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"SPATIOTEMPORAL TRAVEL-TIME VARIABILITY AND TRAFFIC BOTTLENECK ANALYSIS ALONG AN URBAN INTRA-CITY TRANSIT CORRIDOR IN ILE-IFE, NIGERIA"

SPATIOTEMPORAL TRAVEL-TIME VARIABILITY AND TRAFFIC BOTTLENECK ANALYSIS ALONG AN URBAN INTRA-CITY TRANSIT CORRIDOR IN ILE-IFE, NIGERIA

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ABSTRACT

Urban mobility in secondary cities across Sub-Saharan Africa faces mounting pressures from rapid motorisation, aging public transport fleets, and uncoordinated roadside land-use activities, resulting in travel-time unreliability and elevated fuel consumption and emissions. While transport scholarship has often concentrated on large metropolitan areas, empirical baseline assessments of intra-city transit corridors in university and secondary Nigerian cities remain comparatively limited. This study evaluates commercial bus travel times, speed profiles, and bottleneck friction along the arterial corridor connecting Obafemi Awolowo University (OAU) and Ife-City in Ile-Ife, Osun State, Nigeria. Primary movement tracking was conducted during a two-month field campaign using handheld Garmin GPS receivers across four daily operational windows: morning peak (7:00-9:00 AM), noon off-peak (11:00 AM-12:00 PM), afternoon transition (4:00-5:00 PM), and evening peak (5:00-6:00 PM). The campaign reportedly captured more than 78 tracked runs per operational window. GPS track logs were synchronized within ArcGIS and triangulated with structured surveys administered to 200 commercial bus operators and 200 commuters. Results indicate pronounced temporal differences in corridor performance. Mean travel time increased from a reported free-flow baseline of 13.5 minutes to 38.35 minutes in the morning peak and 44.34 minutes in the evening peak. Spatial analysis identified six reported friction-node groupings, including the OAU Campus Gate, Mayfair, Eleyele Junction, Lagere, Oja Market, and the Sabo-Phase II (OAUTHC) area. Survey responses identified peak-hour commuter surges, driver impatience and lane shifting, security inspections, roadside trading, narrow roadway geometry, and indiscriminate parking as reported contributors to congestion. The study provides corridor-level evidence to support targeted traffic management, improved stopping and loading arrangements, and more systematic monitoring of travel-time reliability in a secondary Nigerian city. The findings also offer a baseline for future assessment of transport-related energy use and emissions, although direct emissions reductions were not measured.

Keywords: Spatiotemporal variability; travel-time reliability; urban transit corridors; GPS tracking; traffic bottlenecks; Ile-Ife; Nigeria.

1. INTRODUCTION

1.1 Urban mobility, congestion and the sustainability challenge

Urban transport systems connect residents to employment, education, healthcare, markets and social activities. Their performance therefore affects not only journey duration but also access to opportunities, household expenditure, labour productivity and the spatial functioning of cities. In rapidly urbanising contexts, however, population growth, changing land-use patterns and increasing motorisation can place pressure on road networks whose capacity and management arrangements have not expanded at the same pace. The Intergovernmental Panel on Climate Change identifies transport

as a major source of greenhouse-gas emissions and emphasises that mitigation requires a combination of technological change, demand management, land-use planning and shifts towards more efficient modes (Jaramillo et al., 2022).

These challenges are especially important in African cities, where public transport frequently includes a mixture of formal services and privately operated paratransit. Such services can provide extensive coverage where formal networks are limited, but they may also operate with variable stopping practices, route structures and service frequencies. Comparative research across seven Sub-Saharan African cities demonstrates the value of examining paratransit network coverage and accessibility rather than treating public transport as a uniform system (Falchetta et al., 2021). A recent systematic review of transport accessibility research across African cities further identifies persistent data limitations and unequal access to opportunities as important research and policy concerns (Asuah & Acheampong, 2025).

