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Urban densification, mobility pressure and pathways for sustainable urban innovation in Bamenda city, Cameroon

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Abstract

This study examines how urban densification is associated with traffic congestion in Bamenda city, Cameroon and uses the empirical findings to identify pathways for urban innovation in sustainable mobility governance. A mixed-methods design combined traffic-flow counts, field observations and a questionnaire survey of 400 urban residents and mobility-related actors across Bamenda I, II and III. Traffic was counted at strategic junctions during low-peak and high-peak periods, while the spatial concentration of socio-economic activities was used as an empirical indicator of land-use intensification. The results show pronounced spatial differentiation in both urban activity concentration and traffic demand. Bamenda II, which contains the largest concentration of socio-economic facilities, also records the highest junction-based traffic flow, reaching 4,091 vehicles during the low-peak observation period and 5,206 during the high-peak period. Road-right-of-way encroachment and associated roadside activities were identified as the most prominent traffic-management challenge (35%), followed by poor road conditions and limited alternative routes (20% each). Among the reported consequences, increased fuel consumption (30%) and travel delays (25%) were most prominent. A Pearson correlation based on the three municipal observations produced a very strong positive association ($r = 0.986$); however, the associated two-tailed p-value is approximately 0.107 with $n = 3$, so the relationship is interpreted as descriptive rather than statistically significant. The study proposes an empirically grounded urban-innovation pathway centred on integrated land-use and transport planning, data-informed traffic management, public-space governance, multimodal mobility and institutional coordination.

1. Introduction

Urbanisation is increasingly understood not simply as population growth but as a transformation of interconnected urban systems through which people, goods, services, infrastructure and information circulate. Discover Cities explicitly positions cities as complex and dynamic systems and encourages research that integrates urban science, policy and practice across disciplinary and sectoral boundaries [1]. Transport is particularly important within this systems perspective because mobility outcomes emerge from the interaction of land use, infrastructure, travel behaviour, public-space management, governance and investment rather than from road capacity alone.

Traffic congestion is therefore not only an engineering problem. It is also an expression of how urban growth is spatially organised and governed. Increasing concentrations of population, commerce, education, health services and transport functions can generate substantial travel demand in locations where road capacity, parking, pedestrian space and traffic-management arrangements have not evolved at the same pace. Conversely, poorly coordinated outward growth can lengthen journeys and increase dependence on road-based mobility. The resulting interaction between densification and sprawl creates a governance challenge: cities need to accommodate economic and social intensification while maintaining accessible, safe, efficient and environmentally sustainable mobility systems [2, 3–14].

This challenge is particularly acute in African cities, where urban expansion often occurs under conditions of infrastructure deficits, institutional fragmentation, informality and limited municipal resources [14–23]. Recent research continues to emphasise the need for more equitable and climate-responsive transport systems in African cities [14–15, 17]. In Cameroon, transport systems in major and secondary cities are shaped by rapid urbanisation, heterogeneous travel demand, infrastructure constraints and a substantial role for informal and semi-formal mobility services [24–26]. Bamenda city provides a useful case through which to examine these processes because its role as a regional administrative, commercial, educational and transport centre has intensified mobility pressure while its road network and traffic-management institutions have struggled to respond proportionately.

The contribution of this study is deliberately broader than documenting congestion. It asks how empirical evidence on traffic and land-use concentration can be translated into an urban-innovation pathway. Here, urban innovation is understood pragmatically as the development and institutionalisation of new or significantly improved ways of organising urban knowledge, infrastructure, services, governance and public participation to address persistent urban problems. This interpretation is consistent with recent Discover Cities work emphasising integrated and participatory policy design, governance arrangements and the conversion of urban knowledge into actionable policy [27–28]. In this paper, innovation is therefore not equated with advanced technology alone. It includes informational innovation through systematic traffic and land-use data; institutional innovation through cross-sector coordination; infrastructural innovation through multimodal and public-space improvements and policy innovation through integrated land-use and mobility planning.

The study addresses four questions: (1) How is urban densification spatially associated with traffic congestion in Bamenda city? (2) What spatial variations in traffic flow occur across Bamenda I, II and III? (3) What traffic-management challenges constrain mobility? and (4) What socio-economic effects are associated with congestion? The main objective is to examine the relationship between urban densification and traffic congestion while identifying governance and planning pathways for more sustainable urban mobility. The specific objectives are to: (1) assess the spatial distribution of socio-economic activities (2) evaluate traffic-flow patterns during low and high peak periods (3) identify major traffic-management challenges and (4) examine reported socio-economic implications of congestion.

The paper makes three contributions. First, it provides empirical evidence from a medium-sized African city that is underrepresented in the international urban-mobility literature. Second, it connects spatial patterns of land-use intensification with traffic-management and governance constraints rather than treating congestion solely as a road-engineering issue. Third, it translates the evidence into a systems-oriented pathway for urban innovation that can inform future planning, monitoring and evaluation. This positioning is important for the present collection because recent Discover Cities scholarship highlights the value of integrated governance, local data readiness and policy innovation in moving from fragmented urban interventions towards systemic sustainability transitions [27–29].

2. Conceptual and theoretical framing

2.1 From densification to mobility pressure

Urban densification refers here to the increasing concentration of population, built structures and socio-economic functions within the urban area. Densification can support sustainable urban development when compact development is accompanied by adequate public transport, walkability, mixed land uses and infrastructure capacity [30]. It can also generate congestion where employment, education, commerce and transport functions become concentrated around a limited number of corridors without corresponding improvements in mobility systems. Urban sprawl is treated as a complementary process; outward expansion can increase trip distances and reinforce road dependence [31–32]. The key analytical proposition is therefore not that densification is inherently unsustainable, but that the sustainability of densification depends on whether urban governance and mobility systems adapt to the intensity and spatial distribution of demand.

Traffic congestion is defined as a condition in which traffic demand approaches or exceeds the effective capacity of the transport system, producing lower speeds, queues, unreliable travel and longer journey times [33–35]. Because direct travel-speed and delay measurements were not consistently available across all observation points in the source dataset, traffic-flow volume is used as an operational indicator of traffic pressure. This distinction is important: higher flow is not identical to congestion and the empirical analysis therefore interprets traffic-flow intensity as evidence of mobility pressure rather than as a complete engineering measure of congestion.

2.2 Systems perspective and urban innovation

The analytical framing combines land-use–transport interaction, traffic-flow theory and smart-growth principles. The Land Use-Transport Interaction framework highlights reciprocal relationships between the spatial organisation of activities and transport demand [36]. Traffic-flow theory provides the operational logic that increasing traffic density can reduce movement efficiency when demand approaches network capacity [35]. Smart-growth thinking adds a planning perspective by emphasising compact development, mixed land uses, transport integration and alternatives to private motorised travel. Taken together, these perspectives suggest that mobility outcomes are produced through interactions among urban form, infrastructure, behaviour and governance.

