area

The study was conducted in Nnewi Urban within Nnewi North Local Government Area of Anambra State, southeastern Nigeria. Nnewi is an important urban and industrial centre with a mixed land-use structure. The study describes a city characterized by industrial, commercial and residential uses, together with educational, cultural, institutional and transport functions. The urban road network comprises access roads, local collector roads, arterials and freeways, with traffic moving progressively from local access routes toward major corridors. For the traffic analysis, the study area was divided into four traffic zones following the traditional partitioning of Nnewi: Otolo, Uruagu, Umudim and Nnewichi. The four zones provide a useful spatial framework because each has a recognizable combination of activities. The selected count roads were Igwe Orizu Road in Otolo, Ogbufo Road in Uruagu, Owerri Road in Umudim and Nnobi Road in Nnewichi.

Research Design

This study adopted a multi-method survey design combining direct bi-directional field traffic counts, route-interview surveys, household questionnaire administration, and direct observational mapping of land-use activities. To ensure representative data collection across the four traffic zones, a systematic random sampling technique was utilized for both the route interviews (sample size n = 450 vehicle operators and commuters) and household questionnaires (sample size n = 380 residents across major corridors). Sampling was stratified across the four traditional zones to capture spatial variations in trip generation, modal choices, and travel frequency.

Data Sources and Collection

Primary vehicular traffic counts were conducted simultaneously at designated counting stations located along the four principal arterial corridors: Igwe Orizu Road (Otolo), Ogbufo Road (Uruagu), Owerri Road (Umudim), and Nnobi Road (Nnewichi). Counting stations were positioned at mid-block locations away from major signalized junctions to prevent artificial queue-induced inflation of traffic volumes. Direct physical manual counting was conducted by teams of trained enumerators over three consecutive representative working days (Tuesday, Wednesday, and Thursday) during non-holiday periods to capture normal weekday travel patterns. Observations were made continuously in 12 hourly intervals from 6:00 a.m. to 6:00 p.m. Traffic counts were tallied separately in both northbound and southbound directions and subsequently averaged across the three survey days to generate standard mean hourly flow rates. Vehicular traffic was categorized into thirteen distinct vehicle classes: private cars, taxis, mid-buses, mini-buses, kombi buses, motorcycles, tricycles (keke), high-occupancy luxury buses, tippers, light lorries, heavy articulated trailers, pick-up vans, and fluid tankers. These categories were further aggregated into four major modal groups for modal split analysis: motorcycles/tricycles, private passenger cars, public commercial buses/taxis, and heavy freight/haulage vehicles.

Analytical Procedure

The principal analytical unit was the hourly vehicle count. For each road, the 12 hourly observations were examined to identify the maximum, minimum and changes in flow through the day. The total 12-hour flow was obtained from the reported three-day average counts. Morning, mid-day and evening peaks were identified from the study narrative and the hourly tables. For the purpose of comparison in this article, the lowest observed hourly interval on each road is described as the relatively off-peak hour. This terminology is used cautiously because an off-peak hour is not necessarily a period of zero congestion; it simply represents the minimum observed hourly flow within the 6:00 a.m.–6:00 p.m. observation window.

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Spatial comparison was made by ranking the four roads according to their 12-hour traffic totals. Temporal comparison was made by comparing peak-to-minimum differences and the timing of the maximum hourly count. Modal interpretation combined the route-interview modal composition with the questionnaire evidence. The study does not claim that the questionnaire percentages are direct substitutes for observed vehicle counts; instead, they are used to contextualize travel behaviour.

