Scientific Research Publishing

American Journal of Industrial and Business Management, 2024, 14, 992-1011
https://www.scirp.org/journal/ajibm
ISSN Online: 2164-5175
ISSN Print: 2164-5167

Impact of Road Transportation Network Infrastructure on Regional Development in Kenya

Alfred Eshitera, Lawrence Esho, Casty Gatakaa 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, G. C. (2024). Impact of Road Transportation Network Infrastructure on Regional Development in Kenya. *American Journal of Industrial and Business Management, 14,* 992-1011.
https://doi.org/10.4236/ajibm.2024.147051

Received: June 5, 2024
Accepted: July 28, 2024
Published: July 31, 2024

Abstract

In this study we review literature related to impacts of road transport infrastructure on regional development. We identify the indicators used to measure regional development from existing literature and further correlate it with road network concentration. Spatial metrics have been used to assess the correlation of road infrastructure network and regional development indicators which is further informed with economic models, spatial location theories and the Tobler's first law of geography. From the study, there is a positive correlation between regional development and road transport infrastructure indicators with an R^2 of 0.35. The selected indicators are County Domestic Product (CDP) and Kernel Density (KD) has been used to assess the clustering of road network in various regions hence generating a heat map. Moran's I has been used to calculate the likelihood of spillover effect of the road transport infrastructure network. Central Kenya has been identified to have high concentration of network and has possible spillover effect when it comes to development. This study contributes to regional science theory by applying integrated approach where both econometric and locational models have been used to understand Kenya road transport network and its implication to regional development patterns.

Keywords

Road Transport Infrastructure, Regional Development Indicators, Spatial Metrics

1. Introduction

Transportation is regarded as the main driver of civilization. It takes the power

of transportation to connect billions of people across various continents. From the early stages of civilization, speed and strength of mode of transport used was supreme in the hunt and battle fields. Consequently, centers of empires would be held together as they could be easily accessed by the rulers together with their army while protecting their territories. The forms of movement changed over time from the horse, the wheel, steam power to jet engine. Transportation has therefore become exoskeleton of regional development by allowing flow of goods and services (Siliva, 2017). In developed economies investment in the transport sector and improved technology over the last century has stimulated regional growth (Berg, Deichmann, Liu, & Harris, 2015). On the other hand,developing countries have recorded disparities in transport sector investment leading to inequality in regional development. In such countries there are governance gaps which does not permit sustainable models for financing public infrastructure including roads (Stern School of Business and New York University, 2016).

The early and the first attempt to document the role of transport in regional development was acknowledged by Von Thunen in his book Isolated State in the year 1826 (Ramesh, Luca, & Marco, 2023) and (Mackinnon & Docherty, 2013). Other theories that are built on transport systems include Alfred Weber industrial location model, Walter Christeller on central places, 1933 Losch Model, 1954, Alonzo bid rent, 1960 (Capello, 2011). Several studies on regional science, urban economics, economic geography and urban studies as documented by (Rodrigue & Ducruet, 2020) have extensively studied transportation systems. Despite several studies directly dealing with this topic the relationship between transport and regional development presents a gap which needs to be studied especially at the national level of developing countries. In rural areas roads are the foundation of physical infrastructure which provide cheap access (Jacoby, 2000).

Available modes of transportation include water, air, rail and road. Road transportation has an advantage over other modes of transport due to its flexibility which can offer door to door service as it covers 42% of global mobility (Tini, Shah, & Sultan, 2018). These modes of transport have accelerated regional development in recent centuries by linking regions and centers (Michniak, 2015). Roads provides cheap access to markets in rural areas allowing distribution of farm produce to urban areas in exchange for inputs (Jacoby, 2000). In addition, well connected rural areas are resilient to natural shocks, empowered, socially integrated and they have a reliable supply chain of food and farm inputs (Thynell, 2017).

Despite the fact that most developing countries spend huge percentage on roads sector, little is known about the benefits of such investment (Jacoby, 2000). In Kenya the 2023/2024 gross budget estimates indicates 22.7% (Treasury, 2023) was allocated to the Ministry of transport where the raod sector is domiciled. The objective of this article is to identify indicators of regional development and gauge their performance in relation to road transport infrastructure in the Ke-

nyan context. Research questions answered includes; which region of the country has the most improved/coverage of road transport infrastructure? What are the indicators of regional development as covered in existing literature? What is the relationship between road infrastructure coverage and regional development indicators? Additionally, studies correlating road network infrastructure and regional development are still elusive in Kenya. Therefore, impact of road transport infrastructure on regional development is good hypothesis to test.

2. Conceptual Issues: Road Transport Infrastructure and National Development

There are four main modes of transport that is road, air, maritime and rail. Road transport which is the subject of this study is composed of the following sub modes; walking, animal carriages and automobiles (Tchanche, 2019). The concept of road infrastructure therefore includes all basic facilities and governance structures required for proper functioning of national or a region's economy. Road transport has become key element of physical infrastructure that creates conducive environment for thriving national socio-economic development (Bekisz & Kruszynski, 2021). Regional planners advocate for a system that will support economic growth and welfare advancement of the entire community (Bandyopadhyay & Datta, 1989). The role of transport infrastructure in national development arena is determined by the services it provides. An improvement on road transport infrastructure reduces transport cost which is a major factor in production and distribution chain (Arbues, Banos, & Mayor, 2015). Therefore, national development must include both growth and distributive justice which is a constitutional requirement (Government of Kenya, 2010).

Existing literature on the impact of transport policies and investment have a varied outcome at different spatial levels. An increase in productivity is a positive indicator of welfare of individuals and is a reflection of the impact of road infrastructure investment in a region (Berg, Deichmann, Liu, & Harris, 2015).

Theoretically, the role of transport and its relation to development can be linked to regional economic models. The first work to be published in relation to locational models was done in 1806 by Von Thunen in his book Isolated State as expounded by (Pokharel, Bertolini, & Brommelstroet, 2023). Another location model linking transport and development is the work of Alfred weber where the cost of transportation plays a big role in locating a firm (Rodrigue & Ducruet, 2020).

2.1. The Impact of Transportation Network on National Development

Roads are predominantly used as mode of transport and form a strategic element for National development. Sub-Saharan African countries for example Ghana has invested in road transport infrastructure as it is a policy measure meant to revitalize regional growth and poverty reduction (Boateng & Fricano, Adarkwa, 2015). Both pre and post-independence Kenya national development poli-

cies have emphasized on the need of investing in the transportation sector. The colonial policy commonly known as the Swynnerton plan (Ministry of Agriculture and Water Resources, 1955) recommended investment in road sector in highlands zones mainly in central and rift valley regions which were occupied by white settlers. The settlers were mainly farmers and this policy strategy was seen as a measure of stimulating growth specifically in agriculture sector as it was the main economic activity. The first post-independence policy paper supported heavy investment on road network improvement viewed as a means a means of improving market access for most perishable goods (Government of Kenya, 1965).