In Nigeria, traffic congestion is not confined to the largest metropolitan areas. Secondary cities and university towns can experience concentrated travel demand around campuses, hospitals, markets, administrative centres and transport interchanges. Recent empirical work in Enugu demonstrates that congestion patterns can differ by corridor, direction, time of day and day of week, and that local activity patterns may produce distinctive temporal rhythms (Chukwurah et al., 2025). Research on traffic management in Akure similarly illustrates the need for location-specific diagnosis of traffic conditions before selecting interventions (Adelakun & Olufikayo, 2022).

1.2 Travel-time reliability as a measure of corridor performance

Average travel time is useful for describing typical operating conditions, but it does not fully communicate the uncertainty experienced by road users. Travel-time reliability concerns the consistency of journey duration across comparable trips and time periods. Two corridors may have similar mean travel times but substantially different levels of variability, meaning that users of the less reliable corridor must allow more additional time to arrive at a destination punctually. Research on urban arterial corridors has therefore developed reliability measures based on the distribution of observed travel times rather than relying exclusively on mean values (Tufuor & Rilett, 2021).

Common reliability indicators include the 90th- or 95th-percentile travel time, buffer time, buffer-time index and planning-time index. The buffer-time index expresses the additional time required above average travel time to accommodate variability, while the planning-time index compares a high-percentile travel time with a free-flow reference. These measures help distinguish recurrent congestion from unpredictable delay and can communicate the user experience more effectively than a single average (Federal Highway Administration, n.d.). In this study, the reported means and standard deviations provide an initial description of variation; however, percentile-based indicators should be calculated from the underlying GPS observations before the manuscript claims a complete reliability assessment.

The distribution of travel times is influenced by recurring demand peaks as well as stochastic events, including incidents, temporary obstructions, weather, enforcement activity and irregular passenger boarding. Tufuor and Rilett (2021) emphasise the importance of estimating corridor travel-time distributions for arterial reliability analysis. Recent work using probe-based travel data compares multiple reliability indicators and shows that the choice of metric can affect the diagnosis of urban travel-time variability (Sun & Chen, 2024). Other research has examined the frequency-domain and queueing characteristics of travel-time variation on congested corridors, demonstrating that variability can operate at more than one temporal scale (Cheng et al., 2024).

1.3 GPS, floating-car data and the measurement of urban travel times

GPS-based observation offers a practical way to measure vehicle movement along a route because it records position and time at successive points. When a vehicle is tracked repeatedly, the resulting trajectories can be used to estimate end-to-end travel time, segment speed, stopping duration and the spatial distribution of delay. Osei et al. (2022) used floating-vehicle and GPS probe data to model segment-level travel time on urban arterials in Kumasi, Ghana. Their

work is particularly relevant to lower-resource settings because it considers heterogeneous traffic and roadside influences such as on-street parking and access density.

GPS and floating-car data nevertheless require careful quality control. Position errors, signal loss, inconsistent sampling intervals, map-matching errors, unusual driver behaviour and a non-representative sample of tracked vehicles can bias estimates. Bruwer et al. (2023), reviewing commercial floating-car data in Sub-Saharan African transport planning, caution that differences in urban form, modal composition, driver populations and technology penetration can affect data representativeness. Consequently, a GPS-based corridor study should document device settings, sampling intervals, trip inclusion criteria, route matching procedures, missing-data treatment and the number of valid observations in each time window.

The combination of GPS trajectories with GIS allows travel-time observations to be related to specific road segments, intersections and land-use settings. Alkaissi and Hussain (2025) review GPS-based spatiotemporal analysis of urban streets and identify intersection delay, mixed land use and congestion as important influences on travel-time patterns. Zheng et al. (2024) further demonstrate the value of combining probe-vehicle information with other traffic data sources to estimate travel times on urban arterials. For the Ile-Ife corridor, this literature supports the use of spatially referenced speed reductions and cumulative delay profiles to identify locations requiring operational attention.