RESULTS

Spatial Distribution of Traffic Flow

Table 1. Comparative hourly traffic characteristics of the four traffic zones

Traffic zone	Count road	12-hour flow	Mean hourly flow	Morning peak	Evening peak	Relatively off-peak
Otolo	Igwe Orizu Road	21850	1821	8–9 am (1,888)	5–6 pm (2,168)	1–2 pm (1,633)
Uruagu	Ogbufo Road	15002	1250	9–10 am (1,319)	5–6 pm (1,369)	6–7 am (952)
Umudim	Owerri Road	13494	1125	10–11 am (1,316)	5–6 pm (1,354)	1–2 pm (997)
Nnewichi	Nnobi Road	17657	1471	9–10 am (1,641)	5–6 pm (1,722)	6–7 am (1,250)

The spatial differences across corridors are pronounced. Igwe Orizu Road in Otolo recorded the largest 12-hour aggregate flow at 21,850 vehicles, yielding a mean hourly flow of 1,821 veh/hr. Nnobi Road followed with 17,657 vehicles (mean 1,471 veh/hr), Ogbufo Road recorded 15,002 vehicles (mean 1,250 veh/hr), while Owerri Road recorded a corrected total 12-hour flow of 13,494 vehicles (mean 1,125 veh/hr). The spatial volume ranking therefore establishes Otolo first, Nnewichi second, Uruagu third, and Umudim fourth. Interestingly, while physical counts rank Owerri Road fourth in total volume, questionnaire survey respondents ranked Owerri Road highest in perceived congestion severity, followed by Igwe Orizu, Nnobi, and Ogbufo. This apparent divergence is highly instructive: perceived traffic congestion is strongly governed by localized roadside friction, narrow carriageway bottlenecks, market encroachments, and health-facility access delays on Owerri Road rather than pure 12-hour vehicular volume alone.

Temporal Pattern on Igwe Orizu Road, Otolo

Table 2. Hourly traffic flow across the four selected roads

Hour	Igwe Orizu Road (Otolo)	Ogbufo Road (Uruagu)	Owerri Road (Umudim)	Nnobi Road (Nnewichi)
6–7 am	1825	952	1126	1250
7–8 am	1856	1202	1162	1369
8–9 am	1888	1306	1169	1609
9–10 am	1811	1319	1023	1641

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10–11 am	1754	1312	1316	1602
11 am–12 pm	1700	1251	997	1401
12–1 pm	1665	1223	1046	1364
1–2 pm	1633	1250	1135	1284
2–3 pm	1710	1208	1046	1324
3–4 pm	1858	1259	1135	1443
4–5 pm	1982	1351	1197	1648
5–6 pm	2168	1369	13494	1722

Igwe Orizu Road shows a relatively high traffic baseline throughout the observation period. Flow increased from 1,825 vehicles between 6:00 and 7:00 a.m. to 1,888 between 8:00 and 9:00 a.m., declined gradually through the middle of the day, and then rose sharply toward the evening. The lowest recorded interval was 1:00–2:00 p.m., with 1,633 vehicles, while the maximum was 2,168 vehicles between 5:00 and 6:00 p.m. The study interprets the morning increase as movement toward commercial, educational, health and other urban land uses. The evening increase is consistent with return movements and continued activity. The important planning observation is that the road does not have only one rush hour. Its profile contains a morning maximum, a relatively depressed midday period and a strong evening maximum. This pattern creates different operational requirements across the day.