It is therefore imperative that there is clear link between road transport network distribution and regional growth. Road network provide good access which is the ability of citizens to interact freely with little or no friction (Hassan, Wang, Khoo, & Foliente, 2017). The impact can be all economic, social or political. Economically good, reliable and affordable road transport network allows smooth flow of goods and services conveniently hence improving development (Berg, Deichmann, Liu, & Selod, 2016). Socially the networks allow communities and citizens in general to move around the space and interact while creating social bonds (Thynell, 2017). In the field of regional science road transport network are viewed as a means of improving spatial organization where activities are linked to each other (Rodrigue & Ducruet, 2020).

2.2. National Development

Gross Domestic Product (GDP) is widely used as a measure of national development. In this study we adopt (Frank, Bernanke, Osberg, Cross, & Macleen, 2003) definition of GDP which is the value of final goods and services produced by a country or region over a period of time which is mostly calculated by a given state on annual basis. The macroeconomic model used to calculate GDP is indicated in formula Equation 1 which is adopted from (Mankiw, Kneebone, McKenzie, & Rowe, 2006)

Equation 1: Gross Domestic Product Model

$$Y = C + I + G + (e - i)$$

Where Y = Gross Domestic Product

C = Consumption (expenditure goods and services)

I = Investment (expenditure on assets)

G = Governmnet Purchases

$(e - i)$ = netexport

In an empirical study using data from Russian Statistical Agency (Sergei, Mikail, & Kudrov, 2018) identifies parameters used to calculate Gross Regional Product (GRP). The identified parameters are incomes from key production sectors **Table 1**. These sectors are similar to the ones used to calculate Kenya's Gross County product (GCP) which is an estimate of the size and structure of the forty-seven (47) county economies. GCP is what is international known as Gross Regional Product (GRP) (KNBS, 2022) which is international used indicator of growth.

Table 1. Sectors of economy, source: (KNBS, 2022).

Agriculture, Forestry, fishing	Manufacturing	Mining and quarrying
Water supply, waste collection	Services, Education	Electricity and supply
Repair of motor vehicle	Wholesale and retail trade	Construction
Administration support activities	Transport and storage	Accommodation, food sales
Professional, technical activities	Real estate activities	Financial and insurance activities
Public administration, defense	Human health, social work	Information and communication

Both (Mankiw, Kneebone, McKenzie, & Rowe, 2006) and (Frank, Bernanke, Osberg, Cross, & Macleen, 2003) suggest that GDP is a good single measure of economic wellbeing of any society and is strongly correlated with the measure of quality of life. The GDP approach has a circular flow **Figure 1** as adopted from (Ragan & Lipsey, 2008). The flow indicates circulation of money which includes expenditure and income from all sectors of economy both government, households and private firms.

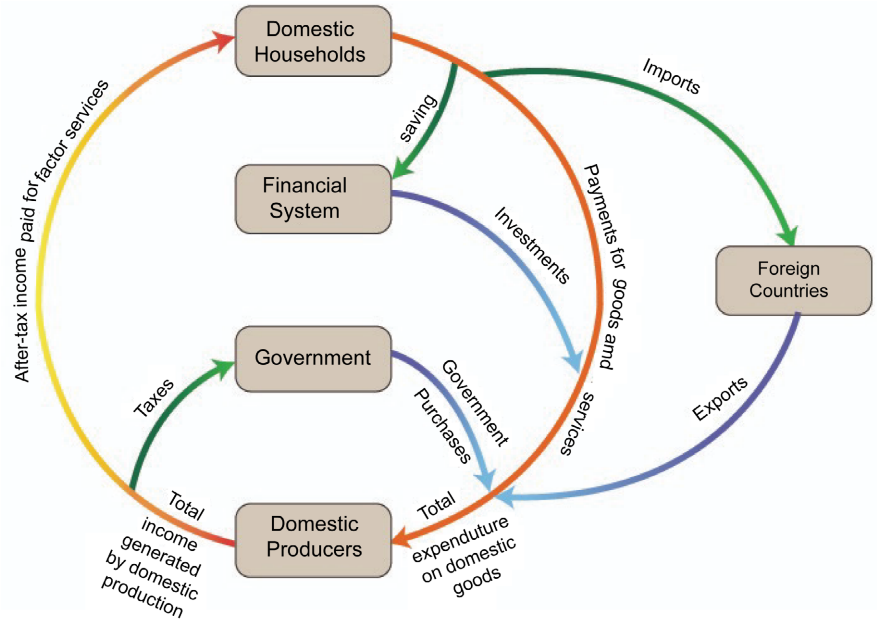


Figure 1. Circular flow of expenditure and income (Ragan & Lipsey, 2008).

2.2.1. The Concept of a Region and Gross Regional Product

First we start by defining a region in the context of this study. We adopt (Sergei, Mikail, & Kudrov, 2018) definition of a region which is a homogenous geographic area which has similar production factors. Regional economies which are used to measure the level of growth are quantified using Gross Regional Product (GRP) which is GDP at a lower level. In some countries for example In-

dia they use states and districts as planning regions (Ohlan, 2012) and (Kurian, 2000). In Kenya counties are used as regions where planning and implementation of development projects is mainly done. Kenya therefore has forty-seven (47) devolved planning regions in the name of counties (Government of Kenya, 2010). The devolved units are meant to promote development and equitable sharing of national resources. The calculation of GRP is important since it used to assess revenue potential and used as an indicator of development progress over time (KNBS, 2022).

In conclusion, development can be explained using regional macroeconomics models which incorporates dimension of space into analysis. Theoretical inputs of regional development are based on macroeconomics, trade theory which are expressed by mathematical formulae (Capello, 2011) as shown in Equation 1. The concept of Gross Domestic Product (GDP) which is includes spending on all production sectors of a region ranging from mining, agriculture and service industry is a good denominator of regional development (Aivazian, Afanasiev, & Kudrov, 2018). In this study the adoption of GCP which is GDP at the County level as an indicator was selected because the formulae used to calculate it is inclusive incorporating all sectors of development (KNBS, 2022), (Kurian, 2000). Using GDP to assess the impact of road infrastructure network investment which is evidenced in the network expansion is an approach which is well supported by several empirical studies (Whittle, 2009), (Nigohosyan & Vutsova, 2017), (Aivazian, Afanasiev, & Kudrov, 2018). Supportive road infrastructure investment policy framework improves competiveness of a region by making it a locational choice. A negative loop is an outcome of unsupportive policy framework (**Figure 2**).

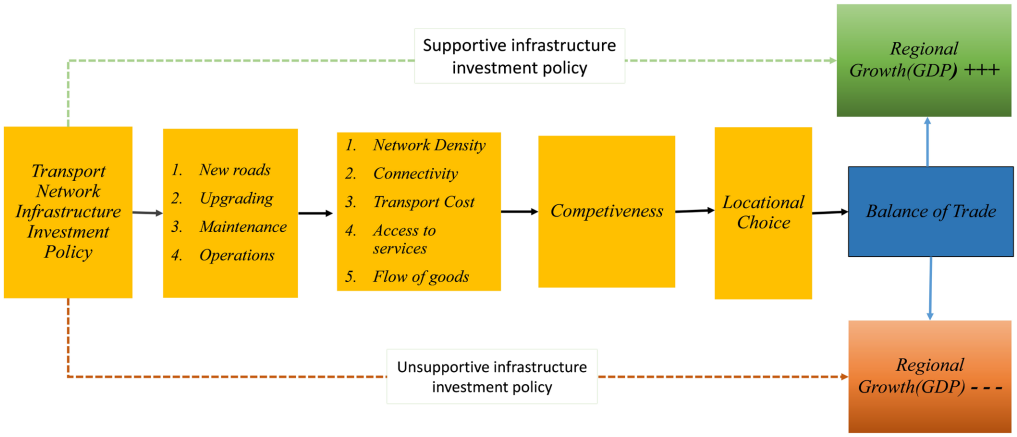


Figure 2. Conceptual framework indicating spill over impact of road infrastructure policy, Source researcher construct.