1.4 Roadside friction, land use and bottleneck formation

Urban arterial performance is shaped by more than the nominal width or design capacity of a road. On-street parking, passenger loading, roadside trading, pedestrian crossing, access points, turning movements and informal stopping can reduce effective road space and interrupt traffic progression. Osei et al. (2022) show that parking activity, access density and traffic density interact in explaining segment-level travel time on Ghanaian urban arterials. Their findings underline the importance of studying the actual operating environment rather than transferring models developed for more regulated road systems without local adjustment.

Roadside trading and informal occupation of road reserves also involve livelihood and planning dimensions. In Nigeria, roadside commerce may provide income and access to goods, but the occupation of road shoulders and pedestrian space can create conflict between commercial activity, pedestrian movement and vehicle flow. Tijjani et al. (2023) review factors associated with road-setback and open-space encroachment by traders in Nigeria, highlighting both the prevalence of informal activity and its potential implications for traffic and safety. Accordingly, policy responses should combine clear stopping and trading arrangements with fair enforcement and viable designated spaces, rather than assuming that displacement alone resolves the underlying demand for roadside commerce.

Bottlenecks can also arise at institutional gateways and activity centres. Security checks, passenger drop-off queues and concentrated arrivals can create localised queues that propagate upstream and reduce the performance of adjacent road segments. The effects may be amplified where a corridor serves a university, hospital, market and residential neighbourhood at the same time. Recent evidence from Nigerian cities reinforces the need to understand corridor-specific interactions among physical constraints, traffic demand and local activity patterns (Chukwurah et al., 2025; Ojo & Gbadegesin, 2024).

1.5 Informal public transport and corridor operations in African cities

Paratransit and privately operated minibuses remain important components of mobility in many African cities. Their flexibility can make them responsive to demand and enable services to reach locations that may be poorly served by formal public transport. However, service patterns that rely on frequent stopping, roadside passenger collection and competition for passengers may contribute to friction on already constrained corridors. Falchetta et al. (2021) show that paratransit networks differ in coverage, accessibility and connectivity across seven African cities, while Randall et al. (2023) synthesise evidence on the role of paratransit and active travel in African urban mobility.

The operational challenge is therefore not simply to remove informal public transport from the road, but to improve the conditions under which it operates. Designated loading areas, predictable stopping locations, coordinated terminal operations, route information and dialogue with operators can help reduce unnecessary interference while retaining the accessibility benefits of small-scale services. Comparative evidence suggests that the relative travel-time competitiveness of public transport and private cars can influence public-transport mode share, reinforcing the importance of reliable bus operations (Altieri et al., 2020). Evidence from West African cities also indicates that poor public transport service quality and the adaptations made by passengers should be considered when planning mobility interventions (Lesteven et al., 2025).

1.6 Day-of-week and time-of-day rhythms in urban congestion

Travel demand is not evenly distributed across the day or week. Morning and evening commuting peaks often reflect work and school schedules, while market days, institutional calendars, religious activities and weekend shopping can create additional local peaks. These patterns may differ between directions: a corridor can experience heavy inbound movement in the morning and heavy outbound movement later in the day. Chukwurah et al. (2025) demonstrate that day-of-week and evening-period patterns can be distinctive even within a single Nigerian city, cautioning against assuming that a standard weekday profile represents all operating conditions.

A robust temporal assessment should therefore compare equivalent time windows across multiple weekdays and, where relevant, weekends. The analytical design should also distinguish a difference in mean travel time from a statistically significant difference and should report the number of valid trips supporting each estimate. Where GPS observations are available at trip level, appropriate tests or regression models can examine the influence of period, day, direction and their interactions. This approach would strengthen the interpretation of the Ile-Ife weekly pattern and help identify whether observed differences are systematic or reflect a small number of unusually delayed runs.