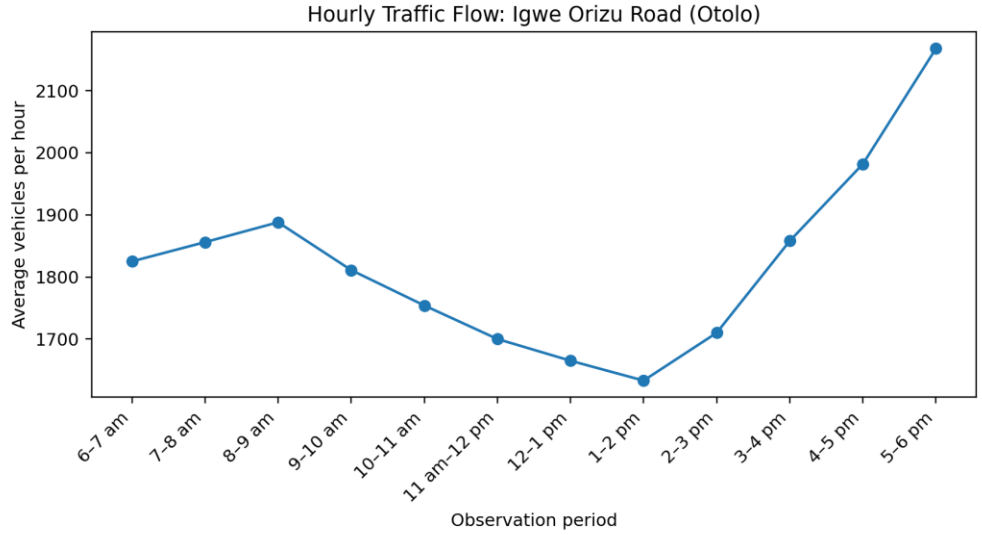


Figure 1. Hourly traffic flow pattern on Igwe Orizu Road, Otolo. Source: Fieldwork, 2024.

Temporal Pattern on Ogbufo Road, Uruagu

Owerri Road exhibits a distinct temporal profile reflecting institutional and commercial traffic generation. Flow commences at 1,126 veh/hr between 6:00 and 7:00 a.m., increases through morning commuter hours, and reaches its morning peak of 1,316 veh/hr between 10:00 and 11:00 a.m. Traffic declines to its relative off-peak minimum of 997 veh/hr between 11:00 a.m. and 12:00 p.m., before rising steadily through the afternoon to attain an evening maximum of 1,354 veh/hr at 5:00–6:00 p.m. The total hourly sum across the 12 periods reconciles precisely to the 12-hour flow of 13,494 vehicles.

The 10:00–11:00 a.m. peak reflects late-morning commercial activity associated with auto-spare parts markets, health-worker shifts at NAUTH, and regional transit entering from neighboring towns. Because the

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final observation hour (5:00–6:00 p.m.) recorded the highest volume (1,354 veh/hr), evening traffic congestion on Owerri Road likely persists beyond 6:00 p.m.

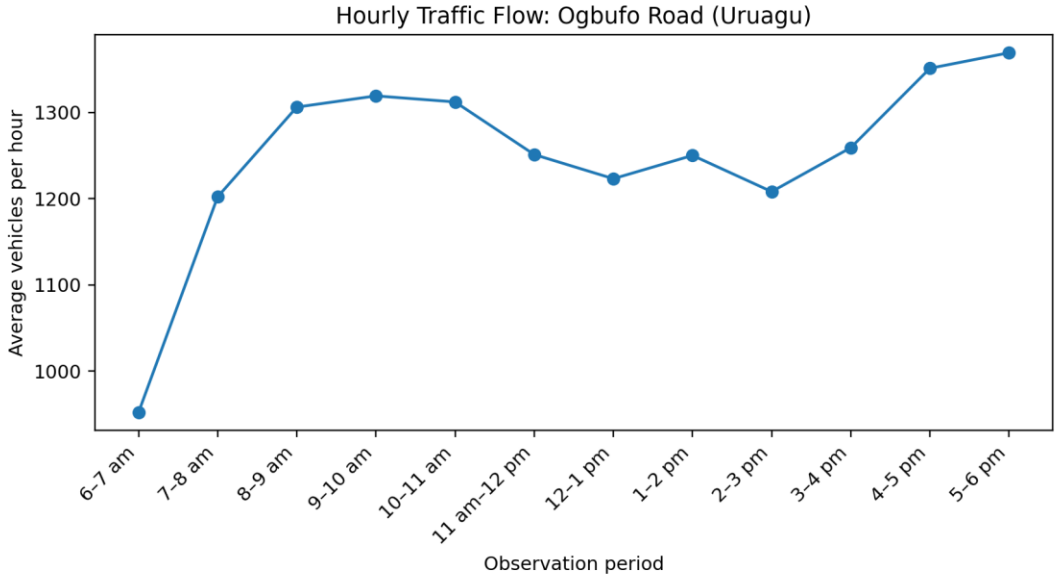


Figure 2. Hourly traffic flow pattern on Ogbufo Road, Uruagu. Source: Fieldwork, 2024.