3. Methodology

3.1. Review of Existing Literature

Existing literature was selected specifically in studies where road transport was treated as an independent variable and regional development indicators treated

as dependent variable. The reviewed documents included policy documents and scientific papers published in various journals and hardcopy textbook from the library. The first literature on attempt to calculate Kenya regions CDP was done by World Bank using night lights as proxy. The approach of using satellite data of night lights was developed by (Henderson, Storeygard, & Weil, 2011) who argued that consumption of electricity is relative to disposable income by all contributors of GDP including households, firms and government entities. Areas with high intensity of night lights give an indication of a high CDP. We use the same approach where the heat map of existing road network is used as a proxy of regional development. We correlate the road infrastructure intensity data with GDP to assess the development patterns of various regions in this study the Kenya Counties and identify those that are lagging behind. This is approach is justified by (Okrasińska & Wojewódzka-Król, 2018) who argues that the benefit of road infrastructure analysis should be done together with the GDP as it is a good indicator of regional growth which is combines all sectors economy of any given region (Mankiw, Kneebone, McKenzie, & Rowe, 2006) and (KNBS, 2022). GDP has been used to measure the growth in various regions.

3.2. Spatial Data Selection and Analysis

The existing road network data for the year 2023 was sourced from Kenya Roads Board (KRB). The existing county boundary was sourced from Kenya Bureau of Statistics (KNBS) and later populated with macroeconomic data sourced from KNBS reports. Network density growth and distribution analysis was done using ArcGIS and Geoda mapping and visualization Apps. Supervised Self Organizing Maps (SOMs) were used to generate heat maps indicating the pattern and clustering of road density in various regions. Kernel density which is a function within Esri Armap GIS is used to calculate network density referred in this paper as Kennel density (KD) value. The formula is indicated below Equation 2 adopted from (ESRI, 2023). Kernel density is used to generate a heat map indicating the general clustering of road network infrastructure on the Kenyan space. The density estimation method was pioneered by (Siverman, 1986) and further published in his book (Silverman, 1998).

***Equation 2*: *Kernel Density Calculation, Source*: (ESRI, 2023)**

$$Density = \frac{1}{(Radius)^2}\sum_{i=1}^{n}\left\{\frac{3}{\pi} - pop_i\left(1-\left(\frac{dista_i}{Radius}\right)^2\right)^2\right\}$$

$$For\ dist_i < radius$$

where

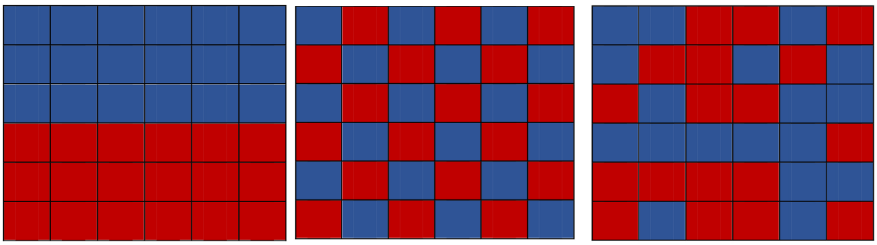
i = 1, …, n are the input points. only points in the sum if they are within the radius of the (x, y) location

Pop_i = the possible population field value of the point i, which is an operational parameter

$dist_i$ = the distance between point *i* and the (*x. y*) location

3.2.1. Assessing the Spillover Effect of Road Network Infrastructure

To assess the spillover effect of road network infrastructure, spatial autocorrelation using Moran's I index was applied. Spatial correlation is commonly used to assess the degree to which similar observation tend to occur near each other within regions as illustrated by (Leitner, Glasner, & Ourania, 2018) in **Figure 3**. This approach of describing the likelihood of a variable to relate to itself and its neighborhood in a region conforms to Tobler's first law of geography which states 'everything is related to everything else but near things are more related than distant things' (Tobler, 1970). Positive spatial autocorrelation is observed when similar values abuts each other. On the other hand, dispersed values are an indication of negative correlation (Moraga, 2023) and (Miller, 2004) as illustrated in **Figure 3**.



(a) (b) (c)

Figure 3. Spatial autocorrelation configuration: (a) Positive correlation; (b) Negative correlation; (c) No correlation (Leitner, Glasner, & Ourania, 2018).

Moran index was calculated using GIS software by converting the data into cells/grids with attribute values having the clustering of road network with Equation 2. The formula applied in Moran's calculation is as shown in Equation 3.

***Equation 3 Moran Index formula, Source*: (Leitner, Glasner, & Ourania, 2018)**

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} wij\left(Xi - X\right)\left(X\ddot{J} - \ddot{X}\right)}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} wij\right)\sum_{i}^{n}\left(X - \ddot{X}\right)}$$

n = number of observations (grid cells)

Xi = the grid or cell value of an attribute being

Xj = the grid or cell value of the same attribute at a different location

X = the mean value of the attribute of the cells being observed

Wij = sum of grids or grids with zero values

Wij = sum of cells/grids with zero values

4. Results and Discussion

In this section the output of the analysis is presented in three parts. In part one the general distribution of the network is presented, while in part two the regional outlook is discussed. Lastly, part three looks at the relationship between road transport infrastructure network and regional development.

4.1. Indicators of Regional Development

A review of existing literature and theoretical frameworks gives a clear indication that there is a close relationship between road network infrastructure network distribution and regional development. A region's total output depends positively on its infrastructure stock where road network takes a big share (Arbues, Banos, & Mayor, 2015).

In summary, (Bekisz & Kruszynski, 2021) observes that for any region to operate optimally, it must have a sound and reliable road transport t system. Existing studies which were reviewed have been summarized in the Table 2 below.

Table 2. Existing literature on development indicators.