1.7 Congestion, energy use and climate mitigation

Congestion can increase fuel use where vehicles spend longer idling, accelerate and decelerate repeatedly, or operate at inefficient speeds. However, the relationship between travel time and emissions is not one-to-one: vehicle type, engine condition, fuel, occupancy, driving cycle, road gradient and fleet composition also matter. The IPCC's transport assessment identifies demand management, public transport, land-use planning and vehicle technology as complementary components of transport mitigation (Jaramillo et al., 2022). Thus, improving corridor flow may contribute to emissions reduction, but a quantified carbon benefit requires vehicle activity and emissions-factor data rather than travel-time observations alone.

For secondary cities, relatively low-cost operational measures may provide useful first steps while larger infrastructure projects are considered. These include managing curbside stopping, enforcing parking rules, providing marked passenger loading areas, improving pedestrian crossings, coordinating institutional entry procedures and monitoring travel times over time. A Nigerian case study in Akure developed a congestion-reduction framework based on local traffic observations, illustrating the relevance of context-sensitive interventions in medium-sized urban centres (Adelakun & Olufikayo, 2022). These measures should be assessed for distributional effects, especially where informal traders and public transport operators depend on roadside access for their livelihoods.

1.8 Empirical research gap and contribution of the study

The literature reviewed above establishes several relevant points: GPS and floating-car data can provide detailed corridor performance evidence; road-user and roadside activities influence travel time; paratransit is central to African urban mobility; and congestion patterns vary spatially and temporally. Nevertheless, much of the available African evidence concerns larger cities or selected arterial roads, while university-centred secondary-city corridors remain less represented in the published empirical record. Recent reviews identify continuing gaps in fine-grained transport data

and in understanding the interaction between informal transport, land use and accessibility across African cities (Bruwer et al., 2023; Asuah & Acheampong, 2025).

This study contributes a corridor-scale assessment of the OAU-Ife-City route in Ile-Ife by combining repeated GPS tracking, GIS-based spatial examination and surveys of commercial bus operators and commuters. Its contribution is the integration of travel-time profiles, mapped friction locations, reported congestion drivers and day-of-week variation within one university-anchored secondary-city corridor. The analysis is intended as a baseline for local transport management and for future monitoring; it does not claim to measure direct greenhouse-gas reductions.

1.9 Research objectives

The specific objectives of the study are to:

1. Map and quantify end-to-end travel times and speed profiles across four operational windows.
2. Identify and spatially delineate primary friction nodes and bottlenecks using GPS tracking and ArcGIS synchronization.
3. Evaluate behavioural, structural and institutional drivers of traffic congestion through structured surveys.
4. Examine day-of-week travel-time variations to identify temporal congestion rhythms.
5. Propose non-capital-intensive traffic demand management strategies to improve corridor reliability and support sustainable urban mobility.

2. METHODOLOGY

2.1 Study area

The study corridor spans the approximately 12-kilometre arterial route connecting the Obafemi Awolowo University (OAU) main campus gate through major urban nodes including Mayfair, Eleyele Junction, Lagere, Oja Market, Sabo and Phase II (OAUTHC) in Ile-Ife, Osun State, Nigeria. The corridor functions as an important academic, commercial and health-service connection within the city. Its daily users include students, university employees, traders, hospital users, residents and commercial transport operators.

2.2 Data collection campaign

Primary movement data were acquired during a two-month field campaign using handheld Garmin Global Positioning System (GPS) receivers. Commercial transport vehicles operating regularly along the corridor were boarded and tracked across four defined operational windows:

6. **Morning peak (7:00-9:00 AM):** heavy inbound commuter movement towards the university and administrative centres.
7. **Noon off-peak (11:00 AM-12:00 PM):** a mid-day period expected to have comparatively lower commuter demand.
8. **Afternoon transition (4:00-5:00 PM):** early outbound movement and commercial activity.
9. **Evening peak (5:00-6:00 PM):** outbound commuter movement from the university and commercial districts.

The field description supplied for this manuscript reports more than 78 tracked runs per operational window. Structured questionnaires were also administered to 200 commercial bus operators and 200 commuters, giving a reported total survey sample of 400 respondents.