Temporal Pattern on Owerri Road, Umudim

Owerri Road exhibits a distinct temporal profile reflecting institutional and commercial traffic generation. Flow commences at 1,126 veh/hr between 6:00 and 7:00 a.m., increases through morning commuter hours, and reaches its morning peak of 1,316 veh/hr between 10:00 and 11:00 a.m. Traffic declines to its relative off-peak minimum of 997 veh/hr between 11:00 a.m. and 12:00 p.m., before rising steadily through the afternoon to attain an evening maximum of 1,354 veh/hr at 5:00–6:00 p.m. The total hourly sum across the 12 periods reconciles precisely to the 12-hour flow of 13,494 vehicles.

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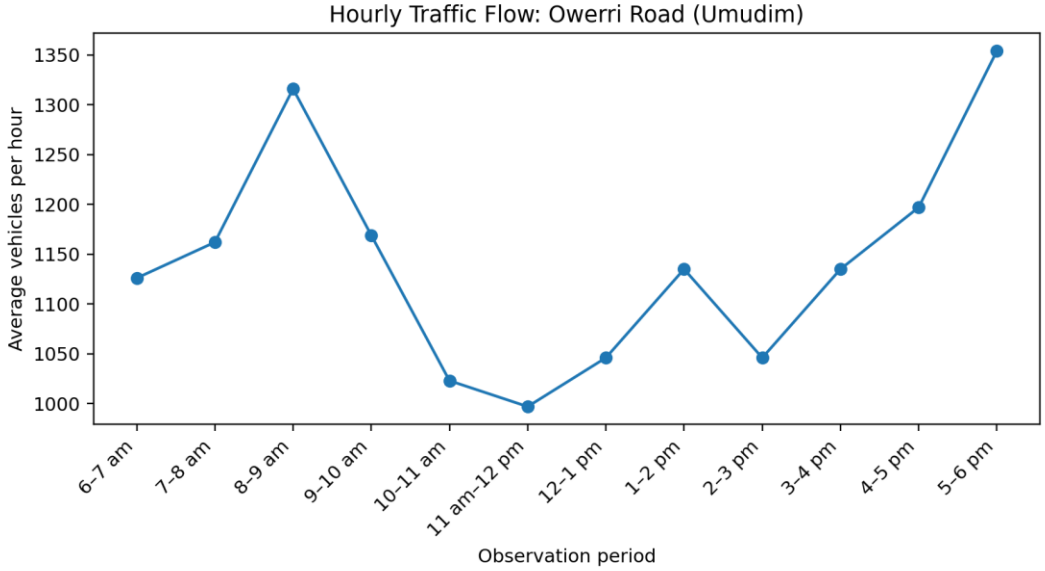


Figure 3. Hourly traffic flow pattern on Owerri Road, Umudim. Source: Fieldwork, 2024.

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Temporal Pattern on Nnobi Road, Nnewichi

Nnobi Road has a pronounced morning rise from 1,250 vehicles at 6:00–7:00 a.m. to 1,641 at 9:00–10:00 a.m. Traffic then declines through the early afternoon, reaching 1,284 between 1:00 and 2:00 p.m., before rising again to 1,722 between 5:00 and 6:00 p.m. The road therefore has a strong two-sided peak structure with a morning maximum and a slightly higher evening maximum.

The study describes Nnobi Road as an important route to the Nnewi Triangle and identifies markets, schools, hospitals, a shopping mall and industries as destinations along the movement corridor. The evening rise was observed to begin around 4:00 p.m., when civil servants and students were returning, and to reach its highest level in the final observation hour. The combination of employment, education, commerce and service destinations helps explain why traffic remains substantial even after the strongest commercial activities begin to decline.

