Journal of Service Science and Management, 2024, 17, 386-399
https://www.scirp.org/journal/jssm
ISSN Online: 1940-9907
ISSN Print: 1940-9893

Road Network and Urban Development: A Comparative Analysis of Bungoma and Kerugoya Municipalities in Kenya

Alfred Eshitera, Lawrence Esho, Casty Gataaka Njoroge

Department of Spatial Planning and Design, Technical University of Kenya, Nairobi, Kenya
Email: aeshitera@tukenya.ac.ke, lawrence.esho@tukenya.ac.ke, casty.njoroge@tukenya.ac.ke

How to cite this paper: Eshitera, A., Esho, L., & Njoroge, C. G. (2024). Road Network and Urban Development: A Comparative Analysis of Bungoma and Kerugoya Municipalities in Kenya. *Journal of Service Science and Management, 17,* 386-399.
https://doi.org/10.4236/jssm.2024.174021

Received: July 8, 2024
Accepted: August 20, 2024
Published: August 23, 2024

Abstract

Road network expansion and urban development have attracted scholars in the fields of regional and urban studies. The attraction has been necessitated by the rate at which the urban population is increasing, due to natural growth and migration. Governments in both developed and developing countries allocate a lot of funds to urban infrastructure, especially the roads sector, with the aim of promoting the smooth flow of goods and services within urban areas. This high investment has attracted scholars in various fields, including regional economists and infrastructure planning experts, aiming to establish the relationship between road infrastructure networks and development. Mostly, studies done in urban areas are related to road infrastructure expansion in relation to land cover changes. In this study, a different exploratory route was taken, with the main purpose of comparing the road network distribution in relation to the actual spatial distribution of the urban landscape. In this context, the urban built-up areas were selected as a key indicator relating to road network distribution and physical urban development. The Normalized Difference Built-up Index (NDBI) was used to estimate the spatial distribution of urban physical growth. Other indicators of urban growth studied include utility distribution, land values, and investment attractiveness. From this study, it is clear that areas with high network connectivity have the highest values of NDBI and land values, together with the concentration of electricity distribution transformers per km^2, which is a sign of a high growth rate. Kerugoya municipality emerged as the urban area with the highest road connectivity index of 77.42%, while Bungoma had 22.22%. Kerugoya has complete road network circuits of 24 compared to Bungoma's 6. Similarly, Kerugoya recorded the highest figures of land values and NDBI indicating high concentration of road network attracts developers. The study results can be used by policymakers to establish priority areas for road network investment.

Keywords

Road Network, Urban Development, Normalized Difference Built-Up Index (NDBI), Kenya

1. Introduction

Urban areas are recording rapid expansion and managers are concerned about promotion of policies supporting compact growth. Road networks have been identified as a driving factor in the growth of urban areas as the two are complementary. Consequently, roads form the backbone of sustainable urban development (Wen, Zhang, & Deng, 2023). Development planners view road infrastructure as a growth catalyst (Gateri & K'Akumu, 2023). Roads can connect various development zones within urban settings while allowing smooth flow of goods and services and the general development of regions (Zhao, Zheng, Yuan, & Zhang, 2017). It is therefore absolutely necessary for urban managers to understand the spatial distribution of built-up areas which may be occasioned by infrastructure network including roads. An analysis of the extent of urban growth, which is part of physical development, is therefore essential for future resource allocation decisions (Khine, Maw, & Win, 2018).

In Kenya, urban areas accommodate 29% of the entire population with a steady annual growth projected to be 4.23% (UN-Habitat, 2024). As per the (KNBS, 2024) entire population of the country is projected to be 51.5 million which implies 14.9 million Kenyans reside in urban areas which makes urban development an important research field.

The study hypothesis is that road network informs development trends at a micro-region level and areas with good network records better growth indicators. This is premised on the finding of (Rodgrigue, 2024) which states road network organizes space. To test this hypothesis, two urban areas have been selected that is Bungoma and Kerugoya municipalities located in Bungoma and Kirinyaga counties respectively. The selected urban development indicators are road network accessibility index, concentration of electricity distribution transformers, attractiveness, land values and urban built-up physical footprint. These indices are part of what is used by UN-Habitat to measure the growth of urban areas (UN-Habitat, 2004). Therefore, the objective of this analysis is to assess the impact of road network concentration on other indicators of urban development.

2. Literature Review

2.1. Local Policies

Historically, Kenya's past and current government policy papers recommend investment in road infrastructure projects within urban areas which are designated as rural trade and production centers (Republic of Kenya, 1978; Republic of Kenya, 1986; Republic of Kenya, 1994; Vision 2030 Delivery Board, 2018).

Within the two municipalities, three agencies that are Kenya Highway Authority (KeNHA), Kenya Rural Roads Authority (KERA) and Kenya Urban Roads Authority (KURA) have been established as the key implementing agencies of road infrastructure (Republic of Kenya, 2012). The county governments also develop and maintain some roads as per constitution of Kenya fourth schedule section two (Republic of Kenya, 2010). Transportation therefore is a key basis of capital formation and it will be important to assess how the network correlates with the indicators of urban development. This can be justified by two policy papers that is the National Spatial Plan (NSP) (Government of Kenya, 2016) and Vision 2030 Vision 2030 (Vision 2030 Delivery Board, 2018), which defines infrastructure as the pillar of other development policy objectives.