2.3 GIS synchronization and spatial analysis

GPS track logs containing spatial coordinates, timestamps and instantaneous velocity measurements were imported, cleaned and synchronized within ArcGIS. Spatial overlays were used to examine speed reductions against distance along the corridor, identify deceleration zones and estimate cumulative delay intervals. Mean travel times and standard

deviations were calculated for the operational windows. The questionnaire data were summarized to describe respondents' perceptions of behavioural, structural and institutional contributors to congestion.

2.4 Analytical considerations and reporting requirements

For reproducibility, the final submission should report the GPS sampling interval, device model, route-matching procedure, treatment of GPS signal gaps, criteria for excluding incomplete trips, number of valid runs by direction and time window, and the statistical tests used for comparisons. The present manuscript text does not provide these details, so they should be supplied from the field records rather than inferred. Reliability measures such as the 90th-percentile travel time, buffer-time index and planning-time index should be calculated from trip-level observations if the underlying dataset is available.

The questionnaire section should also state the sampling approach, questionnaire administration dates, response rate, respondent characteristics, question wording, and whether respondents could select multiple congestion factors. If the percentages in Table 3 are based on multiple-response items, the manuscript should explicitly state this because percentages may legitimately sum to more than 100%. Ethical approval or an institutional exemption, informed consent procedures and data-protection arrangements should be reported according to the journal's requirements.

3. RESULTS AND DISCUSSION

3.1 Baseline speed and travel-time profiles

The empirical findings supplied for this study indicate substantial differences in corridor performance across operational windows. Table 1 presents the reported travel-time and average-speed metrics.

Table 1. Spatiotemporal performance metrics across operational windows

Operational window	Time span	Mean travel time (mins)	Standard deviation (mins)	Average speed (km/h)	Primary traffic state
Free-flow baseline	Unrestricted (night/early)	13.5	± 1.5	54.2	Unconstrained flow
Morning peak	7:00-9:00 AM	38.35	± 10.54	18.7	Inbound congestion surge
Noon off-peak	11:00 AM-12:00 PM	20.10	± 4.20	35.8	Moderate flow stabilization
Afternoon transition	4:00-5:00 PM	31.42	± 6.80	22.9	Outbound accumulation
Evening peak	5:00-6:00 PM	44.34	± 8.30	16.2	Severe congestion

Source: Field survey and GPS tracking data as reported by the study authors.

The reported free-flow mean of 13.5 minutes provides a reference against which peak-period performance can be compared. Morning travel time rises to 38.35 minutes, while the evening-period mean reaches 44.34 minutes. The corresponding average speeds are reported as 18.7 km/h and 16.2 km/h, respectively. This pattern suggests that the evening period is the most congested of the four observed operational windows. Similar corridor-level research in other contexts has shown the value of comparing travel-time distributions and peak-period performance rather than relying on a single daily average (Tufuor & Rilett, 2021; Zheng et al., 2024).

The standard deviations indicate meaningful dispersion around the reported means, particularly during the morning and evening periods. Nevertheless, standard deviation alone does not show the probability of arriving late or the upper tail of the travel-time distribution. The availability of the original GPS trip records would permit calculation of percentile-based reliability measures and a more complete account of commuter uncertainty (Federal Highway Administration, n.d.).

3.2 Spatial identification of corridor friction nodes

GIS synchronization of GPS deceleration logs reportedly identified six friction-node groupings along the corridor. Table 2 presents the locations, distances from the OAU Gate and reported delay characteristics.

Table 2. Spatial delineation of primary friction nodes and dominant delay causes

Friction node	Distance from OAU Gate (km)	Mean delay (mins)	Primary operational bottleneck	Dominant contributory factors
1. OAU Campus Gate	0.0	7.5 ± 2.1	Security check and turnaround	Security clearance inspections; passenger drop-off queues
2. Mayfair Junction	3.2	9.2 ± 3.4	Intersection conflict and trading	Roadside merchandise display; uncoordinated turning
3. Eleyele Junction	5.5	6.1 ± 1.8	Narrow geometry and parking	Indiscriminate commercial vehicle parking
4. Lagere Commercial Core	7.8	11.4 ± 4.0	Pedestrian and market activity	Roadside trading; pedestrian spillover; loading delays
5. Oja Market Hub	9.6	8.8 ± 3.1	Curbside loading and hawking	Informal market spillover onto arterial shoulders
6. Sabo and Phase II (OAUTHC)	12.0	7.0 ± 2.2	Vehicular and junction merging	Intersecting regional traffic; commuter surges

Source: GIS track logs and field surveys as reported by the study authors.

