ISSN No:-2456-2165

Review of Road Network Design: A Case Study of Kiri Kasama LGA – Jigawa State

[1]Pwaviron Kennedy Gambiye
School of Engineering Department of Civil Engineering
Adamawa State Polytechnic

[2]Aliyu Yazid
Department of Civil Engineering Modibbo Adama
University Adamawa State.

[3]Emmanuel Nicholas Jesman
Department of Physical Planning and Development University of Abuja

Abstract:- This paper presents a comprehensive review of road network design, focusing on Kiri Kasama Local Government Area in Jigawa State as the case study. The study highlights the importance of a well-planned road network in enhancing economic growth, social connectivity, and overall quality of life. It discusses the multidisciplinary approach involved in road network design and emphasizes the integration of sustainable and environmentally friendly practices. Additionally, the paper explores the impact of technology and emerging trends on road network design, emphasizing the need for efficient, sustainable, and adaptable transportation systems. The research methodology involves the use of Quantum GIS (QGIS) for designing the road network in Kiri Kasama. The results and discussion section present the step-by-step process of the design method, highlighting the key considerations and decisions made. The conclusion emphasizes the importance of establishing connecting links between wards for future development in the area.

The design of a road network is crucial for the development and sustainability of modern cities and transportation systems. This section highlights the significance of a well-planned road network in facilitating the efficient movement of people and goods, contributing to economic growth, social connectivity, and overall quality of life. It emphasizes the multidisciplinary approach and the integration of sustainable practices in road network design. Furthermore, it discusses the impact of technology and emerging trends on shaping the future of road network design.

Keywords:- *Road network design, sustainable transportation, multidisciplinary approach, technology, Quantum GIS.*

I. INTRODUCTION

The design of a road network is a crucial component in the development and sustainability of modern cities and transportation systems. A well-planned road network not only facilitates the efficient movement of people and goods but also contributes to economic growth, social connectivity, and overall quality of life. The poor state of roads in Nigeria hasn't seen much change or improvement, if any, over the past few decades despite government efforts and promises, highlighting the urgent need for attention to the transportation network in the country. (Wanda et al., 2020)

The process of road network design involves various considerations, including traffic flow, safety, environmental impact, land use, and future growth projections. It requires a multidisciplinary approach, involving urban planners, civil engineers, transportation experts, and other stakeholders, to create a comprehensive and integrated system that meets the diverse needs of a community.

An effective road network design incorporates elements such as road layout, intersection design, lane configurations, signage, and traffic control devices. It aims to optimize the flow of traffic, reduce congestion, minimize travel times, and enhance safety for all road users, including pedestrians, cyclists, and motorists. The functions of a road network extend beyond just transportation, encompassing social and economic aspects as well (Wanda et al., 2020).

Additionally, the design of a road network must account for sustainable and environmentally friendly practices. This includes considering factors like reducing carbon emissions, promoting public transportation, encouraging active modes of transportation, and integrating green infrastructure, such as bike lanes, pedestrian-friendly sidewalks, and tree-lined streets.

Furthermore, the rapid advancement of technology and the rise of smart cities have introduced new opportunities and challenges in road network design. Intelligent transportation systems, data analytics, and real-time monitoring tools enable better management of traffic flows, improved safety measures, and enhanced decision-making for urban planners.

In this era of urbanization and growing population, road network design plays a pivotal role in shaping the future of our cities. By focusing on efficiency, sustainability, safety, and adaptability, we can create road networks that not only meet the present needs but also serve as a foundation for the evolving transportation demands of tomorrow.

The following sections will explore the various aspects of road network design, including its influence on urban development, topological characteristics, classification of transport networks, and the importance of accessibility and mobility in land use integration.

A. Road Network and its Characteristics

A Road by itself is simply a line connecting two points. If an area is crossed by many roads, they form a road network. Road networks are an integral part of any human settlement, facilitating the movement of people, goods, and information. The structural arrangement of a road network can have a profound impact on its performance, mobility, and access to critical infrastructure (Gift Dumedah et al., 2021).

Transport networks can be classified into specific categories depending on a set of topological attributes that describe them. This allows for the establishment of a basic topology of transport networks that relates to their geographical setting, as well as their modal and structural characteristics (Daful et al., 2016).

Networks, such as road networks, can possess different structural properties, displaying both topological and geometric variations. The arrangement and connectivity of nodes and links of a network are referred to as its topology. Geometric attributes such as spacing, shape, orientation, density, and geometric patterns may also be introduced at a higher level of complexity (Feng Xie et al., 2007).