2.2. Urban Roads Improvement Projects in Kenya

Extensive investment in road infrastructure in Kenya is to be majorly done by Kenya Urban Roads Authority (KURA) (Republic of Kenya, 2012) and County Governments (Republic of Kenya, 2010). World Bank has been in partnership with County Governments and Urban Development Department (UDD) and implemented road infrastructure projects at municipal level under Kenya Urban Support Programme (KUSP). Both the two municipalities under this study benefited from KUSP whose objective was to improve infrastructure and was closed on 31st December 2023 (World Bank Group, 2024). Despite having a collaborative approach to improve infrastructure, there is still disparity in road infrastructure in various regions. The Road Sector Investment Programme (RSIP) has programmed roads which need to be developed in the entire country including the two study areas (Kenya Roads Board, 2021).

2.3. Previous Studies

Studies on urban road infrastructure are numerous with different focuses mostly defined by objective of the research and the spatial-temporal scale. The studies range from assessing role of road network in facilitating flow of goods and services. For instance (Xiao, Liu, & Li, 2022), documented the impact of the Belt and Road Initiative on global stage in terms of information flow targeting to connect cities which were at the same economic growth scale. Focus on network studies has also been informed by urban processes including communication and other social interaction patterns (Derudder & Neal, 2018; Derruder, 2019; (Sun & Hou, 2020). There are also studies concentrating on traffic management and understanding the accident hot spots within the road network majorly in big cities that generate large volumes of traffic (Jibril, Aule, Garba, & Adewuyi, 2023). Current studies and analysis of urban road networks focus on sustainability by assessing vulnerability of road network during crisis occasioned by climate change as documented by (Roosta, Javadpoor, & Ebadi, 2022) and locational optimization of terminal infrastructure (Allate, 2019).

In summary, existing literature indicates, there is a symbiotic relationship between transport systems and urban development indicators. An empirical study by (Duranton & Turner, 2012) found that 10% increase in the highway has a spillover effect of 15% increase in employment. A Road network forms a basis on which motor vehicle and non-motorized modes of transport operates. (Padam & Signh, 2004) postulate that a good transport system is a symbol of good governance as it is one of the determinants of quality of life and an indicator of sustainable urban development. Road network growth and structure can therefore be used to model economic growth behavior of a region especially if all development players are involved in the modelling process (Capello, 2000)

In the Kenyan Context a quick web search clearly indicates studies on urban networks are mainly done in major urban areas. A recent study by (Gateri & K'Akumu, 2023) was done in the capital city of Nairobi focusing on impact of a new road segment on per-urban land use changes. Another search gives a case study of Kisumu, which investigates impact of new road projects on socio-economic development in peri-urban areas of Kisumu Kenya and Accra Ghana (Khanani, Adugbila, Martinez, & Pfeffer, 2021) which are both big cities. It will be of great importance to have a study within two municipalities that are far away from the main cities.

3. Study Area

The case study areas are Bungoma and Kerugoya Municipalities located in Bungoma and Kirinyaga counties respectively. They are municipalities as per Urban areas classification criteria as specified by the legal framework (Republic of Kenya, Rev. 2019). Bungoma is located in Western Part of Kenya while Kerugoya is found in Central Kenya on slopes of Mounts Elgon and Kenya respectively. Geographical location of the study areas is in **Figure 1**.

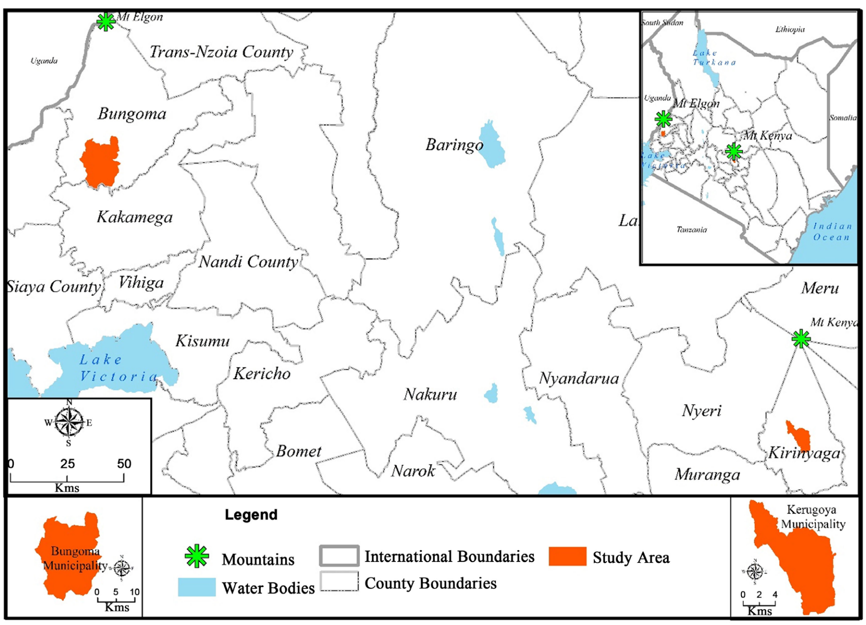

Figure 1. The study area.