For this study, the systems perspective is extended through four dimensions of urban innovation. Informational innovation concerns the routine collection, integration and use of traffic, land-use and activity data. Institutional innovation concerns coordination among the city council, transport authorities, planning institutions, traffic-management agencies, market actors and communities. Infrastructural innovation concerns changes that increase the functionality of the mobility system, including public transport, pedestrian infrastructure, cycling facilities, parking and alternative routes. Policy innovation concerns the adoption and implementation of integrated planning rules, right-of-way protection, demand-management measures and adaptive monitoring. These dimensions are mutually reinforcing: data without institutional capacity may not change decisions; infrastructure without land-use coordination may reproduce congestion; and policy without monitoring may be difficult to evaluate.

2.3 Analytical model

The conceptual model treats land-use intensification as the principal explanatory condition and traffic pressure as the outcome, while recognising traffic management, road-network quality, land-use planning, enforcement and transport-system structure as contextual factors. The model is intentionally non-causal because the study is cross-sectional and based on three municipal spatial units for the correlation analysis. The empirical objective is to establish spatial association and identify system mechanisms that can inform future longitudinal research (Fig. 1).

Urban Change

- Population growth
- Activity concentration
- Build-up expansion
- Transport function

Figure 1. Systems framing of urban densification, mobility pressure and pathways for sustainable urban innovation in Bamenda city

Source: Authors' synthesis based on the empirical evidence and theoretical framing of the study

3. Materials and methods

3.1 Study area

The study was conducted in Bamenda Municipality, comprising Bamenda I, Bamenda II and Bamenda III sub-divisions in Mezam Division of Cameroon's North West Region (Fig. 2). Bamenda functions as a regional administrative, commercial, educational and transport centre. The study area has experienced demographic growth and spatial expansion accompanied by increasing concentration of socio-economic activities and pressure on the road network.

Source: Geo-database of Cameroon (2016)

3.2 Research design and data sources

A mixed-methods design combined quantitative traffic-flow counts with questionnaire data and field observations. Primary data comprised questionnaire responses, manual traffic counts and direct observations of mobility conditions. Secondary materials included Bamenda City Council reports, Council Development Plans, demographic information from BUCREP, published research and planning documents. The mixed-methods design was used to connect measurable traffic patterns with the spatial and institutional conditions observed in the field.

3.3 Sampling and field data collection

The study surveyed 400 respondents across Bamenda I, II and III. Respondents included transport operators, commercial drivers, students, workers, businesspersons, vehicle owners, municipal officials and other urban residents. Random sampling was used in major traffic hotspots and commercial areas, while snowball sampling facilitated access to transport operators and knowledgeable key informants. Participation was voluntary and respondents were informed about the purpose of the study. Confidentiality and anonymity were maintained.

Traffic counts were undertaken at strategic nodes: Governor's Office Junction, Mile One Junction and GBHS Bamendankwe Junction in Bamenda I; Nangah Junction, Azire Old Town Junction and Ntarinkon Junction in Bamenda II; and Mile Four Junction, Firewood Junction and Bambui Junction in Bamenda III. Counts were conducted between 07:30am and 09:30am by a team of five trained assistants, with each assistants recording different vehicle categories including taxis, buses, motorcycles, private cars and trucks. Two observation periods were used: August 2025 as the low-peak period and December 2025 as the high-peak period. August was selected as the low peak period because educational institutions were on vacation and socio-economic activities were relatively reduced while December represented the high peak period because it is characterized in Bamenda by festive activities and increased population mobility.

3.4 Variables and analysis

Urban densification was operationalised using the spatial concentration of socio-economic facilities and built-up change, including secondary schools, health facilities, markets, hotels, motor parks and travel agencies. Traffic pressure was operationalised primarily through traffic-flow volume. Descriptive statistics were used to compare municipal patterns and reported impacts. Pearson correlation was used to explore the association between the densification indicator and traffic-flow intensity across the three municipal observations. The correlation was based on only three municipal observations (n = 3).

The hypothesis tested was stated as follows:

H_0: There is no statistically significant relationship between urban densification and traffic congestion in Bamenda Municipality.

H_1: There is a statistically significant relationship between urban densification and traffic congestion in Bamenda Municipality.

The level of significance for the analysis was fixed at 5% level. Microsoft Excel 2016 was utilized for both descriptive and inferential statistical analyses and 2016 Excel for graphical presentation. Traffic flow patterns were compared across the three municipalities and between low and high peak periods to evaluate spatial variations in vehicular movement and congestion intensity.

3.5 Ethical Approval

and Accordance

Ethical clearance attestation for this study was issued by The Ethical Review Committee/Institutional Review Board of The University of Bamenda, after a study of the project proposal, and in keeping with existing regulations, hereby had no objections on ethical grounds provided the project is carried out as described in the protocol submitted to the Committee/Board. This attestation is non-transferable. Any changes to the protocol and/or personnel must get the approval of the Ethical Committee/Institutional Review Board otherwise the Ethical Clearance will be nullified.

4. Results

4.1 Spatial concentration of socio-economic activities and urban densification

The empirical evidence indicates pronounced spatial differentiation in the concentration of socio-economic activities across Bamenda. Bamenda II records the largest number of secondary schools, health facilities, hotels, motor parks and travel, while Bamenda I records the lowest values for most indicators. This concentration is important from a systems perspective because facilities that generate trips are also spatially concentrated within the same road network (Table 1).

Table 1
Spatial distribution of socio-economic activity indicators across Bamenda municipalities

Municipality	Secondary schools	Health facilities	Markets	Built-up change	Hotels	Motor parks	Travel agencies
Bamenda I (SE)	9	5	2	1,343.70	4	1	1
Bamenda II (NW)	39	57	5	3,116.70	41	4	8
Bamenda III (NE)	22	31	4	2,607.21	14	3	5
Total	70	93	11	—	55	8	14

Source: DDSE Statistics (2021/2022); Bamenda Health District Annual Report (2021); Council Development Plans of Bamenda II and III (2020–2021); fieldwork (2025)

Bamenda II's concentration of socio-economic functions provides an important empirical anchor for the mobility analysis. The pattern suggests that congestion is generated not simply by population density but by the spatial concentration of trip-generating activities, including education, commerce, health services, accommodation and transport functions. This finding supports the land-use-transport interaction perspective while also pointing towards the need for coordinated management of activity nodes and surrounding public space.