The largest reported mean delay occurs at Lagere Commercial Core (11.4 minutes), followed by Mayfair Junction (9.2 minutes) and Oja Market Hub (8.8 minutes). These locations are characterised in the field description by pedestrian activity, roadside commerce, loading and turning conflicts. The pattern is consistent with evidence from Ghanaian arterials showing that on-street parking and access density can materially influence segment travel time (Osei et al., 2022). It also aligns with Nigerian research identifying roadside encroachment and road-reserve occupation as issues requiring integrated planning and management responses (Tijjani et al., 2023).

The OAU Campus Gate is reported to experience delay associated with security clearance and passenger drop-off queues. This is an institutional rather than purely geometric bottleneck and may therefore be addressed through operational coordination, queue management and designated stopping arrangements. Any proposed intervention should preserve necessary security procedures while reducing avoidable queue spillback onto the public road.

3.3 Behavioural, structural and institutional congestion drivers

The survey of 200 commercial bus operators and 200 commuters identified several perceived contributors to congestion. Table 3 presents the reported proportions and their stated operational effects.

Table 3. Perceived behavioural and structural drivers of corridor congestion

Driver category	Specific factor / parameter	Percentage reporting	Primary impact on traffic flow
Behavioural	Peak-hour commuter surges	34.5%	Sudden capacity saturation at terminal nodes
Behavioural	Driver impatience and lane shifting	30.0%	Intersection blocking and opposing-lane conflicts
Institutional	Security gate inspections	26.0%	Queueing at university entry terminals
Structural	Roadside merchandise display and trading	23.0%	Reduced effective lane width and pedestrian friction
Structural	Narrow roadway geometry	21.0%	Limited capacity for two-way traffic
Operational	Indiscriminate on-street parking	18.5%	Loss of usable curb-lane capacity

Source: Operator and commuter survey data (N = 400), as reported by the study authors.

Peak-hour commuter surges were the most frequently reported factor (34.5%), followed by driver impatience and lane shifting (30.0%). These findings suggest that congestion is not attributable to a single infrastructure constraint. Rather, the corridor appears to experience interacting demand, behavioural, institutional and roadside-use pressures. Comparable Nigerian research has also reported the influence of peak-period travel, driver behaviour, road condition and transport policy on congestion (Ojo & Gbadegesin, 2024).

The reported percentage values should be interpreted as respondents' reported perceptions, not as causal estimates of the proportion of congestion attributable to each factor. If respondents could select more than one factor, the table should be labelled as a multiple-response summary. A stronger analysis could cross-tabulate responses by operator and commuter group, and test whether perceptions differ significantly between these two populations.

3.4 Temporal rhythms and day-of-week variations

Weekly tracking logs reportedly revealed differences in morning and evening peak travel durations across the seven days. Table 4 summarizes the supplied day-of-week values.

Table 4. Day-of-week variations in morning and evening peak travel durations

Day	Mean morning peak (mins)	Mean evening peak (mins)	Dominant mobility catalyst
Monday	36.2 ± 8.1	41.5 ± 7.2	Weekly administrative resumption and institutional opening
Tuesday	35.1 ± 7.5	39.8 ± 6.9	Standard academic and commercial operations
Wednesday	37.4 ± 8.0	42.1 ± 7.4	Mid-week commercial market restocking
Thursday	41.8 ± 11.2	46.5 ± 8.9	Market days and institutional movement
Friday	42.5 ± 11.8	48.2 ± 9.4	Weekend travel and religious-service traffic
Saturday	28.4 ± 5.6	35.1 ± 6.8	Social events and commercial shopping
Sunday	16.5 ± 2.8	21.0 ± 3.4	Lower-volume religious and recreational movement

Source: Weekly GPS tracking campaign, as reported by the study authors.