Based on their geographic location the two studies areas have similar agro climatic conditions. This implies their hinterland is agriculturally rich and they offer market for residents who are mainly farmers. The studies areas also provide services such as banking, insurance and supplies to agro related enterprises. They offer social services such educational, religious, entertainment and hotel industry. The location of the two study areas makes them suitable candidates for a comparative study.

4. Data and Methodology

A study on urban networks can be informed by three approaches which include understanding the nodes, development density and accessibility index (Cheng, Bertolini, Clercq, & Kapoen, 2013). Accessibility index can be used to measure movement convenience and GIS software can simplify analytical work and visualization of results for easy interpretation by non-experts (Ma, Wang, & Liu, 2019). This study has applied both network analysis, GIS and remote sensing techniques to understand the growth pattern of two municipalities in relation to tarmac road distribution.

Data Sources

Spatial data for the study areas was extracted using municipal boundaries (County Government of Bungoma, 2020) and (County Government of Kirinyaga, 2020). Road network data was sourced from Kenya Roads Board database Road Inventory and Condition Survey (RICS) (Kenya Roads Board, 2023). Electricity lines and transformer distribution data were sourced from (World Bank, 2023). The remotely sensed data was downloaded from the United States Geological Surveys (USGS) portal (USGS, 2024) by loading municipal boundaries to extract the area of interest. Only band 5 and 6 of Landsat 9 were downloaded and used to compute Normalized Difference Built-Up Index (NDBI). The downloaded satellite image bands are shown in **Table 1** below.

Table 1. Satellite data bands.

Location	Date Captured	Path/Row	Band	Wavelength (Micrometers)	Resolution (meters)	Source
Bungoma	12th May 2024	170/060	5 (NIR) and 6 (SWIR1)	0.851 - 0.879	30	(USGS, 2024)
Kerugoya	21st May 2024	168/060	5 (NIR) and 6 (SWIR1)	1.566 - 1.651	30	(USGS, 2024)

Other indicators of urban development such as attractiveness and land values were gathered from key informants who were mainly from county lands department using a guided template. The data was collected on 17th May 2024 and 22nd May 2024 for Kerugoya and Bungoma respectively. The two municipalities did not have distinct growth zones. The zones only existed in the minds of planners, for Bungoma participatory mapping was used to indicate the spatial distribution of the development zones. For Kirinyaga, the land use planner linked the zones to point features and Thiessen polygons were generated to indicate the extent of zones around the point features using ArcMap GIS (ESRI, 2024).

5. Methodology

5.1. Data Processing

The zoning map for Bungoma prepared by participatory mapping was scanned, georeferenced and digitized use ArcMap GIS to extract shape files. Zone names and development indicators attribute data were then populated. Paved roads were separated from the main GIS layer by clipping and snipping tool in ESRI ArcMap App. Various road segments were joined to form a complete one edge linking various zones.

5.2. Connectivity Index

The best informative approach to studying accessibility is by analyzing the transport network as an integrated entity and graph theory can be applied in measuring connectivity index (Daniel, Saravanan, & Mathew, 2020), (Sarkar, Sarkar, & Mondal, 2021). The assumption is all roads in a region combine to form road network system connecting central places. The graph theory was applied where road network distribution indicative maps were presented in the simplest format which is easily interpreted. The area of interest was the position of points (central places) and lines (connections) that is development nodes and road networks respectively (Rahman & Kumar, 2023; Jazdzewska, 2021). A well-connected region must have vertices/nodes that are linked together with several network lines (edges) (Rodrigue, 2020). To measure the number of complete fundamental road circuits the Cyclomatic number will be calculated using Equation (1) and Equation (2) adopted from (Christopher Bull, 1984) and (Rodgrigue, 2024).

Equation (1): Cyclomatic number calculation

$$CN = E - v + 1$$

where CN = Cyclomatic Number;

E = Number of Edges (Roads within the region);

V = Number of Vertices (Nodes/central places in the region).

To carry out a comparison between the two case studies, all areas which are not linked by transport network will be considered by calculating the alpha index using Equation (2).

Equation (2): Alpha Index Calculation

$$\alpha = \left(\frac{CN}{\text{The Maximum possible value of cyclomatic number}} \right) \times 100$$

where $\alpha \ge 0 < 100$.

Assumption: a network viewpoint emphasizes that behaviour of complex system is shaped by strong interactions among residents and offers possibility within an abstracted, mathematically and well tractable framework (Stanislav

Sobolevsky et al., 2013).

5.3. Normalized Difference Built-Up Index (NDBI) Computation

Remote sensing approaches have simplified extraction of urban physical features (Jibril, Aule, Garba, & Adewuyi, 2023). Using this approach, NDBI algorithm can be used to separate residential and nonresidential areas from satellite images (Ukhnaa, Huo, & Gaudel, 2019). Urban areas which have a continuous built-up area records high reflective properties at spectral band 5 to 6 in Landsat 8 and 9. These bands were used to extract NDBI values which normally range from −1 to +1. Negative values of NDBI represent non-core urban built-up land cover while positive values are an indication of continuously built areas which are an indicator of urban development (Mugambi, Njuguna, & Karanja, 2022). The formula indicated in Equation (3) was used to calculate the NDBI in ArcMap GIs raster calculator programmed in the map algebra tool (ESRI, 2021).