4.2 Population growth and spatial urban expansion

Bamenda city has witnessed substantial population growth over the past five decades, accompanied by expansion of built-up areas towards peripheral and peri-urban zones. Bamenda II and Bamenda III show particularly pronounced growth trajectories (Fig. 3). The spatial expansion of the built-up area indicates that Bamenda faces the simultaneous pressures of central intensification and peripheral expansion. Such a pattern can produce a dual mobility burden: concentrated activity nodes generate high short-distance traffic pressure, while peripheral growth increases longer-distance travel and dependence on road-based modes.

Source: BUCREP (2005) and projections from Council Development Plans of Bamenda I, II and III (2022)

Figure 3 reveals a significant surge in population across Bamenda Municipality (Bamenda I, II & III sub-divisions) from 1970 to 2022. This population growth trend however shows disparity within the sub-divisions. Bamenda II recorded the highest demographic growth trajectory, growing from approximately 28,253 inhabitants in 1976 to about 281,974 inhabitants in 2022. Bamenda III equally experienced substantial population growth from approximately 8,190 inhabitants in 1976 to 252,150 inhabitants in 2022, while Bamenda I records comparatively lower demographic growth during the same period. Overall, the municipal population growth reflects increasing urbanization pressure.

This rapid demographic growth has intensified demand for housing, transportation, education, healthcare and commercial services. Consequently, built-up areas have expanded significantly from the urban core towards peri-urban zones, particularly along the north-western and north-eastern corridors, with Bamenda III demonstrating rapid urban expansion after 1996. The spatial expansion of built-up areas reflects the increasing process of urban sprawl within the municipality (Fig. 4). Expansion of settlements and socio-economic activities along major road corridors has increased daily commuting distances and vehicular concentration.

Source: Landsat imagery (1996 and 2018) and fieldwork (2025)

From Fig. 4, it is evident that urban expansion in Bamenda is most significant towards the north-western axis (Bamenda II), as portrayed by the thickness of the arrow. The expansion towards peri-urban zones reflects increasing urban sprawl. Also, the growth in built-up areas corresponds with increasing traffic demand especially due to the outcrop of educational institutions especially along road axis that interferes traffic as the pupils/student population increases the volume of traffic and even create gridlocks especially in the afternoon period. Figure 5 presents the distribution of educational institutions along road axis in Bamenda.

Source: National Institute of Cartography and fieldwork (2025)

The spatial evidence further indicates that educational institutions and other activity generators are frequently located along major road axes. Such concentration creates predictable peaks in travel demand and localised conflicts through traffic, stopping, parking, pedestrians and motorcycles. From an urban-innovation perspective, these locations provide potential priority zones for integrated corridor

management, school-area mobility plans, designated loading and parking areas, pedestrian improvements and time-sensitive traffic management.

4.3 Traffic-flow patterns across Bamenda

Fieldwork reveals that traffic flow increases significantly during high peak periods and decreases with increasing distance from the urban core (Point A) (Table 2). In all, Bamenda II records the highest traffic intensity.

Table 2
Junction-based traffic-flow totals during low and high peak observation periods in Bamenda city

Municipality	Period	Point A	Point B	Point C	Total flow
Bamenda I	Low peak	1,525	839	229	2,593
Bamenda II	Low peak	1,072	1,177	1,842	4,091
Bamenda III	Low peak	1,484	984	686	3,136
Bamenda I	High peak	2,006	1,124	432	3,569
Bamenda II	High peak	1,423	1,418	2,365	5,206
Bamenda III	High peak	2,279	1,786	896	4,961
Source: Fieldwork, August and December 2025					

Traffic flow patterns vary substantially among the three municipalities. Bamenda II records the highest total junction-based flow during both observation periods, increasing from 4,091 vehicles in the low peak period to 5,206 in the high peak period. Bamenda III records 3,136 and 4,961 respectively, while Bamenda I records 2,593 and 3,569. The increase from low to high peak is especially pronounced in Bamenda III, where traffic is distributed across the major nodes captured by the survey. The results reinforce the importance of considering spatially differentiated mobility management rather than applying a uniform municipal intervention.

The fleet-type finding indicates that motorcycles are the dominant recorded vehicle category in Bamenda, followed by taxis and private cars. This reflects the role of flexible and informal mobility services in meeting travel demand where formal public transport capacity is limited. At the same time, high concentrations of motorcycles at junctions and loading areas create conflicts through traffic, pedestrians and roadside commerce. The policy challenge is therefore not simply to suppress motorcycles but to integrate them into a safer, more predictable and multimodal mobility system.

4.4 Traffic-management constraints

The study identified several traffic management constraints affecting the Bamenda Municipality as shown in Table 3.

Table 3
Reported traffic-management challenges in Bamenda Municipality

Traffic-management challenge	Share (%)
Densification and encroachment on road rights-of-way	35
Poor state of roads	20
Limited alternative roadways	20
Weak traffic-control systems	15
Reckless driving	10
Total	100
Source: Fieldwork (2025)	

Road-right-of-way encroachment is the most frequently reported challenge. Roadside commerce, informal vending, transport agencies and parking activities occupy space intended for circulation, pedestrian movement or junction operations. Poor road conditions and limited alternative routes each account for one-fifth of reported challenges leading to traffic holdup (Photo 1). Weak traffic control systems and reckless driving further reduce network efficiency. These findings point to a governance problem as much as an infrastructure problem: the functionality of existing road space depends on how competing uses are coordinated, regulated and enforced.

Photo 1. Traffic holdup associated with roadside commercial activity and motorcycle concentration at Mile 3 Nkwen, Bamenda III Municipality

Source: Fieldwork (2025)

The absence of functional traffic signals and reliance on manual intervention at major junctions constrain the capacity of the existing system to respond to fluctuating demand. This does not imply that technology alone will solve congestion. Rather, traffic management technologies would be most useful when embedded within a broader institutional system that includes reliable data, maintenance arrangements, enforcement protocols, clear responsibilities and mechanisms for learning from traffic conditions.

4.5 Reported socio-economic implications

The identified socio-economic effects of traffic congestion on the population of Bamenda are presented in Table 4.

Table 4
Reported socio-economic implications of traffic congestion

Reported effect	Frequency	Percentage (%)
Increased operational cost	80	20
Reduced productivity and efficiency	60	15
Increased travel-delay time	100	25
Increased fuel consumption	120	30
Increased emissions	40	10
Total	400	100

Source: Fieldwork (2025)

Increased fuel consumption is the most frequently reported consequence, followed by travel delays and increased operational costs. Reduced productivity and efficiency and increased emissions were also reported. These findings illustrate the multi-dimensional nature of congestion: its costs are distributed across household mobility, business operations, energy use, environmental quality and time. In a systems framework, these outcomes represent feedback effects that can further undermine urban productivity and the attractiveness of public spaces and commercial corridors.