The supplied values show the highest morning and evening means on Friday (42.5 and 48.2 minutes, respectively), with Sunday recording the lowest means (16.5 and 21.0 minutes). The pattern is consistent with the proposition that institutional, commercial and social schedules shape weekly travel demand. A recent Nigerian study in Enugu similarly reports distinctive weekday and evening congestion patterns, demonstrating the importance of analysing local temporal rhythms (Chukwurah et al., 2025).

The proposed explanations in the final column should be treated as contextual interpretations unless they were measured directly. To support causal claims about market days, religious activities or institutional schedules, the study would need to document the relevant activity calendar or include these factors as explanatory variables. Statistical testing of the daily differences is also needed before describing the observed ranking as statistically significant.

4. CONCLUSION AND POLICY IMPLICATIONS

This study provides a corridor-scale baseline assessment of travel-time variation and reported bottleneck locations along the OAU-Ife-City transit corridor in Ile-Ife. The supplied GPS results indicate that average corridor travel time rises substantially during morning and evening peak periods compared with the reported free-flow baseline. Spatial analysis identifies friction-node groupings around the campus gate, junctions and commercial activity centres, while survey responses point to commuter surges, driver behaviour, security checks, roadside trading, narrow geometry and parking as perceived congestion contributors.

4.1 Policy implications

- Manage passenger loading and stopping: Establish clearly marked and appropriately located loading areas near high-demand activity centres, developed in consultation with commercial bus operators and local businesses.
- Improve curbside and parking management: Apply consistent parking controls at critical junctions and market frontages, while providing alternative stopping and parking arrangements where feasible.
- Coordinate institutional gate operations: Review passenger drop-off, vehicle turnaround and security-check procedures at the OAU Gate to reduce queue spillback without compromising legitimate security requirements.
- Manage pedestrian and market interfaces: Improve pedestrian crossing points, maintain usable walking space and work with trader associations to organise roadside activity and protect road capacity.
- Introduce routine corridor monitoring: Repeat GPS tracking across comparable time windows and report mean, median, 90th-percentile travel time, buffer-time index and segment-level speed measures.
- Use phased, evidence-led interventions: Prioritise low-cost operational measures, evaluate their effects and scale up only where monitoring demonstrates measurable improvement.

4.2 Climate and sustainability implications

Improved traffic flow may reduce unnecessary idling and stop-start operation, but the present study did not directly measure fuel consumption or greenhouse-gas emissions. The climate relevance of the findings should therefore be framed as a potential co-benefit and a basis for future monitoring, not as a demonstrated emissions reduction. Future research could combine GPS trajectories with vehicle class, fuel type, occupancy, engine characteristics and recognised emissions factors to estimate corridor-level energy use and emissions. This would strengthen the link between local traffic management and wider transport mitigation objectives (Jaramillo et al., 2022).

4.3 Limitations and directions for further research

The study is limited by the information currently reported about GPS sampling frequency, valid trip counts, direction-specific observations, survey sampling procedures and statistical tests. The supplied manuscript also does not report direct traffic counts, vehicle composition, fuel consumption or emissions measurements. These omissions do not invalidate the descriptive value of the field observations, but they constrain the strength and scope of inference. Future work should publish anonymised trip-level data or summary distributions, report reliability indices, distinguish direction-specific travel times and test the statistical significance of temporal differences.

Further research could also examine how the corridor performs during university vacations, examination periods, major market days, road works and exceptional events. A before-and-after evaluation of designated loading bays, parking enforcement or gate-management changes would provide stronger evidence about intervention effectiveness. Such work would help move from a descriptive baseline towards a continuous corridor performance-management framework.

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