Equation (3): NDBI Calculation

$$\text{NDBI} = \frac{(\text{Band6} - \text{Band5})}{(\text{Band6} + \text{Band5})}$$

6. Results and Discussion

6.1. Road Network Distribution

Study results indicate Kerugoya municipality has the best road network connectivity with CN value of 24. On the other hand, Bungoma municipality had CN value of 6. This implies the two municipalities had 24 and 6 complete fundamental circuits respectively. The Kerugoya complete circuits are around the Central Business District (CBD) zone, the southern part surrounding Kabatiro has the lowest connection. Only six nodes are not linked to a tarmac road that is Riagithiga, Kiamiciri, High Vision and Kabatiro denoted by development nodes 15, 19, and 15 in **Figure 2**. Other nodes not connected to a tarmac road are 1, 10 and 13.

The overall connectivity that is alpha index is 22.22% for Bungoma and 77.42% for Kerugoya respectively. Most of the tarmac roads in Bungoma do not have complete network circuits as indicated in **Figure 2** hence the lower connectivity index. For instance, the Mateka node denoted with number 15 is not fully connected due to the missing bridge. The road passing through Siritanyi is also not complete as it is partially constructed the residents have to use a longer path to access the Central Business District (CBD) making the trip more expensive. If the link is completed the trip will be 5 Kilometers shorter. This makes Siritanyi denoted as node 7 in **Figure 2**, less attractive to potential developer's despite being close to the CBD. The Western part of Bungoma is totally disconnected from tarmac roads. Development node 12 which hosts one of the national technical training institutes that is Sang'alo is connected to the CBD by a road that is poorly maintained. This can discourage prospective students from selecting such training institution. Consequently, Kutus located to the southern part of Kerugoya municipality and hosts several learning institutions has a better network concentration. This infers that in Bungoma residents use untarmacked roads to move around the municipality. This is in contrast to Kerugoya which has a well woven network around its key development nodes of Kutus and Kerugoya CBD. The differences in the level of network quality are attributed to differences in political orientation of the municipality residents. Kirinyaga Municipality has had presence senior politicians and civil servants in government who have managed to bargain for more resources which have been used to improve their road network.