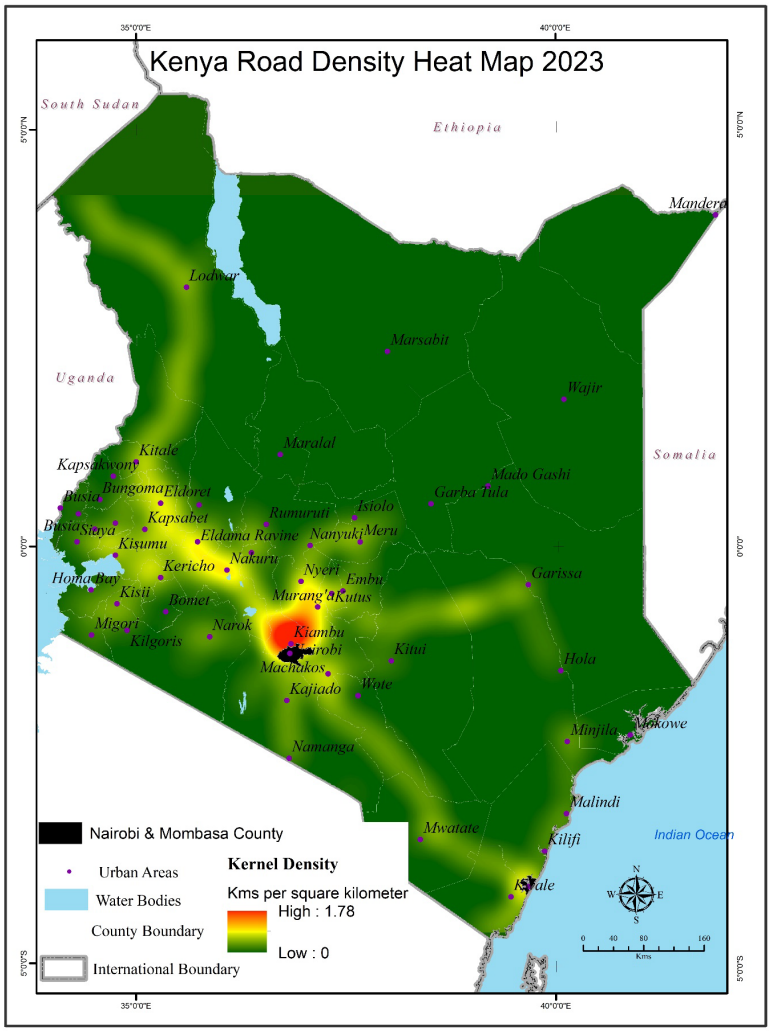
	Author(s)	Development indicators	GDP sub themes
1.	(Ivanova & Masorova, 2013), (Ivanova & Masorova, 2013), (Bhattacharya & Sakthivel, 2004), (Gereffi & Funda, 1992), (Meadows & Jackson, 1984) (Sergei, Mikail, & Kudrov, 2018)	Gross Domestic Product (GDP)	• Employment, wages, consumption, savings, investment and tourism • Employment, wages, consumption, savings, investment and tourism • Agriculture • Industry • Manufacturing • Services • Welfare (life expectancy at birth, infant mortality, adult illiteracy)
2.	(Tini, Shah, & Sultan, 2018)	Social services and environmental	• Access, to health care • Reduced CO_2 emissions
3.	(Asher & Novosad, 2020)	• Social development	• Number of primary schools • Number of medical centers • Electricity connections • Area under irrigation • Distance to the nearest town • Literacy levels • Land ownership
4.	(Ng, Jakarni, & Kulanthayan, 2018)	• Length of road • Population • Socioeconomic indicators	• Road network • Exports • Education • Physical capital stock • urbanization
5.	(Thynell, 2017)	• Food security • Uninterruptable food Supply chain	
6.	(Ohlan, 2012)	• Thematic (Agriculture) • Infrastructural facilities • Industries	• Area of land planted • Crop grown • Extension services • Production • Livestock/poultry • Machineries • Literacy levels, number of schools, health institutions, banks, commercial activity, urbanization • Factories, employment, power connections
7.	(Majumder, 2005)	Development sectors (country India)	• Agriculture, industrial development, manufacturing, • Social (literacy, mortality) • Infrastructure (physical and financial) • Transport

Existing studies linking road transport network to development have been summarized in Table 2. It can therefore be concluded a region's road network infrastructure is directly correlated to its development.

In the review there are others measures of calculating regional growth but GDP is widely used.

4.2. National Outlook of Road Transport Infrastructure Network Distribution

The results from this section are for the data collected in 2023 by Kenya Roads Board. The heat map is therefore generated indicating the intensity of the road transport infrastructure network clustering within various regions. The network is clustering around central region and the white highlands which are rich agriculturally and located in lower North Rift and Mount Kenya region as indicated in Map 1. This should have been an effect of the (Ministry of Agriculture and Water Resources, 1955) policy which gave priority to investment in white



Map 1. Map 2: 2023 road network infrastructure density, source: (Kenya Roads Board, 2023).

highlands due to the white settlers' interest in farming. The follow-up policy (Government of Kenya, 1965) by independent government supported investment in the same region, the buyers of land in the former white settlers were individuals who were politically connected and could influence the where major investment were to be done.

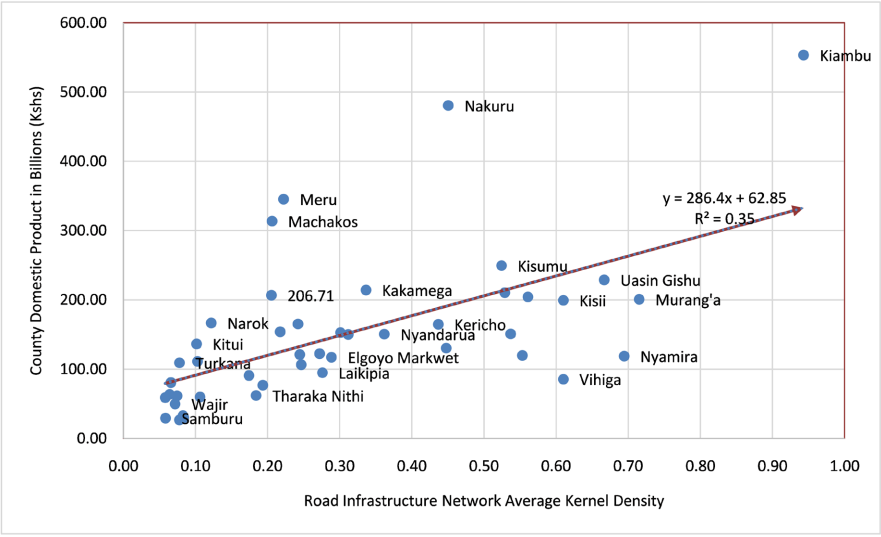
The maximum value for road network kernel density ranges from 0.00 to 1.78 as illustrated in **Map 1**. The high concentration is around Kiambu and neighbouring counties which are zoned as Mountain region economic bloc (State Department for Devolution, 2023). Other regions especially those surrounding Kisii, Nakuru, Eldoret and partially Kisumu also have improved their network density.

4.3. Correlation between Road Clustering and Regional Development

A correlation scatter plot of independent variable (road infrastructure network density) and dependent variable (regional development indicator) indicates a positive correction. When a trend line is fitted an R^2 of 0.35 is observed as indicated in **Graph 1**. The linear correlation equation is

Equation 4: Correlation between Road Transport Infrastructure and County Development

$$y = 286.48x + 62.854$$



Graph 1. Correlation between road density and county domestic product, data source: (Kenya Roads Board, 2023), (KNBS, 2022).