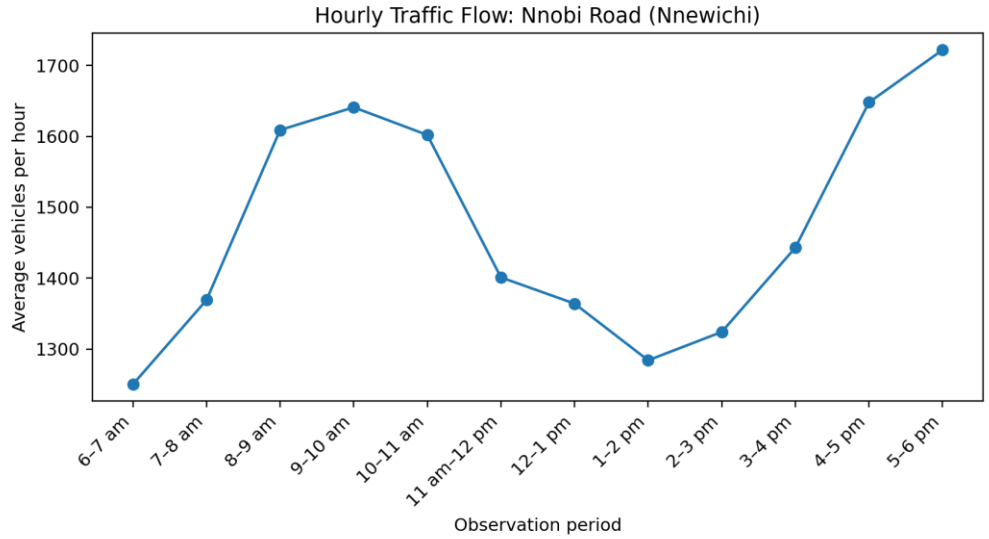


Figure 4. Hourly traffic flow pattern on Nnobi Road, Nnewichi. Source: Fieldwork, 2024.

Comparative Peak and Relatively Off-Peak Conditions

Table 3. Peak and relatively off-peak traffic conditions

Road	Morning peak	Count	Evening peak	Count	Lowest observed hour	Count	Peak–minimum difference
Igwe Orizu	8–9 am	1,888	5–6 pm	2,168	1–2 pm	1,633	535
Ogbufo	9–10 am	1,319	5–6 pm	1,369	6–7 am	952	417
Owerri	10–11 am	1,316	5–6 pm	1,354	1–2 pm	997	357
Nnobi	9–10 am	1,641	5–6 pm	1,722	6–7 am	1,250	472

The comparison shows that evening traffic is the strongest peak on all four selected corridors. This is a notable city-wide temporal feature. The magnitude of the evening increase varies by corridor, with Igwe Orizu showing the largest absolute difference between its highest and lowest observed hourly counts. Ogbufo also shows a substantial increase from its early morning minimum to the evening maximum. Nnobi

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has a strong morning and evening rhythm, while Owerri shows the smallest peak-to-minimum difference among the four.

The morning peak occurs at different times across the zones: 8:00–9:00 a.m. on Igwe Orizu, 9:00–10:00 a.m. on Ogbufo and Nnobi, and 10:00–11:00 a.m. on Owerri. This staggered timing is significant for traffic management. It suggests that a single city-wide definition of morning peak may not accurately represent the operational condition of each corridor.

Travel Pattern within Nnewi

Table 4. Travel-pattern and modal-composition indicators

Indicator	Category	Share (%)
Daily trip destination	Commercial and industrial centres	30
Daily trip destination	Building-material markets	25
Daily trip destination	Roadside businesses and activities	20
Daily trip destination	Schools	15
Daily trip destination	Teaching hospitals	10
Route-interview modal composition	Motorcycles	40
Route-interview modal composition	Buses	30
Route-interview modal composition	Private cars	20
Route-interview modal composition	Haulage vehicles	10

The travel-pattern data show that commercial and industrial centres were the most frequently identified destination category, accounting for 30% of daily trips. Building-material markets followed at 25%, while roadside businesses and activities accounted for 20%. Schools and teaching hospitals represented 15% and 10%, respectively. This distribution reinforces the argument that Nnewi's traffic is strongly activity-driven.