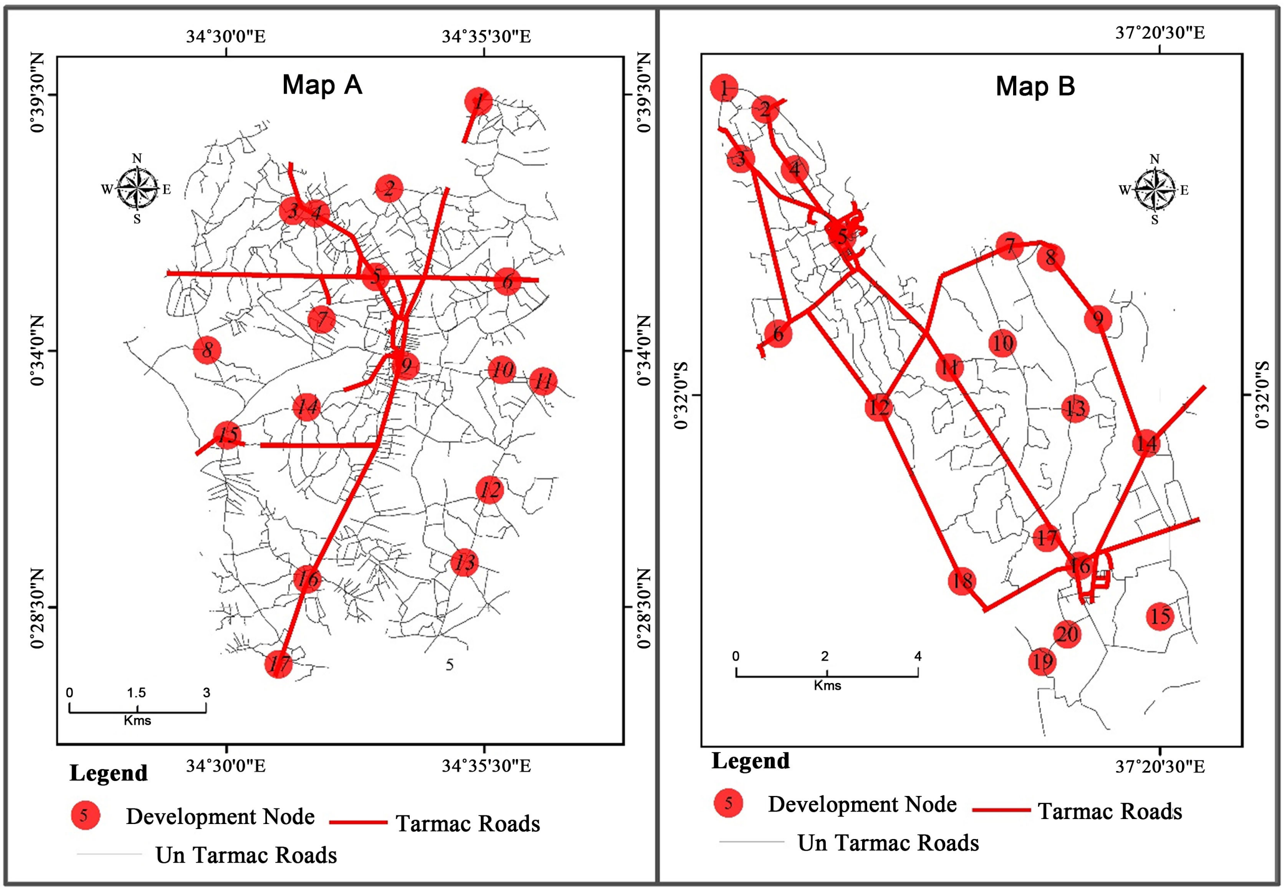

Figure 2. Road network distribution in Map A: Bungoma and Map B Kerugoya municipalities respectively.

In summary, major connection links which were programmed in the investment plan (Kenya Roads Board, 2021) for improvement or reconstruction in Bungoma municipality have never been implemented. For instance, the main link to Kakamega through Sang'ala was allocated to a contractor who had not completed the work due to lack of funds. The main road within the municipality which should be maintained by Kenya National Highway Authority (Republic of Kenya, 2012) was improved by the county with resources that could have been used to improve the local network.

6.2. Other Urban Development Indicators

The NDBI values were used to gauge urban development density, Kerugoya recorded values ranging from 0.0 to 0.22 while Bungoma ranged from 0.00 to 0.15. This gives a clear indication that built-up areas are more compact in Kerugoya than Bungoma. The values were joined to form one class called built-up areas. There are two major development nodes for the two municipalities. Kerugoya Municipality major nodes are CBD marked zone 9 in the North and Kutus to the South as indicated in Figure 3. The other node is around Kutus which has a Public University. Bungoma municipality also has two major nodes one at the CBD marked zone A and another one at Kibabii labelled zone B which also hosts a public university as shown in Figure 4. The Kibabii node is not fully developed and also hosts two secondary schools that is Kibabii girls and Boys.

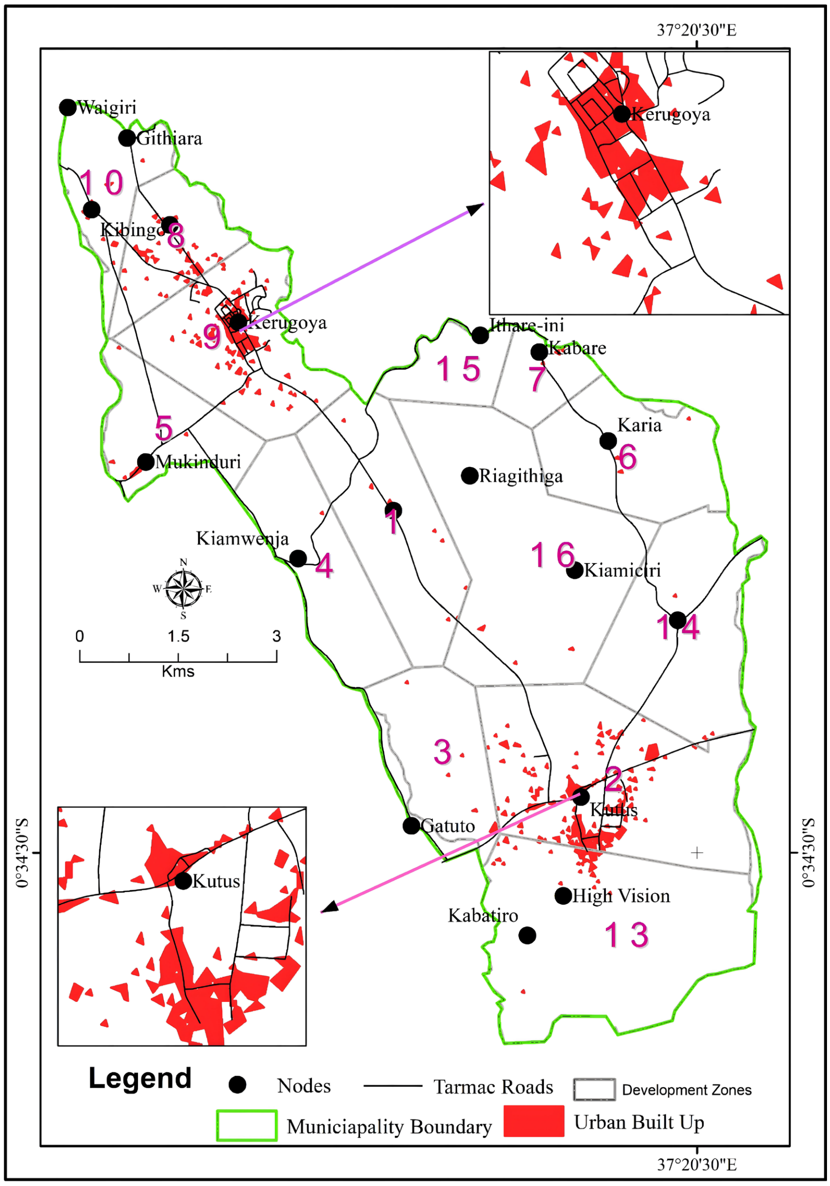

Figure 3. Road network, development zones vs built-up areas in Kerugoya municipality.