B. Types of Road Networks

There are different types of networks, such as:

- Road Network – a series of interconnected roads. They cover an area and connect a number of destinations.
- 3-dimensional network – a road network in which the individual links have been defined (and perhaps constructed) in terms of a hierarchy of functions (see also "road hierarchy"). Also known as a function-based network.
- 2-dimensional or "flat" network – a road network in which the individual links have not been defined in terms of any hierarchy of functions. Not unusual for cycle or pedestrian networks
- Broken Network – a network in which the links are not all contiguous; a network to which not all destinations have a connection.
- Vehicle-based network – a network specific to a particular type of "vehicle", for example pedestrians or cyclists, or handicapped users.
- Purpose-Based network – a network specific to a particular type of purpose, such as scenic networks, farm-to-market networks, emergency service networks etc.
- Scalar Network – a road network which is contiguous regardless of the scale of magnification under which it is being observed.

C. Functions of Road Networks

The road network serves multiple functions that contribute to social, economic, and mobility aspects:

- **Social:** The road network facilitates the movement of people for social interaction and connectivity of isolated local communities with public transport. It connects remote communities with areas where employment options are more concentrated and services and facilities are readily available (Slack, 2013).
- **Economic:** Road networks connect geographic locations and facilitate the transport and movement of people, goods, and services, thereby enhancing the welfare of individuals and promoting economic growth (Slack, 2013).
- **Mobility:** The function of a road network is to facilitate movement from one area to another, determining the accessibility of an urban area. It plays a crucial role in urban environments to facilitate mobility and is closely tied to public transport options (Slack, 2013).

D. Road Network Design and its Impact

Transportation plays a vital role in economic development, improving the standard of living, and enhancing productivity. Well-planned transportation systems contribute to the efficiency of movement and the availability of a good transport network. Integrating land use with various transport networks is essential for ensuring accessibility and connecting people with opportunities (Daful et al., 2016). Furthermore, transportation directly influences urban development and the spatial distribution of opportunities. Integrated transport planning strategies, considering accessibility, are crucial for shaping the development and spatial distribution of opportunities in new areas (Enisan & Agbaje, 2022).

However, designing a road network comes with challenges such as adverse weather conditions, human errors, technological breakdowns, and environmental issues. These disruptions impact traffic flow, emergency management, and overall economic and social well-being. Despite these challenges, road network design also provides opportunities for innovation and improvement in traffic management, safety measures, and decision-making processes (Gauthier et al., 2018; Shi et al., 2019).

Road network operations encompass a strategic methodology aimed at optimizing efficiency on both current and future road infrastructure. At a tactical level, this approach involves enhancing operational practices to achieve objectives such as minimizing traffic delays and operating in a consistently efficient manner on a daily basis. Consequently, the research aims to develop an optimal road network design that spans the entirety of the Kiri Kasama Local Government Area, which will aid in proactively planning and managing traffic flows in real-time, as well as provide timely and consistent information to road users regarding the current traffic conditions.

The lack of essential infrastructure, particularly accessible roads, presents a significant challenge for rural farmers and communities in Nigeria. This absence of motorable roads hampers the ability of farmers in these areas to access markets and sell their produce. Despite their diligent efforts to make a living through farming, this infrastructure deficit poses a major obstacle. Additionally, the inaccessibility of roads for rural communities not only hinders the provision of essential services such as education and information but also undermines the sustainability and growth of local enterprises. Consequently, there is a pressing need for the establishment of a well-designed road network

ISSN No:-2456-2165

to address these challenges and facilitate overall development in these areas.

Furthermore, the absence of a road network in rural areas creates a significant barrier to socio-economic development and contributes to poverty. The lack of infrastructure deprives community members of access to basic goods and services, further exacerbating their disadvantaged situation. Consequently, the establishment of a road network is crucial in alleviating these challenges, enabling improved socio-economic conditions, and providing opportunities for growth and prosperity within rural communities.

II. STUDY AREA

The study area is Kiri Kasama Local Government Area in Jigawa State. Jigawa State was created on 27th August 1991 from Kano State by the reign of General Ibrahim Babangida, its capital is Dutse, Jigawa is situated in Central Northern Nigeria. Jigawa State covers 23,154 square kilometers and lies between latitude 11.000N to 13.000N and longitude 8.000E to 10.150E. Jigawa State shares a common border with Kano and Katsina States to the West and to the South East, Yobe and Republic of Niger to the North.