4.6 Descriptive association between densification and traffic pressure

To statistically examine the relationship between urban densification and traffic congestion, a Pearson correlation analysis was conducted using indicators of socio-economic activity concentration and traffic flow intensity across Bamenda I, II, and III municipalities (Table 5).

Table 5
Pearson correlation between urban densification and traffic-flow intensity

Variables	Pearson r	Two-tailed p	Interpretation
Urban densification and traffic-flow intensity	0.986	≈0.107	Very strong positive descriptive association; not statistically significant with n = 3

Source: Calculated from field work within the three municipal observations

The correlation coefficient indicates a very strong positive association between the municipal densification indicator and traffic flow intensity (r = 0.986). However, the analysis is based on only three observations, producing one degree of freedom. Under these conditions, the two-tailed p-value is approximately 0.107. The result therefore does not support rejection of the null hypothesis at the

conventional 5% level. The finding therefore shows a strong descriptive pattern that is consistent with the theoretical expectation that concentrated urban functions generate mobility demand.

5. Discussion

The empirical evidence supports a systems interpretation of congestion in Bamenda city. The municipality's mobility problem is produced through the interaction of activity concentration, urban expansion, infrastructure constraints, public space occupation, transport mode composition and institutional capacity. Bamenda II illustrates this interaction most clearly: it has the highest concentration of socio-economic facilities and the highest junction-based traffic flow in both observation periods. The pattern is consistent with land-use-transport interaction theory, which proposes that the location and intensity of urban activities influence travel demand while transport infrastructure in turn shapes urban development [36].

The findings also caution against treating densification itself as the problem. Compact development can contribute to sustainability when accompanied by accessible public transport, walking and cycling infrastructure, coordinated land-use planning and effective management of public space. The problem in Bamenda city is the apparent mismatch between intensification and system capacity. Where commercial, educational and transport activities concentrate around limited corridors without adequate parking, pedestrian space, alternative routes and traffic management, the benefits of proximity is offset by congestion and conflict over road space.

The prominence of motorcycles reveals another dimension of system adaptation. Motorcycles provide flexible mobility in contexts where formal public transport is inadequate, but their concentration at junctions and loading areas can also increase disorder and safety risks. This suggests that sustainable mobility policy should move beyond a binary distinction between formal and informal transport. An innovation-oriented approach would seek to improve the organisation, regulation and integration of existing mobility services while expanding safer and more reliable public transport and non-motorised options.

The governance findings are particularly important for the collection's focus on systems and policy pathways. Road-right-of-way encroachment reflects an institutional coordination problem involving planning, enforcement, commerce, transport operations and public-space management. The same physical road can therefore perform differently depending on the institutional arrangements governing its use. Recent Discover Cities scholarship similarly emphasises that urban policy innovation depends on governance structures, collaboration and the ability to move beyond sectoral silos [27]. In Bamenda, this suggests that infrastructure investment should be accompanied by institutional innovation rather than treated as a standalone solution.

The role of information is equally important. The study demonstrates that relatively simple field-generated traffic and land-use data can reveal spatial concentrations and priority corridors. Recent work in Discover Cities on small and midsize cities similarly emphasises that governance and data readiness

are foundational conditions for more advanced urban intelligence [29]. Bamenda city does not need to begin with sophisticated digital-twin or artificial intelligence systems. A more context-appropriate innovation pathway would start with reliable traffic counts, georeferenced land-use inventories, corridor-level incident records, parking and loading data and interoperable municipal databases. These foundations could later support more advanced analytics if institutional capacity and data governance mature.

Finally, the study's evidence on fuel consumption, delays, operational costs and emissions demonstrates why mobility should be treated as a sustainability issue rather than a narrow transport issue. Congestion creates economic and environmental costs that can undermine broader urban sustainability. The pathway towards improvement therefore requires simultaneous attention to spatial planning, transport operations, infrastructure, public-space management, environmental performance and institutional learning.

6. An urban-innovation pathway for sustainable mobility in Bamenda

The empirical findings support an urban-innovation pathway organised around five linked stages: diagnose, coordinate, experiment, institutionalise and learn (Fig. 6). The pathway is designed as a policy framework rather than as a tested causal model. Its purpose is to show how the evidence generated by this study could be translated into an iterative urban governance process.

Source: Source: Authors' synthesis from the empirical findings

Stage 1-Diagnose

The city should establish a continuously updated mobility and land-use evidence base. Priority datasets include traffic volumes by mode and time, activity-node locations, road conditions, pedestrian movements, parking and loading locations, road-right-of-way encroachment, crash locations and public transport routes. The immediate innovation is informational through transforming occasional field observations into a repeatable municipal evidence system.

Stage 2-Coordinate

Evidence should be brought into a cross-sector urban mobility platform linking the Bamenda City Council, relevant planning and transport authorities, traffic-management institutions, market and transport operators, communities and other stakeholders. The objective is to reduce institutional fragmentation and align land-use decisions with mobility capacity. This reflects the participatory and responsible policy-design orientation increasingly emphasised in urban innovation scholarship [27].

Stage 3-Experiment

Rather than attempting city-wide transformation immediately, the municipality could test integrated corridor interventions at high-pressure nodes identified by the study. Potential interventions include

protected pedestrian space, designated loading and parking areas, improved junction management, school-area mobility measures, motorcycle loading zones, selective traffic signalisation and public transport route rationalisation. Experiments should be monitored against clearly defined indicators such as traffic delay, pedestrian safety, illegal parking, travel reliability and user satisfaction.

Stage 4-Institutionalise

Successful interventions should be incorporated into planning regulations, municipal budgets, corridor-management protocols and routine maintenance systems. Institutionalisation is essential because pilot projects can remain isolated unless responsibilities, financing, enforcement and monitoring are clearly assigned. Innovation becomes sustainable when it changes routines and decision structures rather than merely introducing a temporary project.

Stage 5-Learn and adapt

Mobility conditions will change as Bamenda city continues to grow. The city should therefore establish periodic reviews of traffic, land use and service performance and use the results to revise interventions. This creates a feedback loop between evidence and policy. Such adaptive governance is consistent with the broader systems orientation of Discover Cities and with recent research emphasising policy learning, governance capacity and data readiness as conditions for sustainable urban transformation [28–29].