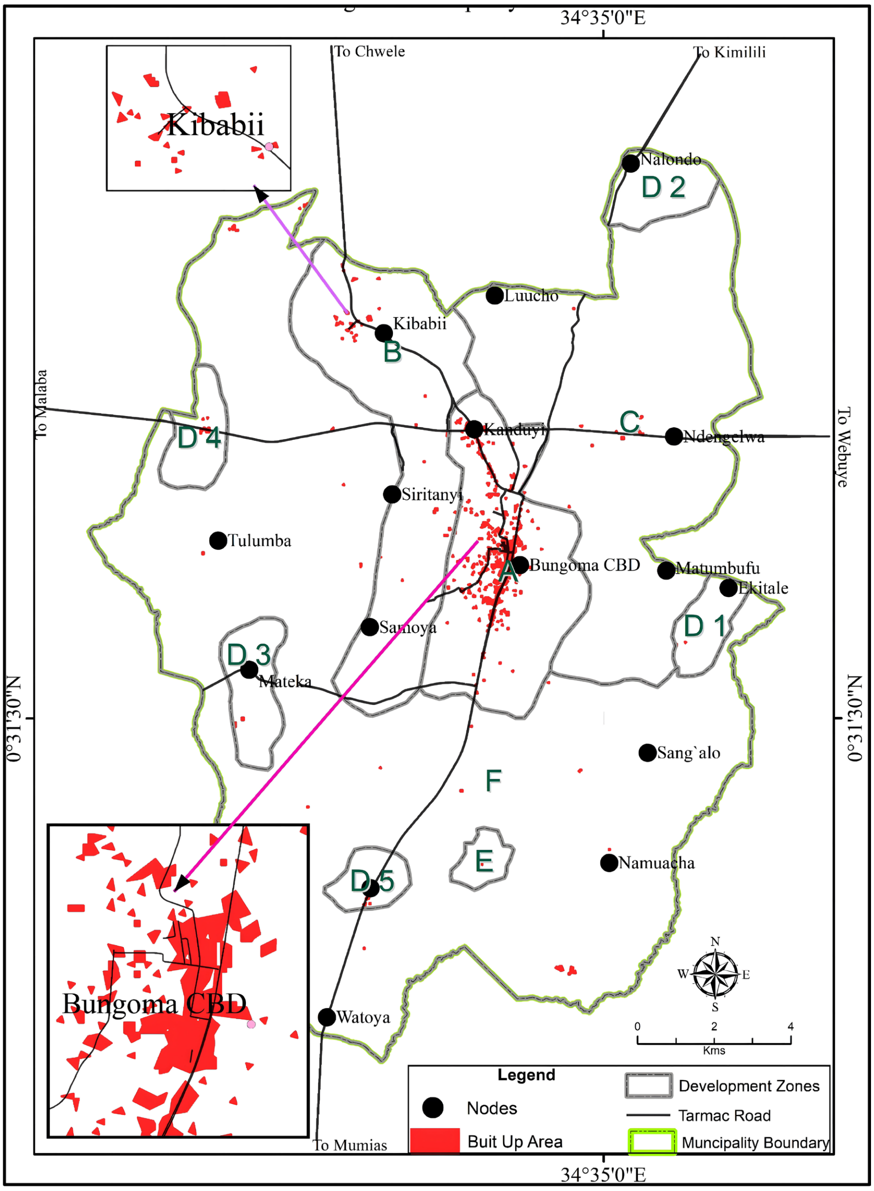

Figure 4. Road network, development zones vs built-up areas in Bungoma municipality.

The built-up areas are highly concentrated in places with a high intensity of tarmac roads, as shown in Figure 3 and Figure 4. Another indicator of urban development is the distribution of utilities, such as electricity-related infrastructure. Electricity step-down transformers, which serve as the basis for distributing power to households and supporting urban development activities, are utilized. The distribution pattern is connected to the major road network. The two development nodes with the highest concentration of built-up areas in each municipality also have the highest density of transformers per square kilometer, as summarized in Table 2 and Table 3.

Kerugoya CBD which is development zone 9 has the highest transformer density four per Km^2 and also recorded the highest land value of Khs.8 million. Additionally, on a Likert scale of 1 to 5, with 1 being the highest score it was selected to be among the most the most attractive development zone to investors as shown in Table 2.

Table 2. Kerugoya Urban development indicators.

Zone	Attractiveness	Land Value Kshs (Millions)	Transformer Density/Km^2
1	3	0.80	2.2
2	1	3.00	1.7
3	2	1.50	0.8
4	2	0.60	1.0
5	1	0.90	2.3
6	1	1.50	1.3
7	3	0.50	1.0
8	1	1.50	2.3
9	1	8.00	4.0
10	3	1.00	2.3
13	4	0.35	0.7
14	4	1.00	1.2
15	2	0.50	2.0
16	1	0.90	0.6

Table 3. Bungoma Urban development indicators.