III. KIRI KASAMA LOCAL GOVERNMENT AREA

Kiri kasama is a local government area of Jigawa State, its headquarter is a town of Kirikasama, it lies on latitude $12^0$41'33"N and longitude $10^0$15'16"E and has an area of 797 kilometre square of the population of 191,523 at the 2006 population census.

This section provides an overview of the study area, Jigawa State, and focuses on Kiri Kasama Local Government Area. It highlights the geographical location, size, and population of the area, emphasizing the need for a well-designed road network to address the challenges faced by rural communities in terms of accessibility to markets, essential services, and socio-economic development.

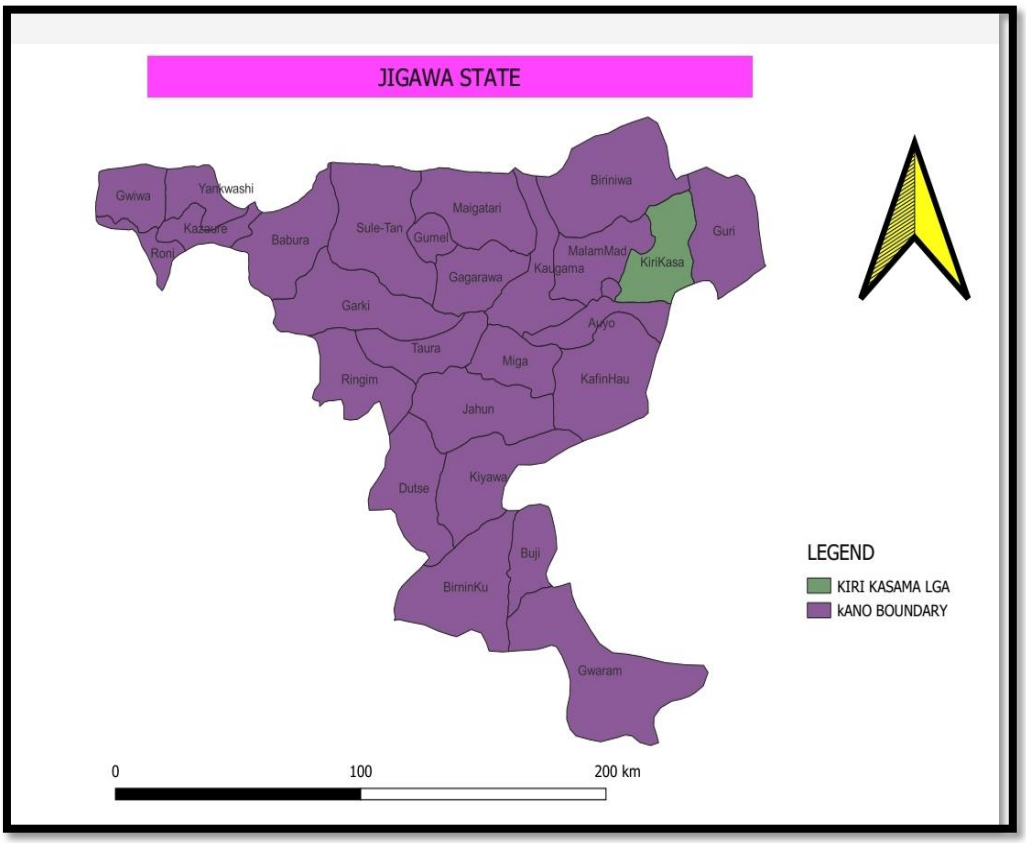

Fig. 1: Map of Jigawa State

ISSN No:-2456-2165

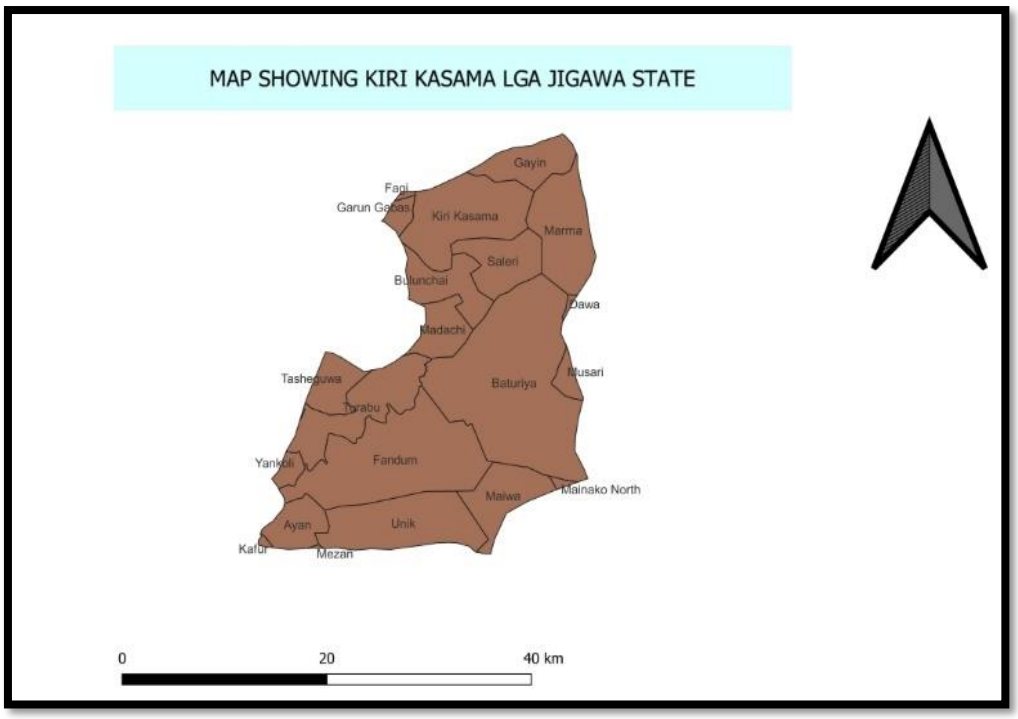

Fig. 2: Map of Kiri Kasama L.G.A Jigawa State

IV. RESEARCH METHOD

Designing Kiri Kasama Road network using QGIS (Quantum GIS) involves several steps, including data preparation, network analysis, and visualization. Here's a general outline of the process:

A. The Design Method Step by Step

- Applying the design method results in designs for the collective and individual distinguished networks for each scale level and the interchange points where the networks are connected.
- Every network at every scale level is designed independently, thereby ensuring that each network is optimally geared towards its function. Possibly, in a later state of the design process, some of the connections from different scale levels will be combined on one route, or even on one road or railway line.
- However, it is a conscious choice, a trade-off between the advantages and disadvantages of combining functions on that particular connection. Because the situation of the access points for the collective systems is much more important than for the individual systems, the collective network for a scale level is always designed before the individual network.

➢ *Step 1: Distinguish Urbanization Levels (Urban/Rural)*

The edges of urban areas provide good locations for intermodal transfer points, so the border between urban and rural area must be indicated on the map for later use.

➢ *Step 2: Define the Hierarchy of Cities and Towns*

In this step, the rule of thumb for the number and size of the nodes (cities and towns) the network meant to connect was used to define which towns should be accessible via the network, and in what order of importance. In doing so (for the Scale level under consideration), first and second level nodes are selected and indicated on the map.