7. Policy implications and implementation priorities

The findings suggest that Bamenda city's congestion challenge should be addressed through a coordinated portfolio rather than a single infrastructure project. First, integrated land-use and transport planning should become a routine municipal function. New concentrations of schools, markets, commercial facilities and transport hubs should be assessed for their implications for road capacity, pedestrian movement, parking and public transport access before approval or expansion.

Second, the city should prioritise corridor-level public-space management. Protecting road rights-of-way, providing designated loading and parking spaces and relocating activities that obstruct junction operations can increase effective road capacity without requiring immediate large-scale road widening. Enforcement should be predictable, transparent and linked to viable alternative spaces for affected activities.

Third, sustainable mobility alternatives should be strengthened. The dominance of motorcycles in the observed fleet indicates strong demand for flexible mobility, but the long-term objective should be a multimodal system in which public transport, walking, cycling, motorcycles, taxis and private vehicles are integrated rather than competing chaotically for the same road space. Pedestrian infrastructure and safe crossing facilities should be treated as core transport infrastructure.

Fourth, traffic management should become increasingly data-informed. Even before advanced smart-city technologies are considered, the municipality can establish standardised traffic count protocols, digital

or spreadsheet-based traffic dashboards, incident reporting and georeferenced records of recurrent congestion points. More sophisticated technologies can be introduced incrementally as data governance and institutional capacity improve.

Fifth, urban innovation should be evaluated through measurable sustainability outcomes. A future monitoring framework could track travel-time reliability, traffic volumes, pedestrian accessibility, public transport use, fuel consumption, emissions proxies, road-space encroachment, user satisfaction and equity across neighbourhoods. The present study does not claim to have measured all these indicators; it identifies them as priorities for subsequent evaluation.

8. Limitations and directions for future research

Several limitations were encountered in the study. First, the principal inferential analysis is based on only three municipal observations. The resulting correlation is useful for identifying a spatial pattern but cannot provide robust statistical inference. Second, traffic flow volume is an operational proxy for congestion and does not directly measure speed, travel time, queue length or reliability. Third, the study uses two seasonal observation periods and therefore cannot fully represent daily, weekly and seasonal variation. Fourth, the mixed sampling approach supports access to relevant respondents but does not establish a probability sample representative of every urban resident.

Future research should therefore expand the spatial and temporal scale of observation, integrate GIS-based land-use and network analysis, measure travel speeds and delay directly and use repeated observations or panel designs. Larger samples would permit multivariable modelling of the relationship among land-use intensity, road capacity, transport mode choice and congestion. Future work could also test the urban-innovation pathway proposed here through pilot interventions and before-and-after evaluation. Such research would move the present study from descriptive diagnosis towards evidence-based experimentation and evaluation.

9. Conclusion

This study demonstrates that traffic pressure in Bamenda city is closely associated, at the descriptive spatial level, with the concentration and expansion of urban activities. Bamenda II, where the study records the greatest concentration of socio-economic facilities, also records the highest junction-based traffic flow. Road-right-of-way encroachment, poor road conditions, limited alternative routes and weak traffic control arrangements further constrain the performance of the mobility system. The reported consequences particularly fuel consumption, travel delays and operational costs show that congestion has consequences extending beyond transport to urban productivity and environmental sustainability.

The principal contribution of the study is to reinterpret these findings through an urban-innovation lens. Sustainable mobility in Bamenda requires more than road expansion. It requires an integrated system of information, institutional coordination, public space governance, multimodal infrastructure, adaptive policy and continuous learning. The proposed pathway (diagnose, coordinate, experiment,

institutionalise and learn and adapt) offers a practical framework through which empirical evidence can be translated into urban governance and mobility innovation. The framework remains a proposition for future testing rather than a demonstrated causal model. Its value lies in connecting the specific empirical challenges documented in Bamenda with a structured pathway for more sustainable and adaptive urban transformation.

Declarations

Clinical trial number: not applicable.

Ethics approval and consent to participate:

Participation in the study was voluntary and informed consent was sought.

Consent for publication:

Not applicable.

Competing interests:

The authors declare no competing interests.

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Author Contribution

M. E. A., L. C. T. and C. M. W. contributed to study conception, methodology, investigation and writing; C. F. F. contributed to the planning and technical framing. All authors reviewed and approved the manuscript.

Data Availability

Data supporting the findings will be made available from the corresponding author upon request.

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Photo

Photo 1 is available in the Supplementary Files section.