Zone	Attractiveness	Land Value Kshs (Millions)	Transformer Density
A	1	1.50	2.3
B	3	0.60	0.9
C	3	0.30	0.6
D1	2	0.40	1.0
D2	2	0.60	0.9
D3	2	0.60	0.4
D4	2	6.00	1.1
D5	2	0.60	0.4
E	3	0.20	3.1
F	3	0.20	0.4

For Bungoma, the CBD denoted as development zone A in Figure 4 has the highest attraction score of 1 and high land value of Kshs 1.5 million with a transformer density of 2.3 per Km^2 (Table 3). The CBD also has the highest concentration of tarmac roads as indicated in Figure 4.

7. Conclusion

Road network is a key aspect of urban development for any region. From this study, it can be concluded that areas which have a high road network connectivity index are preferred by developers and hence have high property values. This is because they allow easy circulation of goods and services and can be accessed at any time. Despite the fact that the road network plays a critical role in the development of urban areas, other utilities such as electricity are also required for a fully functional settlement. The availability of roads forms the basis for the establishment of other activities, since they share the same space for installation. Social services, including educational institutions, can also stimulate growth. Kirinyaga and Kibabii universities have attracted development in the two municipalities, hence increasing the rate of built-up areas. Political and senior civil servants can influence the allocation of resources, and in this case, Kirinyaga has benefited in this respect, hence enjoying a good road network.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Allate, B. M. (2019). Terminal Location Models for Intermodal Transport Network Optimization. *Open Journal of Applied Sciences, 9,* 307-315. https://doi.org/10.4236/ojapps.2019.95025

Capello, R. (2000). The City Network Paradigm: Measuring Urban Network Externalities. *Urban Studies, 37,* 1925-1945. https://doi.org/10.1080/713707232

Cheng, J., Bertolini, L., Clercq, F. L., & Kapoen, L. (2013). Understanding Urban Networks: Comparing a Node-, a Density- and an Accessibility-Based View. *Cities, 31,* 165-176. https://doi.org/10.1016/j.cities.2012.04.005

Christopher Bull, P. D. (1984). *The Geogrpahy of Rural Resources.* Oliver and Boud.

County Government of Bungoma (2020). *Report on Review of Bungoma Urabn Area Boundary.*

County Government of Kirinyaga (2020). *Kutus Municipality Local Physical and Land Use Plan, 2020-2030.*

Daniel, C. B., Saravanan, S., & Mathew, S. (2020). GIS Based Road Connectivity Evaluation Using Graph Theory. In T. Mathew, G. Joshi, N. Velaga, & S. Arkatkar (Eds.), *Transportation Research* (pp. 213-226). Springer. https://doi.org/10.1007/978-981-32-9042-6_17

Derruder, B. (2019). Reving Network in Geography. *Journal of Economic and Human Geography, 112,* 404-420.

Derudder, B., & Neal, Z. (2018). Uncovering Links between Urban Studies and Network Science. *Networks and Spatial Economics, 18,* 441-446. https://doi.org/10.1007/s11067-019-09453-w

Duranton, G., & Turner, M. A. (2012). Urban Growth and Transportation. *The Review of Economic Studies, 79,* 1407-1440. https://doi.org/10.1093/restud/rds010

ESRI (2021). *ArcGIS Desktop.* https://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/map-algebra/a-quick-tour-of-using-map-algebra.htm

ESRI (2024). ArcGIS Pro. https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/create-thiessen-polygons.htm

Gateri, C. W., & K'Akumu, O. (2023). Highway Engineering and Land Use Change in Peri-Urban Nairobi: Assessing Inclusive Development Outcomes for Host Communities in the Northern Bypass Corridor. *Local Economy: The Journal of the Local Economy Policy Unit, 38,* 139-154. https://doi.org/10.1177/02690942231191981

Government of Kenya (2016). *National Spatial Plan 2015-2016.* Ministry of Lands and Physical Planning, Directorate of Physical Planning.

Jazdzewska, I. A. (2021). Use of Graph Theory to Study Connectivity and Regionalisation of the Polish Urban Network. *Area, 54,* 290-303. https://doi.org/10.1111/area.12774

Jibril, M. S., Aule, D. S., Garba, B. D., & Adewuyi, T. O. (2023). Network Analysis of Road Traffic Crash and Rescue Operations in Federal Capital City. *International Journal of Geosciences, 14,* 36-51. https://doi.org/10.4236/ijg.2023.141003

Kenya Roads Board (2021). *Road Sector Investment Programme 2028-2022.*

Kenya Roads Board (2023). *Roads Inventory and Condition Survey.*

Khanani, R. S., Adugbila, E. J., Martinez, J. A., & Pfeffer, K. (2021). The Impact of Road Infrastructure Development Projects on Local Communities in Peri-Urban Areas: The Case of Kisumu, Kenya and Accra, Ghana. *International Journal of Community Well-Being, 4,* 33-53. https://doi.org/10.1007/s42413-020-00077-4

Khine, M. M., Maw, Y. Y., & Win, K. M. (2018). Change Analysis of Indices (NDWI, NDVI, NDBI) for Wawlamyine City Area Using Google Earch Engine. *Journal of the Myanmar Academy of Arts and Science, XVI,* 297-313.