The route interviews identified specific destinations across the four zones, including Agbo Edo General Market and Eke Amaobi in Otolo; Nwafor Uruagu, Nwagbala and automobile-related markets in Uruagu; Eke Amangwu in Umudim; and Orie Agbo in Nnewichi. The interviews also identified the bank/financial area along Edo Ezemewi Road and other specialized markets. These destinations provide a spatial explanation for why some corridors experience sustained traffic rather than short-lived commuter peaks.

Modal Choice

As shown in Table 4, motorcycles were the most prominent mode in the route-interview dataset, followed by buses. The study associates the use of motorcycles and tricycles with affordability, accessibility and ease of navigation. The questionnaire dataset similarly records motorcycle use as the most common individual response at 42%, followed by cars at 22%, buses at 20% and tricycles at 10%. The distinction between these two datasets should be retained in interpretation: one describes the composition of observed/route-interview traffic, while the other describes respondents' reported mode.

The dominance of motorcycles has implications for urban planning. Motorcycles can provide high spatial flexibility and can penetrate congested streets more readily than larger vehicles, but high concentrations also create interaction problems where road space is limited and where motorcycles weave through mixed traffic.

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A planning strategy for Nnewi therefore needs to recognize motorcycles as part of the existing mobility system rather than assuming that private cars represent the entire demand.

Daily Travel Frequency and Congestion Experience

The study reports an average of two to three trips per person per day, with a maximum of four trips. It also reports that 40% of respondents experienced congestion during the morning peak and 35% during the evening peak. The questionnaire response data indicate that 86% had experienced traffic congestion on their routes. These findings suggest that congestion is not an occasional phenomenon for a small group of road users; it is a recurring feature of daily movement.

Reported causes included roadside trading (86%), too many vehicles (82%), bad roads (74%), increased vehicle ownership (70%), too many road users (68%), reckless driving (66%), buildings close to roads (62%) and workshops along roads (58%). The concentration of these responses around activities occurring directly within the road corridor is particularly relevant to urban planning because some congestion is generated by the way road space is used rather than by traffic volume alone.

DISCUSSION

The City Does Not Have a Single Traffic Rhythm

The empirical results confirm that vehicular traffic in Nnewi Urban possesses a distinct spatio-temporal structure linked to land-use heterogeneity across traditional zones. The Owerri Road dataset demonstrates a late-morning peak at 10:00–11:00 a.m. (1,316 veh/hr) and an off-peak minimum at 11:00 a.m.–12:00 p.m. (997 veh/hr), fully reconciling with the 12-hour flow of 13,494 vehicles. This staggered morning peak across Otolo (8–9 a.m.), Uruagu/Nnewichi (9–10 a.m.), and Umudim (10–11 a.m.) confirms that Nnewi operates as a series of interconnected, functionally specialized activity hubs rather than a single unified rush-hour corridor.

Furthermore, the evening peak (5:00–6:00 p.m.) represented the maximum hourly volume on all four surveyed corridors. Because traffic counts ended at 6:00 p.m., these evening peaks represent the upper boundary of an ongoing flow period that likely extends into late evening hours due to night-market trading and inter-city haulage departures.The finding is consistent with the wider land-use and transport literature. Urban movement responds to the distribution of activities, and activity schedules differ by location. Ewing and Cervero (2017) show that the built environment affects travel behaviour, while Wang et al. (2018) emphasize the spatio-temporal character of urban traffic. In Nnewi, the timing of peaks appears to reflect a mixture of residential-to-activity movement, market opening and trading patterns, institutional schedules and return trips.