4.4. Regional Distribution

The spatial location of key contributors to the CDP econometric model is distributed randomly on the Kenyan space. The regions which are mostly homogenous in terms of natural resources are further divided into counties as administrative units. Each region is characterized by its production factors forming va-

ried sectors (Aivazian, Afanasiev, & Kudrov, 2018). The sectors are agriculture, fishing and forestry which contribute to the CDP sectors, others includes manufacturing, tourism, livestock production and mining (KNBS, 2022).

4.5. Correlating Road Infrastructure Network and Regional Development

Existence of reliable and accessible road transport infrastructure is an important policy tool that promotes regional growth while reducing disparity. The logic behind this argument is, existence of good road infrastructure network necessitates mobility. Mobility promotes trade while trade which is a stimulant of regional economic growth (Elburz & Cubukcu, 2020). Governments formulates regional policies among them allocation of resources for road infrastructure development which enhance competiveness of region while attracting investors whose spillover effect is development (OECD, 2009). This implies that areas with good road network will record a progressive regional development trend (Rokicki & Stepniak, 2018).

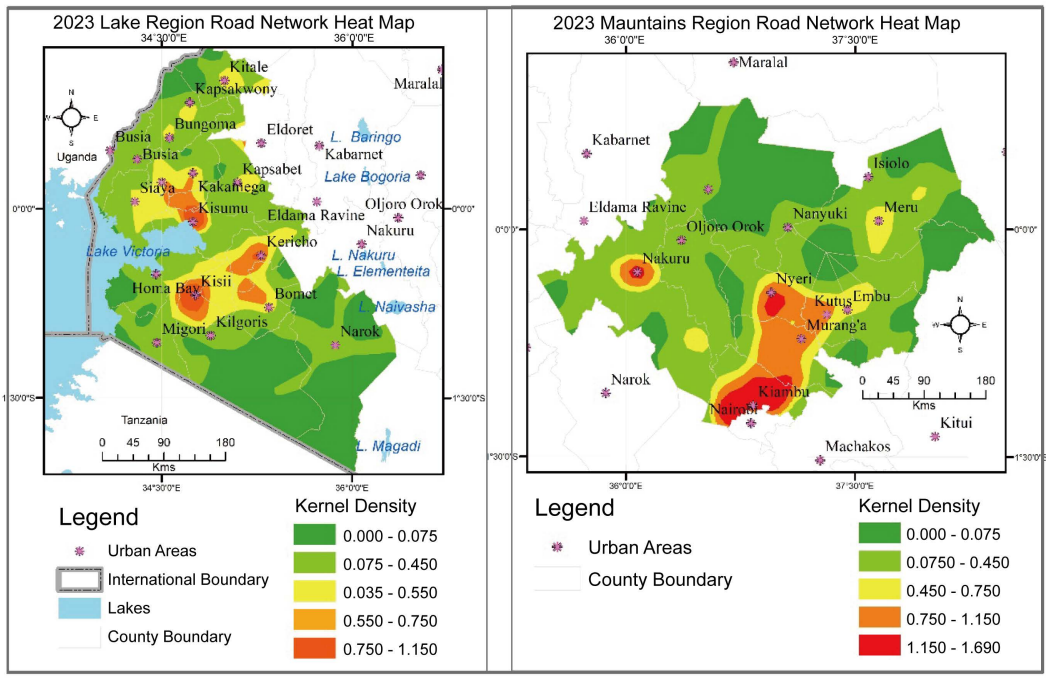
From the above paragraph roads can be used as a good indicator of regional development, for the analyzed results which are presented here, road network density is therefore used as a proxy of regional development and disparity. Moran's I index computation results which were calculated based on the heat map generated using Kernel Density approach will be presented. The presentation is based on how counties are distributed over Kenya classified into economic blocs (State Department for Devolution, 2023). Coincidentally the economic blocs are related on the production sectors of the country ranging from agriculture, tourism, mining among others.

4.6. Mountain Region Counties and Lake Basin Region Counties

These are the counties which actively contribute to National GDP where agriculture, fishing and forestry are the main economic activities with a total of 20% (KNBS, 2022). The counties include Meru, Nakuru, Murang'a, Nandi, Nyandarua, Kiambu, Bungoma, Kisii, Kakamega, Kericho, Bomet, Narok, Nyeri, Trans-Nzoia, UasinGishu, Kirinyaga and Nyamira. Others include Homabay, Machokos, Migori, and Kisumu. Since Narok county is not in any of the trading blocs (State Department for Devolution, 2023) it was included in lake region due its agricultural production. Agricultural products need to be transported to the market urgently since they are perishable hence require good road network.

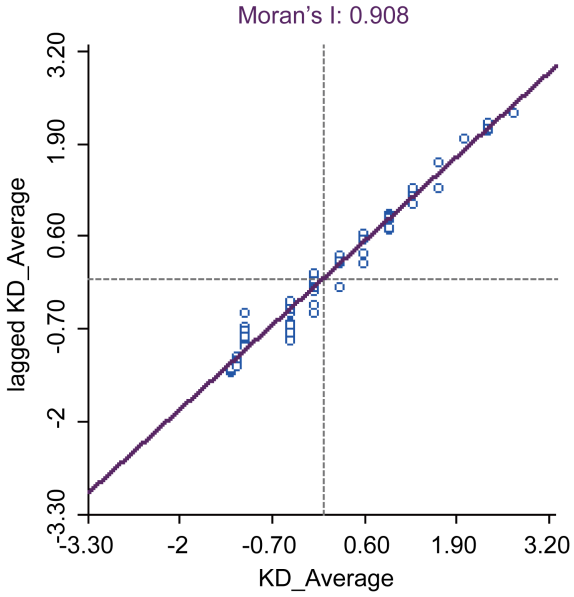
The mountain region which is defined with Mount Kenya and Arbadare Ranges has the highest clustering of road network density. The clustering is uniform recording a maximum value of 1.690 kilometers of tarmac road per Km^2 spreading around Kiambu, Nakuru and Nyeri Municipalities. The intensity in heat map diminishes as you move towards Meru (**Map 2**).

The lake region also depends on agriculture as indicated in (KNBS, 2022) report on County Gross Product (CGP) report. The kernel density values ranges

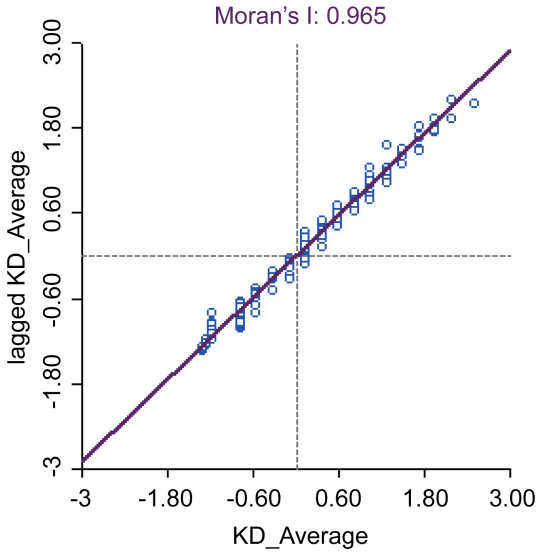


Map 2. Road Heat map for Lake and Mountain Region.

from 0.0 to 1.15 with the southern part covering County having lower values. The areas surrounding Kisii and Kisumu recorded high values of kernel density values ranging from 0.750 to 1.150. The continuity values which are Moran's I index are 0.913 and 0.965 as indicated in **Graph 2** and **Graph 3**. Since road density has been used as indicator of development the mountain region will record more development has it has a continuous patch stretching from Kiambu to Nyeri and Nakuru of good road network concentration.