Figures

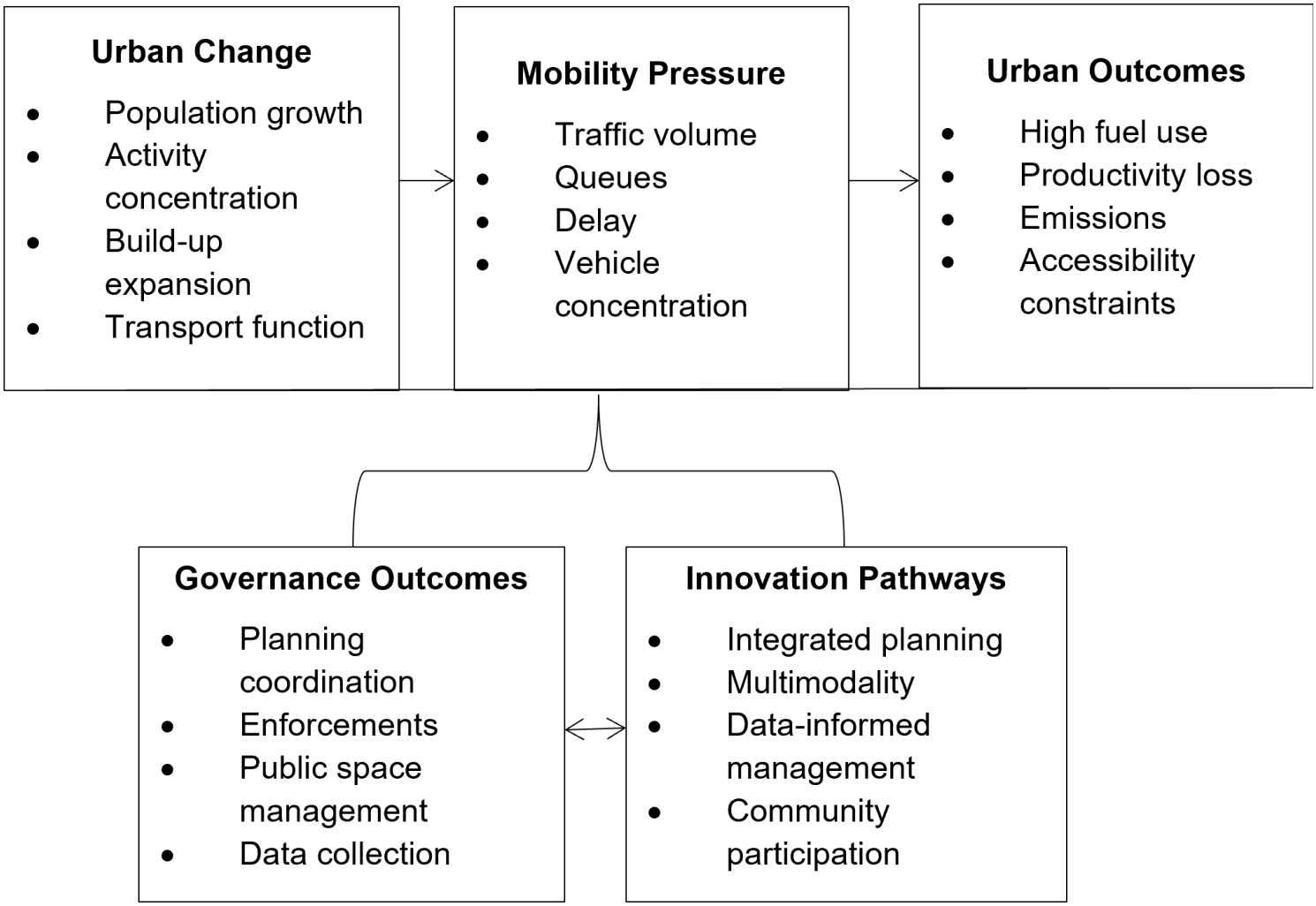


Figure 1

Systems framing of urban densification, mobility pressure and pathways for sustainable urban innovation in Bamenda city

Source: Authors' synthesis based on the empirical evidence and theoretical framing of the study

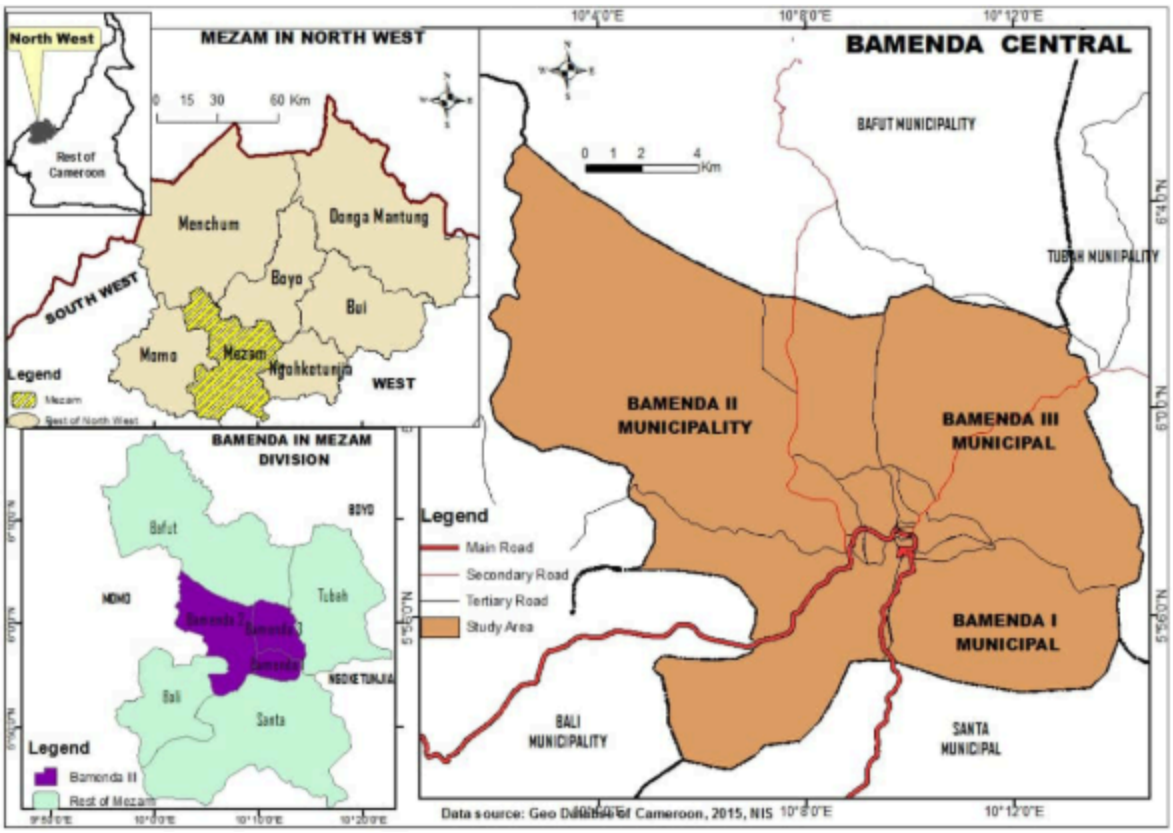


Figure 2

Location of Bamenda I, Bamenda II and Bamenda III municipalities in the North West Region of Cameroon

Source: Geo-database of Cameroon (2016)