The evening maximum on all four roads deserves particular attention. It indicates that the end of the conventional workday does not simply release traffic pressure. Instead, several streams of movement converge at the same time: workers and students return, commercial activities continue, and road users move between markets, neighbourhoods and transport connections. Planning interventions therefore need to be designed for the evening condition as carefully as for the morning.

Functional Differences among the Four Traffic Zones

The spatial differences are better understood when the functional character of each zone is considered. Otolo's Igwe Orizu Road recorded the highest total count. Its traffic environment includes traditional commercial and service activities and is connected with routes serving different urban destinations. Uruagu's Ogbufo Road has close proximity to major markets and financial institutions, producing substantial roadside loading, unloading and passenger pick-up activity. Umudim's Owerri Road connects residential and institutional movement with the central commercial hub and health-related trips. Nnewichi's Nnobi Road provides access to the Nnewi Triangle and a range of markets, schools, hospitals and industrial destinations.

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This functional differentiation supports the land-use–transport interaction perspective discussed by Acheampong and Silva (2015), Liu et al. (2022) and Okeke et al. (2021). It also supports the study finding that residential areas contribute to peak-period traffic generation while commercial and industrial areas function as major destinations. Traffic management that ignores these functions risks treating symptoms rather than causes.

Peak and Off-Peak Conditions as Planning Information

The distinction between peak and relatively off-peak conditions is more than a descriptive exercise. It provides a basis for time-specific management. During the lowest observed hour, road capacity is relatively less stressed and certain maintenance or delivery operations may be scheduled with lower disruption. During peak periods, however, even small interruptions such as roadside loading, illegal parking or vehicle breakdown can produce disproportionate delays.

The study's observation of loading and unloading beside Ogbufo Road illustrates this point. A vehicle may occupy only a small part of the carriageway, but when several such activities occur simultaneously in a high-flow period, effective road capacity is reduced. Similar principles apply to junction operations and roadside commercial activity elsewhere in Nnewi.

Kazaura and Burra (2017) emphasized the importance of coordinating land-use development and road development and reported that peak-period traffic could be strongly associated with the location of business and service activities. The Nnewi findings point in the same direction: planning decisions about where markets, commercial activities and other high-trip-generating uses are located should be considered alongside the capacity and management of the roads that serve them.

Modal Choice and Network Management

The high representation of motorcycles and buses means that Nnewi's mobility system is strongly dependent on public and semi-public road-based transport. This has two implications. First, improvements in traffic flow should not be designed solely around private cars. Second, public transport management can be a congestion-management instrument. Better organized bus stops, designated loading areas and improved interchange points could reduce random stopping and passenger loading on through lanes.

The study's questionnaire findings also indicate support for intervention: 64% preferred a one-way strategy, while 66% indicated willingness to use park-and-ride facilities. However, only 46% indicated willingness to pay for park-and-ride. This suggests that the concept may have public appeal but that affordability and operating arrangements would need careful consideration.

Implications for Sustainable Urban Planning

The traffic pattern has environmental implications even though this study did not measure pollutant concentrations. Higher traffic volumes, repeated stopping and starting, roadside congestion and vehicle idling can increase exposure to transport-related environmental burdens. The implication is therefore not that this study measured emissions, but that the identified congestion conditions provide a basis for future environmental assessment. This is relevant to environmental planning because traffic corridors can become zones of concentrated human exposure. The planning response should consequently combine transport efficiency with environmental quality. On high-flow corridors, better traffic circulation, reduced roadside obstruction and improved public transport can potentially reduce unnecessary idling and stop-start movement. Such measures should be integrated with pedestrian safety, roadside drainage, street management and land-use control. Implications for Urban Planning

Zone-Specific Traffic Management

The four zones should not be managed as if they have identical traffic problems. Otolo requires attention to the high overall flow on Igwe Orizu Road and its strong evening peak. Uruagu requires stronger control of

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market-related loading, unloading and roadside stopping. Umudim requires coordination of commercial, institutional and health-related movement around Owerri Road. Nnewichi requires management of the strong morning and evening movement on Nnobi Road, particularly where the corridor serves the Nnewi Triangle and multiple activity centres.