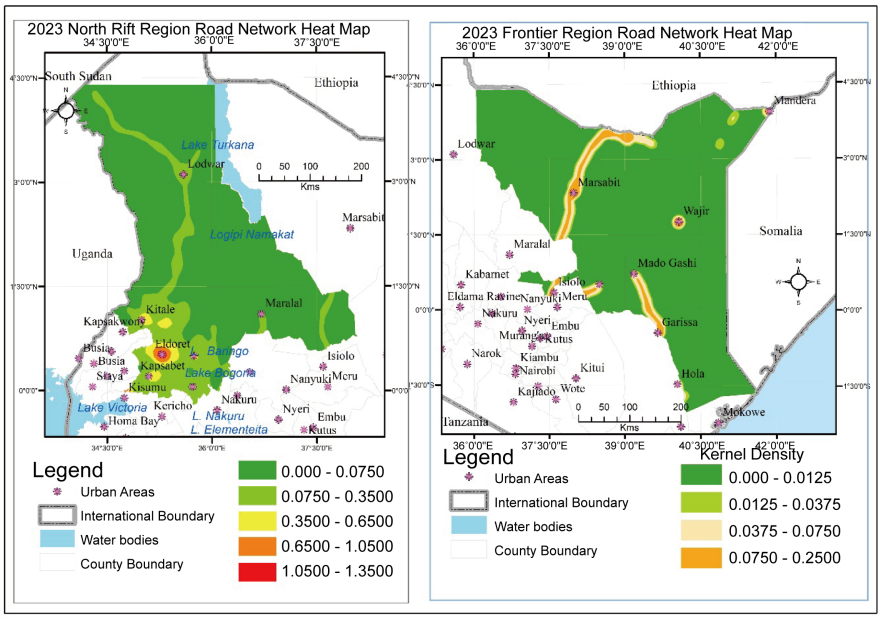
Graph 2. Moran I Index for Lake Basin Region.



Graph 3. Moran I Index for Mountain Region.

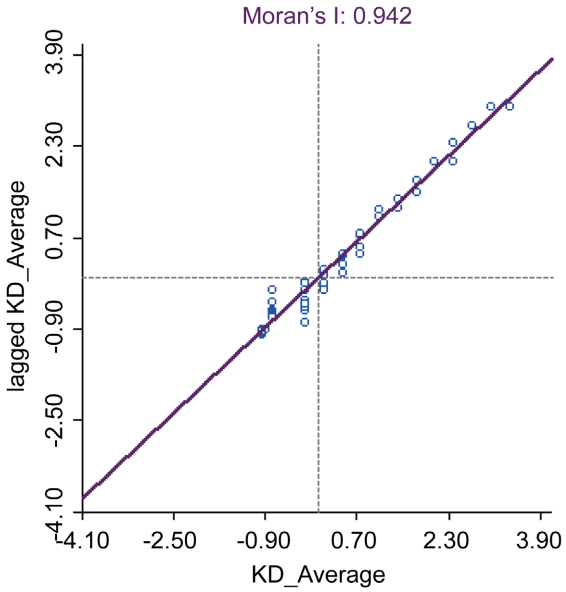
4.6.1. North Rift and Frontier Counties

This region County Gross Product is majorly drawn from livestock and mining sector (KNBS, 2022) as it is mainly arid and semi-arid. Kernel density is highest in areas around Eldoret (**Map 3**) with this zone having different agro climatic condition which allows residents to participate in rain fed agriculture, the area is also a key transport hub with several storage facilities and agro industries.

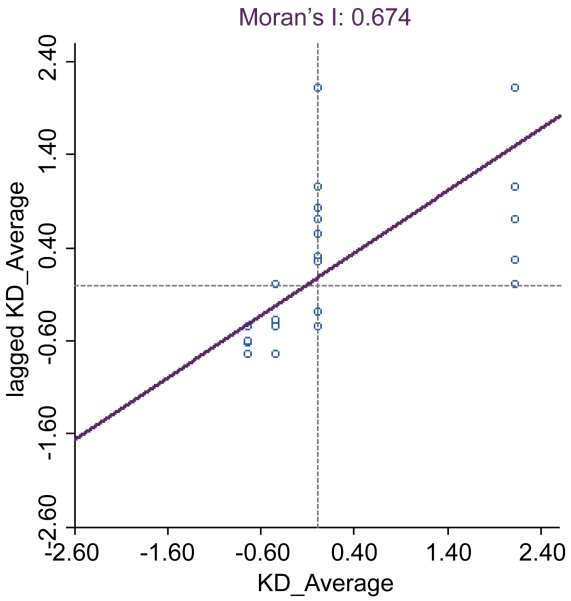


Map 3. Road Heat map for North Rift and Frontier Region.

The patch continuity indices for the two regions are 0.942 in **Graph 4** and 0.674 in **Graph 5**. Frontier region index is high and continuous patch of low network density implying there is less development.



Graph 4. Moran I Index for North Rift Region.



Graph 5. Moran I Index for Frontier Region.

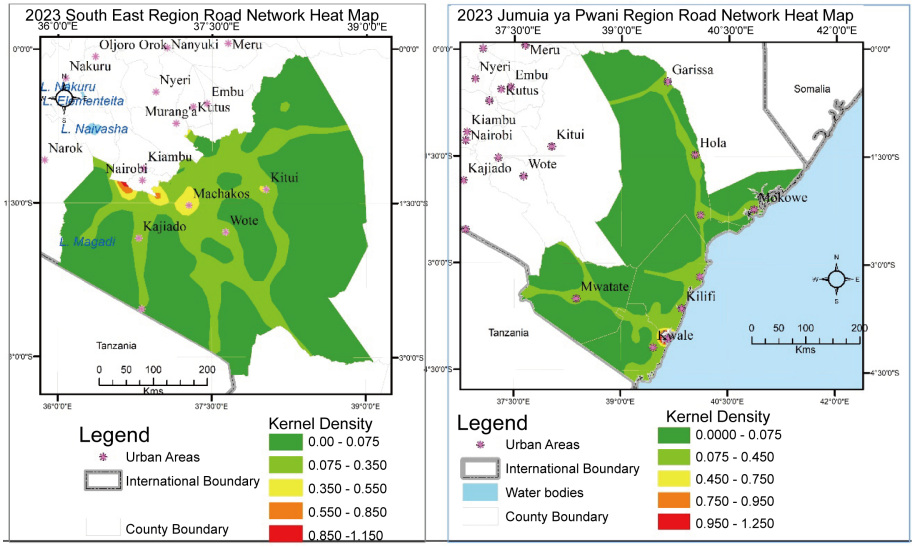
4.6.2. Coast (Pwani) Region and South East Regions

Lastly, the South East and Pwani regions key aspects of production are tourism, livestock and mining.