KNBS (2024). *The Kenya National Bureau of Statistics.* https://knbs.or.ke/

Ma, L., Wang, H., & Liu, B. (2019). Convenience Analysis of Citizen Using Garden Green Space Basing on Road Network's Accessibility: A Case Study of Tai'an Centaral City. *Current Urban Studies, 7,* 311-320. https://doi.org/10.4236/cus.2019.73015

Mugambi, C. M., Njuguna, M., & Karanja, D. (2022). Examining Rate of Built-Up Areas on the Vegetation Cover along River Riara Riparian within Kiambu Town, Kenya. *Journal of Geoscience and Environment Protection, 10,* 144-158. https://doi.org/10.4236/gep.2022.103011

Padam, S., & Singh, S. K. (2004). Urbanization and Urban Transport in India: The Search for a Policy. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.573181

Rahman, F., & Kumar, S. (2023). Analysis of Road Network Accessibility Using Graph Theory and GIS Technology: A Study of Bhojpur District, Bihar. *International Journal of Applied Research, 9,* 104-110. https://doi.org/10.22271/allresearch.2023.v9.i4b.10731

Republic of Kenya (1978). *Human Settlment Strategy in Kenya; A Strategy for Urban and Rural development.* Ministry of Lands and Settlement; Department of Physical Planning.

Republic of Kenya (1986). *Sessional Paper No 01 on Economic Management for Renewed Growth.* Government Printer.

Republic of Kenya (1994). *Sessional Paper No. 1 of 1994 on Recovery and Sustainable Development to the Year 2010.* Government Printer.

Republic of Kenya (2010). *The Constitution of Kenya.* Government Printer.

Republic of Kenya (2012). *Kenya Roads Act No. 2 of 2007, Revised 2012.* Government Printer.

Republic of Kenya (2019). *Urban Areas and Cities Act.* Government Printer.

Rodgrigue, J. P. (2024). Transport and Spatial Organization. In J. Rodgrigue (Ed.), *The Geography of Transport Systems* (6th ed., Chap. 2). Routledge.

Rodrigue, J. P. (2020). Transportation and the Spatial Structure. In J. P. Rodrigue, C. Comtois, & B. Slack, *The Geography of Transport Systems* (5th ed., pp. 56-89). Routledge. https://doi.org/10.4324/9780429346323-2

Roosta, M., Javadpoor, M., & Ebadi, M. (2022). A Study on Street Network Resilience in Urban Areas by Urban Network Analysis: Comparative Study of Old, New and Middle Fabrics in Shiraz. *International Journal of Urban Sciences, 26,* 309-331. https://doi.org/10.1080/12265934.2021.1911676

Sarkar, T., Sarkar, D., & Mondal, P. (2021). Road Network Accessibility Analysis Using Graph Theory and GIS Technology: A Study of the Villages of English Bazar Block, India. *Spatial Information Research, 29,* 405-415. https://doi.org/10.1007/s41324-020-00360-8

Sobolevsky, S. et al. (2013). Delineating Geographical Regions in an Expansive Set of Countries. *PLOS ONE, 8,* e81707.

Sun, J., & Hou, L. (2020). A Review for Urban Network Research. *Open Journal of Social Sciences, 8,* 412-418. https://doi.org/10.4236/jss.2020.86031

Ukhnaa, M., Huo, X., & Gaudel, G. (2019). Modification of Urban Built-Up Area Extraction Method Based on the Thematic Index-Derived Bands. *IOP Conference Series: Earth and Environmental Science, 227,* Article ID: 062009. https://doi.org/10.1088/1755-1315/227/6/062009

UN-Habitat (2004). *Urban Indicators Guidelines, Monitoring the Habitat Agenda and The Millenium Development Goals.* United Nations Human Settlements Programme.

UN-Habitat (2024). *Kenya.* https://unhabitat.org/kenya

USGS (2024). *EarthExplorer.* https://earthexplorer.usgs.gov

Vision 2030 Delivery Board (2018). *Marking 10 Years of Progress (2008-2018), Sector Proigress and Project Updates.*

Wen, W., Zhang, W., & Deng, H. (2023). Research on Urban Road Network Evaluation Based on Fractal Analysis. *Journal of Advanced Transportation, 2023,* Article ID: 9938001. https://doi.org/10.1155/2023/9938001

World Bank (2023). *EnergyData.Info. Kenya Eletricity Network.* https://energydata.info/dataset/kenya-electricity-transmission-network

World Bank Group (2024). *What We Do. Kenya Urban Support Programmme.* https://projects.worldbank.org/en/projects-operations/project-detail/P156777

Xiao, C., Liu, C., & Li, Y. (2022). Directional and Weighted Urban Network Analysis in the Chengdu-Chongqing Economic Circle from the Perspective of New Media Information Flow. *ISPRS International Journal of Geo-Information, 12,* Article 1. https://doi.org/10.3390/ijgi12010001

Zhao, G., Zheng, X., Yuan, Z., & Zhang, L. (2017). Spatial and Temporal Characteristics of Road Networks and Urban Expansion. *Land, 6,* Article 30. https://doi.org/10.3390/land6020030