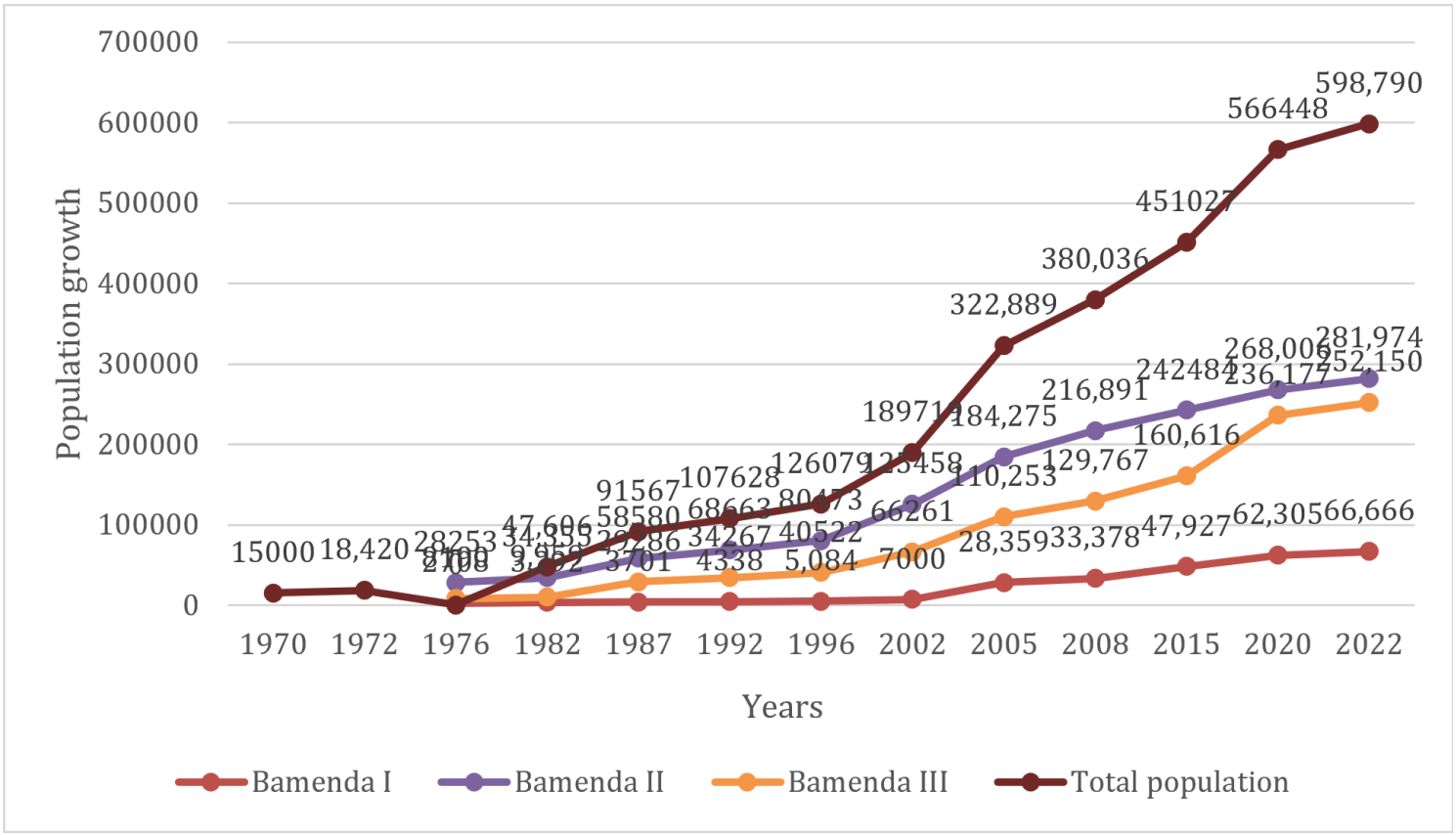


Figure 3

Evolution of the Population of Bamenda Municipality from 1970–2022

Source: BUCREP (2005) and projections from Council Development Plans of Bamenda I, II and III (2022)

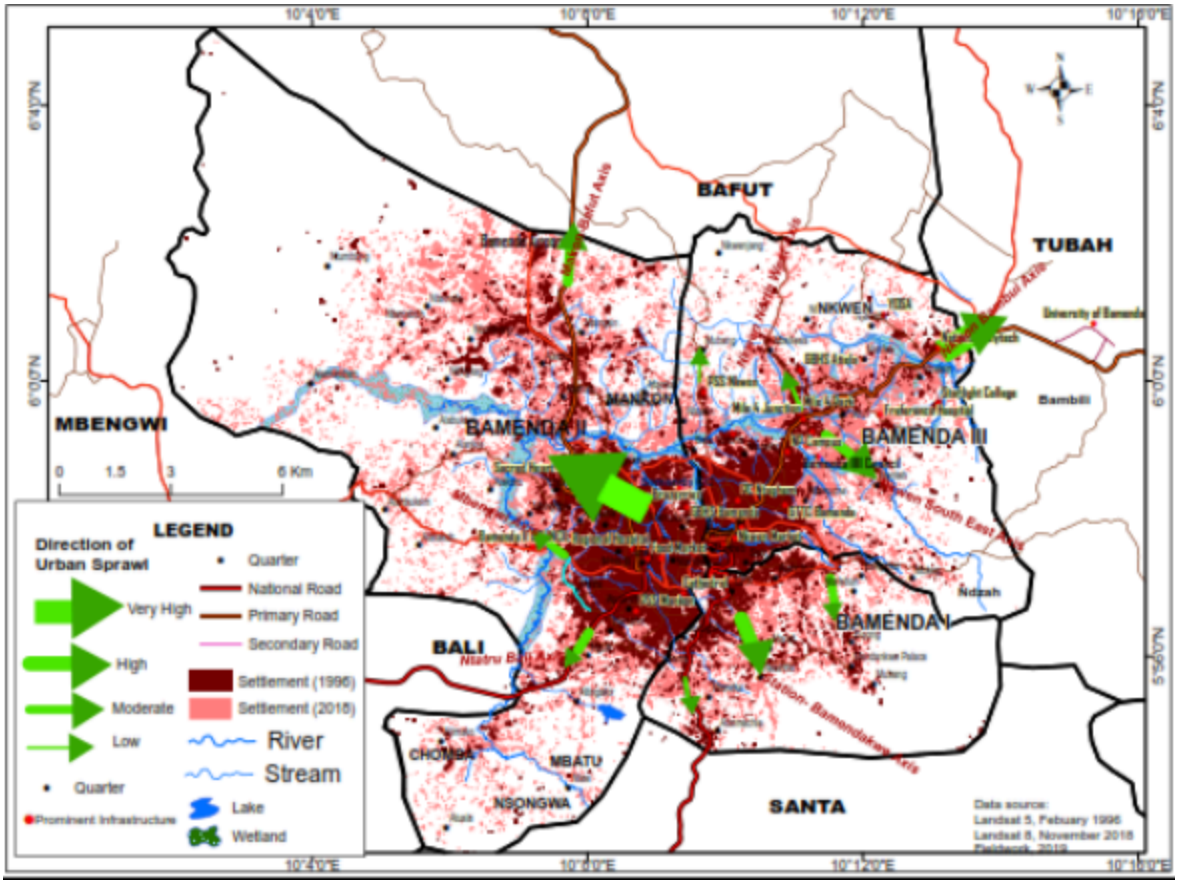


Figure 4

Direction of spatial expansion of built-up areas in Bamenda Municipality, 1996–2024

Source: Landsat imagery (1996 and 2018) and fieldwork (2025)