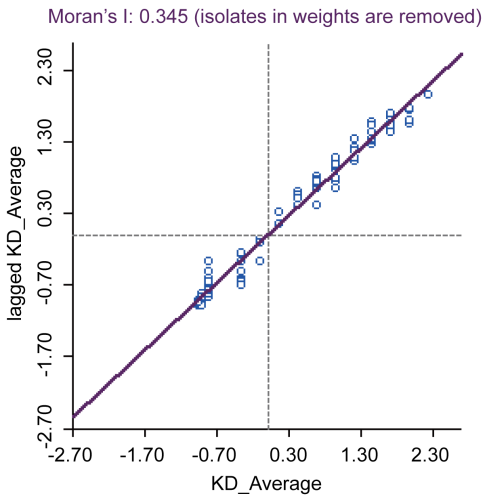
The regions have lower density of road network (**Map 4**) the patches are continuous as shown in **Graph 6** and **Graph 7** giving a clear indicating that the region's growth is lower compared other regions.

4.6.3. The Impact of Road Network on Regional Development

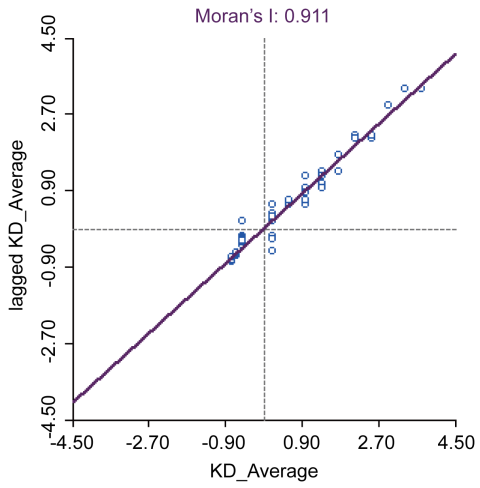
Based on the results it can be summarized that the spillover effect of road network density is high in the mountain region which has the highest mean value of



Map 4. Road Heat map for South East and Pwani Region.



Graph 6. Moran I Index for Coast Region.



Graph 7. Moran I Index for South East Region.

0.59 with a standard deviation of 0.43. The frontier region has a lower mean of 0.07 meaning it is lagging behind it terms of development in the entire country when road density is used as a proxy for development Table 3.

Table 3. Summary of road density indices.

	Observed values for road density network					Spatial lag	Impact Rank
	Region	Maximum	Minimum	Mean	Standard Deviation	Moran I	
1	Mountain Region	1.69	0.00	0.59	0.43	0.965	1
2	Lake Region	1.15	0.00	0.36	0.28	0.913	2
3	North Rift	1.35	0.00	0.32	0.31	0.942	3
4	Pwani	1.25	0.00	0.37	0.38	0.674	4
5	South East	1.15	0.00	0.20	0.26	0.911	5
6	Frontier	0.25	0.00	0.07	0.08	0.945	6

5. Conclusion

There is a positive correlation between road transport network and regional economic development. Areas which recorded higher road network density also had a better regional growth indicator. With the advance of 2010 Kenya constitution, all regions were to be treated equally in terms of infrastructure investment which necessitated the establishment of equalization fund. The fund was meant to balance development by uplifting lagged regions. Equally Kenya national development blue prints which is Vision 2030 and national spatial plan recognizes the importance of road infrastructure and gives it more emphasis by referring it to the pillar of other sectors. As per this blue print other sectors of development which are economy, social and politically can only pick off if the base which is infrastructure which includes road network is properly distributed on the national space. Despite this emphasis in the constitution and development blue prints gap in road network distribution has widened with some regions recording more road network expansion than others. The northern, Eastern and partial regions of southern part have received a lower share of network expansion. This implies they will continue lagging behind in terms of development which is against the spirit of Kenya Constitution.

The study contributes to the theory of regional development by giving an insight on how regional spatial metrics can be used to understand network growth and its impact on regional development. Pedagogical an integrated approach that includes geography theory, economic models and indicative maps have used which makes it easy to understand the distribution of network and add value to the lines which have always been used. We recommend more details study to link the road network work investment patterns vis-à-vis the politics and the role of executive in decision making when it comes to distribution of resources

against constitutional requirements.

Conflicts of Interest

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

References

Aivazian, S., Afanasiev, M., & Kudrov, A. (2018). Indicators of Regional Development Using Differentiation Characteristics. *Montenegrin Journal of Economics, 14,* 7-22. https://doi.org/10.14254/1800-5845/2018.14-3.1

Arbués, P., Baños, J. F., & Mayor, M. (2015). The Spatial Productivity of Transportation Infrastructure. *Transportation Research Part A: Policy and Practice, 75,* 166-177. https://doi.org/10.1016/j.tra.2015.03.010

Asher, S., & Novosad, P. (2020). Rural Roads and Local Economic Development. *American Economic Review, 110,* 797-823. https://doi.org/10.1257/aer.20180268

Bandyopadhyay, R., & Datta, S. (1989). Strategies for Backward-Area Development: A Systems Approach. *Journal of the Operational Research Society, 40,* 737-751. https://doi.org/10.1057/jors.1989.136

Bekisz, A., & Kruszynski, M. (2021). Analysis of the Diversity of Regional Development of Road Transport Infrastructure in Poland. *European Research Studies Journal, XXIV,* 712-723. https://doi.org/10.35808/ersj/2260

Berg, C. N., Deichmann, U., Liu, Y., & Harris, S. (2015). *Transport Policies and Development.* World Bank Group.

Berg, C. N., Deichmann, U., Liu, Y., & Selod, H. (2016). Transport Policies and Development. *The Journal of Development Studies, 53,* 465-480. https://doi.org/10.1080/00220388.2016.1199857

Bhattacharya, B. B., & Sakthivel, S. (2004). Regional Growth and Disparity in India: Comparison of Pre and POSR Reform Decades. *Economic and Political Weekly, 39,* 1071-1077.

Boateng, R. S., Fricano, R. J., & Adarkwa, F. (2015). Assessing the Socio-Economic Impacts of Rural Road Improvements in Ghana: A Case Study of Transport Sector Program Support (II). *Case Studies on Transport Policy, 3,* 355-366. https://doi.org/10.1016/j.cstp.2015.04.006

Capello, R. (2011). Location, Regional Growth and Local Development Theories. *Aestimum, 58,* 1-25.

Elburz, Z., & Cubukcu, K. M. (2020). Spatial Effects of Transport Infrastructure on Regional Growth: The Case of Türkiye. *Spatial Information Research, 29,* 19-30. https://doi.org/10.1007/s41324-020-00332-y

ESRI (2023). *How Kernel Density Works.* How Kernel Density Works—ArcGIS Pro/ Documentation. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-kernel-density-works.htm

Frank, R. H., Bernanke, B. S., Osberg, L., Cross, M. L., & Macleen, B. K. (2003). *Principles of Macroeconomics, First Canadian Edition.* Mc Graw Hill.

Gereffi, G., & Fonda, S. (1992). Regional Paths of Development. *Annual Review of Sociology, 18,* 419-448. https://doi.org/10.1146/annurev.so.18.080192.002223

Government of Kenya (1965). *African Sociolism and Its Application to Planning in Kenya.* Government Printer .