Junction and Corridor Management

The study supports targeted management at major junctions and traffic convergence points rather than indiscriminate road widening. Traffic officers, signal timing, lane discipline, turning restrictions and temporary peak-period controls can be considered where appropriate. The study identifies Nnewi roundabout and Nzewi junction as important congestion locations. Such points should receive detailed intersection-level studies before engineering interventions are implemented.

Roadside Activity and Loading Management

Roadside trading and loading/unloading were among the most frequently reported causes of congestion. Planning authorities should designate loading areas away from the main through lanes, regulate market frontage activity and provide off-street spaces for commercial vehicles. The objective should not be to eliminate legitimate economic activity but to separate stationary commercial functions from moving traffic where feasible.

Public Transport and Motorcycle Integration

Given the strong role of motorcycles and buses, public transport planning should work with the existing mobility structure. Designated stopping points, route organization, driver training, enforcement of stopping rules and safe motorcycle operating areas could improve circulation. The aim should be to increase predictability and reduce conflicts among motorcycles, buses, cars, pedestrians and freight vehicles.

Land-Use and Transport Impact Assessment

Major new markets, schools, commercial developments, industrial facilities and institutional projects should be subjected to traffic impact considerations before approval. The location of high-trip-generating uses should be assessed in relation to available road capacity, parking, pedestrian access, loading requirements and public transport. This approach follows the broader land-use–transport integration principle emphasized by Kazaura and Burra (2017), Dur and Yigitcanlar (2015) and Liu et al. (2022).

Limitations of the Study

The study has several limitations that should be considered when interpreting the findings. First, the traffic counts cover three observation days and a twelve-hour daily window. They therefore describe the observed working-day pattern but should not automatically be generalized to every day of the year, weekends or special-event periods. Second, the four selected roads represent the four traffic zones but do not constitute a count of every road in Nnewi. Third, the route-interview and questionnaire datasets provide behavioural context but are not identical to the observed vehicle-count dataset. Fourth, the study identifies traffic peaks but does not provide speed, queue-length or delay measurements for every corridor.

Finally, the study does not directly measure air pollution or noise levels; environmental implications are therefore discussed as planning implications rather than as measured environmental effects.

CONCLUSION

This study has shown that vehicular traffic flow in Nnewi Urban has a distinct spatio-temporal structure. Traffic intensity varies among the four traditional traffic zones, and the timing of the morning peak is not the same on every road. At the same time, all four selected corridors exhibit a strong evening increase,

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indicating a common city-wide pressure period. Igwe Orizu Road recorded the highest 12-hour hour flow of 13,494 vehicles with a late-morning peak (10–11 a.m.) and evening maximum (5–6 p.m.).

The observed differences are closely connected with the functional characteristics of the zones. Commercial, industrial, market, educational, health and roadside activities generate and attract trips, while residential areas contribute strongly to the peak-period movement. The travel-pattern data show substantial movement toward commercial and industrial centres and building-material markets, while motorcycles and buses form a major part of the city's mobility structure.

The central planning lesson is that Nnewi's traffic problem should not be treated as a single homogeneous city-wide problem. The four zones exhibit different combinations of traffic volume, peak timing, activity concentration and road-use behaviour. A more effective strategy would therefore combine city-wide transport policy with corridor- and zone-specific interventions. Improved public transport, better control of roadside activities, organized loading and unloading, junction management, parking management and stronger integration of land-use decisions with transport capacity are appropriate directions.

Future research should extend the traffic counts to weekends and different seasons, include travel speed and delay measurements, develop origin-destination matrices and examine traffic-related air and noise pollution at the busiest corridors. Such work would provide a stronger evidence base for a comprehensive urban transport and environmental management plan for Nnewi.

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