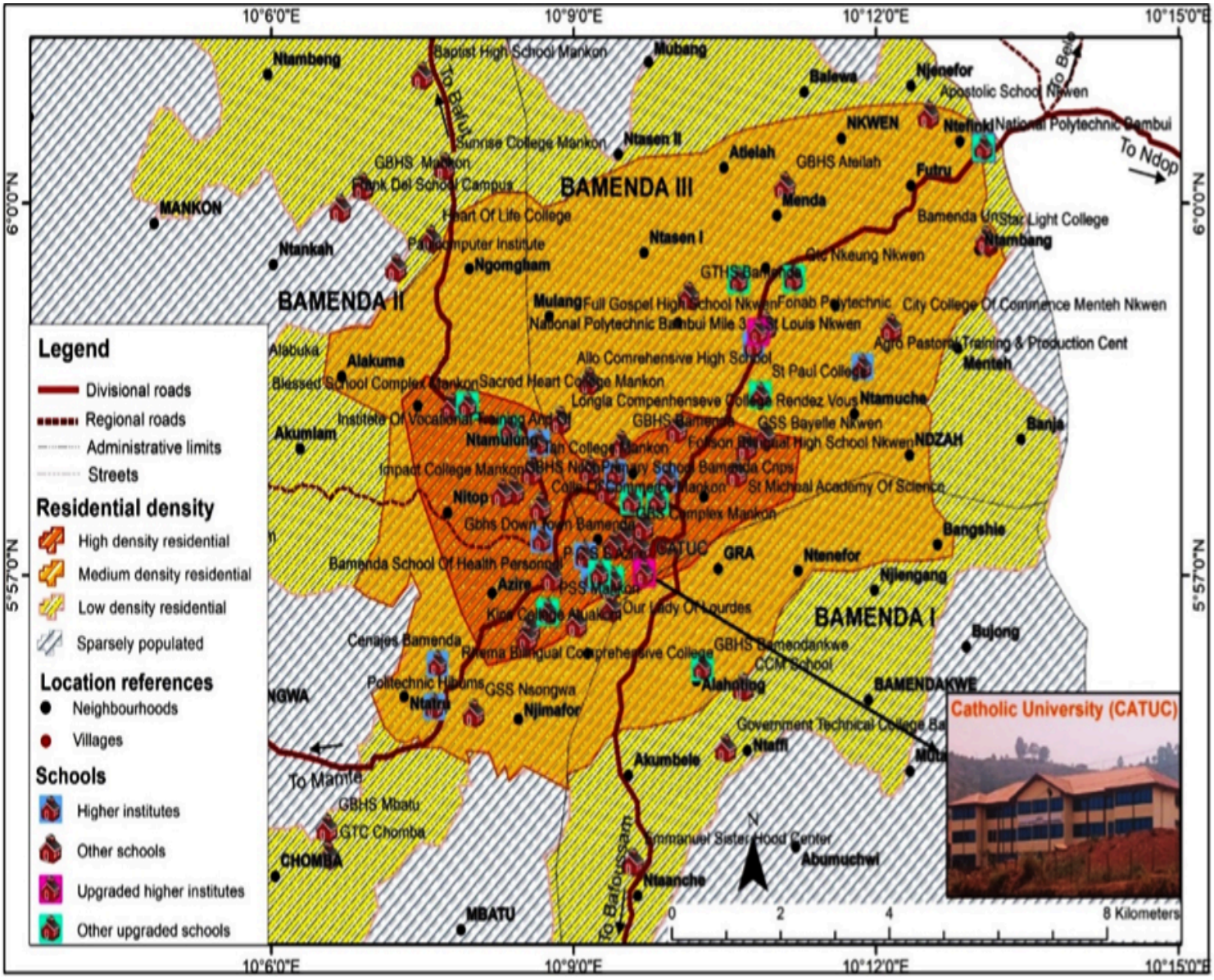


Figure 5

Distribution of educational institutions along major road axes in Bamenda Municipality

Source: National Institute of Cartography and fieldwork (2025)

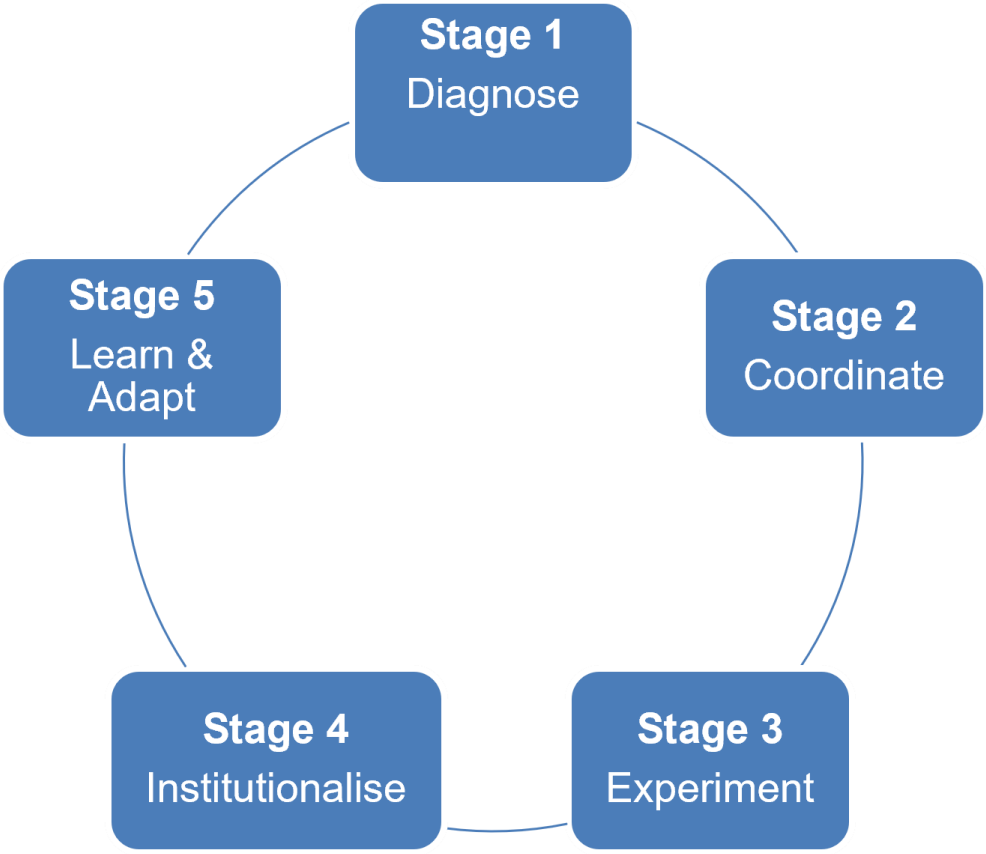


Figure 6

An urban-innovation pathway for sustainable mobility governance in Bamenda city

Source: Source: Authors' synthesis from the empirical findings

Supplementary Files

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