Government of Kenya (2010). *The Constititution of Kenya.* Government Printer.

Hassan, S., Wang, X., Khoo, Y. B., & Foliente, G. (2017). Accessibilty and Socio-Economic Develoment of Human Settlemnts. *PLOS ONE, 12,* e0179620.

Henderson, V., Storeygard, A., & Weil, D. N. (2011). A Bright Idea for Measuring Economic Growth. *American Economic Review, 101,* 194-199. https://doi.org/10.1257/aer.101.3.194

Ivanová, E., & Masárová, J. (2013). Importance of Road Infrastructure in the Economic Development and Competitiveness. *Economics and Management, 18,* 263-274. https://doi.org/10.5755/j01.em.18.2.4253

Jacoby, H. G. (2000). Access to Markets and the Benefits of Rural Roads. *The Economic Journal, 110,* 713-737. https://doi.org/10.1111/1468-0297.00562

Kenya Roads Board (2023). *Road Condition Survey 2023.* Kenya Roads Board.

KNBS (2022). *Gross County Product (GCP).* Kenya Natiaonal Burea of Standards (KNBS).

Kurian, N. J. (2000). Widening Disparities in India: Some Indicators. *Economic and political Weekly, 35,* 538-550.

Leitner, M., Glasner, P., & Ourania, K. (2018). *Laws of Geography.* Oxford Research Encyclopedias, Criminilogy and Criminal Justice. https://doi.org/10.1093/acrefore/9780190264079.013.325

Mackinnon, D., & Docherty, I. (2013). Transport and Economic Development. In J. P. Rodrigue, T. Notteboom, & J. Shaw (Eds.), *The Sage Handbook of Transport Studies* (pp. 3-5). Sage.

Majumder, R. (2005). Infrastructure and Regional Development: Interlikanges in India. *Indian Economic Review, XXXX,* 167-184.

Mankiw, G. N., Kneebone, R. D., McKenzie, K. J., & Rowe, N. (2006). *Principles of Macroeconomics* (3rd ed.). Thomson/Nelson.

Meadows, W. J., & Jackson, P. M. (1984). Infrastrucure and Regional Development: Empirical Findings. *Built Environment, 10,* 270-281.

Michniak, D. (2015). Main Problems of Transport Infrastructure Development in Slovakia and Effects on Regional Development. *Geographia Polonica, 88,* 21-39. https://doi.org/10.7163/gpol.0004

Miller, H. J. (2004). Tobler's First Law and Spatial Analysis. *Annals of the Association of American Geographers, 94,* 284-289. https://doi.org/10.1111/j.1467-8306.2004.09402005.x

Ministry of Agriculture and Water Resources (1955). *A Plan to Intensify the Development of African Agriculture in Kenya.* Colony and Protectorate of Kenya.

Moraga, P. (2023). Spatial Autocorrelation. In P. Moraga (Ed.), *Spatial Statistics for Data Science: Theory and Practice with R.* Chapman & Hall.

Ng, C. P., Jakarni, F. M., & Kulanthayan, S. (2018). Road Infrastructure Development and Economic Growth. *IOP Conference Series: Material Science and Engineering, 512,* Article ID: 012045.

Nigohosyan, D., & Vutsova, A. (2017). The 2014-2020 European Regional Development Fund Indicators: The Incomplete Evolution. *Social Indicators Research, 137,* 559-577. https://doi.org/10.1007/s11205-017-1610-8

OECD (2009). *Governing Regional Development Policy; The Use of Performance Indicators.* OECD Publishing.

Ohlan, R. (2012). Pattern of Regional Disparities in Socio-Economic Development in India: District Level Analysis. *Social Indicators Research, 114,* 841-873. https://doi.org/10.1007/s11205-012-0176-8

Okrasińska, I., & Wojewódzka-Król, K. (2018). Transport Infrastructure Expenditures and the Regional Competitiveness. *Transport Economics and Logistics, 77,* 95-104. https://doi.org/10.26881/etil.2018.77.09

Pokharel, R., Bertolini, L., & te Brömmelstroet, M. (2023). How Does Transportation Facilitate Regional Economic Development? A Heuristic Mapping of the Literature. *Transportation Research Interdisciplinary Perspectives, 19,* Article ID: 100817. https://doi.org/10.1016/j.trip.2023.100817

Ragan, C. T., & Lipsey, R. G. (2008). *Macroeconomics.* Pearson .

Ramesh, P., Luca, B., & Marco, B. (2023). How Does Transportation Facilitate Regional Economic Dvelopment? A Leuristic Mapping of Literature. *Transportaion Research Interdisciplinary Perspectives, 19,* Article ID: 100817.

Rodrigue, J. (2020). Transportation and the Spatial Structure. In J. P. Rodrigue (Ed.), *The Geography of Transport Systems* (pp. 56-89). Routledge. https://doi.org/10.4324/9780429346323-2

Rokicki, B., & Stępniak, M. (2018). Major Transport Infrastructure Investment and Regional Economic Development—An Accessibility-Based Approach. *Journal of Transport Geography, 72,* 36-49. https://doi.org/10.1016/j.jtrangeo.2018.08.010

Sergei, A. A., Mikail, A. Y., & Kudrov, A. V. (2018). Indicators of Regional Development Using Differentiation Characteristics. *Montenegrin Journal of Economics, 14,* 7-22. https://doi.org/10.14254/1800-5845/2018.14-3.1

Siliva, J. (2017). *National Geographic.* The Power of Transportation. https://www.youtube.com/watch?v=Svg7vgniC2c

Silverman, B. W. (1998). *Density Estimation for Statistics and Applied Probabilty.* Routledge.

Siverman, B. W. (1986). *Density Estimation for Statistics and Data Analysis.* Chapman and Hall.

State Department for Devolution (2023). *Regional Economic Blocs.* Office of the Deputy President, State Department for Devolution.

Stern School of Business and New York University (2016). Beyond Economics: Governance and Infrastructure Development. In I. Walter (Ed.), *The Infrastructure Finance Challenge* (pp. 40-46). Open Book Publisher.

Tchanche, B. (2019). A View of Road Transport in Africa. *African Journal of Environmental Science and Technology, 13,* 296-302. https://doi.org/10.5897/ajest2018.2575

Thynell, M. (2017). Road to Equal Access: The Role of Transport in Transforming Mobility. *Transport and Communications Bulletin for Asia and The Pacific, No, 87,* 1-12.

Tini, N. H., Shah, M. Z., & Sultan, Z. (2018). Impact of Road Transportation Network on Socio-Economic Well-Being: An Overview of Global Perspective. *International Journal of Scientific Research in Science, Engineering and Technology, 4,* 282-296.

Tobler, W. R. (1970). A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography, 46,* 234-240. https://doi.org/10.2307/143141

Treasury (2023). *2023/2024 Estimates of Development Expenditure of the Government of Kenya, for the Year Ending 30th June, 2024, Volume II, 9vOTE 10910.* Government Printer.

Whittle, J. (2009). *A Short Synthesis of the Link between Infrastructure Provision/Adequacy and Economic Growth.* DFID UK.