➢ *Step 3: Design Desired Connections*

The desired connections (heart-to-heart) are drawn on the map, according to the following rules:

- First connect first-level nodes.
- And connections to second-level nodes.

➢ *Step 4: Design the Ideal Network*

This is the most difficult and intuitive stage in the design method. The existing situation was ignored. The desired connections translated into an efficient network with the right density. The access points put in the right place.

➢ *Step 5: Assess Current Network*

The ideal network differs from the existing network in several aspects:

- The connections that have been included
- The major traffic flows (which have implications for the layout of the interchanges of roads)
- Step 5 has been included to assess how much of the existing network meets the requirements set by the method.
- This was done by looking at the existing connections that would most likely serve as a connection in the ideal network.
- The information gathered can be used in a later stage, when deciding which part of the ideal network is given up in order to create a feasible network or to establish which parts of the network should be adapted first.

This section outlines the research methodology employed in designing the road network for Kiri Kasama using Quantum GIS (QGIS). It presents a step-by-step process, including data preparation, network analysis, and

ISSN No:-2456-2165

visualization. The design method is explained, emphasizing the distinction between urban and rural areas, the hierarchy of cities and towns, and the desired connections. It discusses the assessment of the existing network and the importance of adapting the ideal network to create a feasible and realistic road network design.

V. RESULTS AND DISCUSSION

This section presents the results of the road network design for Kiri Kasama using the QGIS methodology. It discusses the key decisions made at each step of the design process, including the distinction between urban and rural areas, the hierarchy of cities and towns, and the desired connections. The existing network is compared to the ideal network, highlighting the areas that require adaptation and improvement. The discussion emphasizes the need for connecting links between wards to facilitate future development in the area.

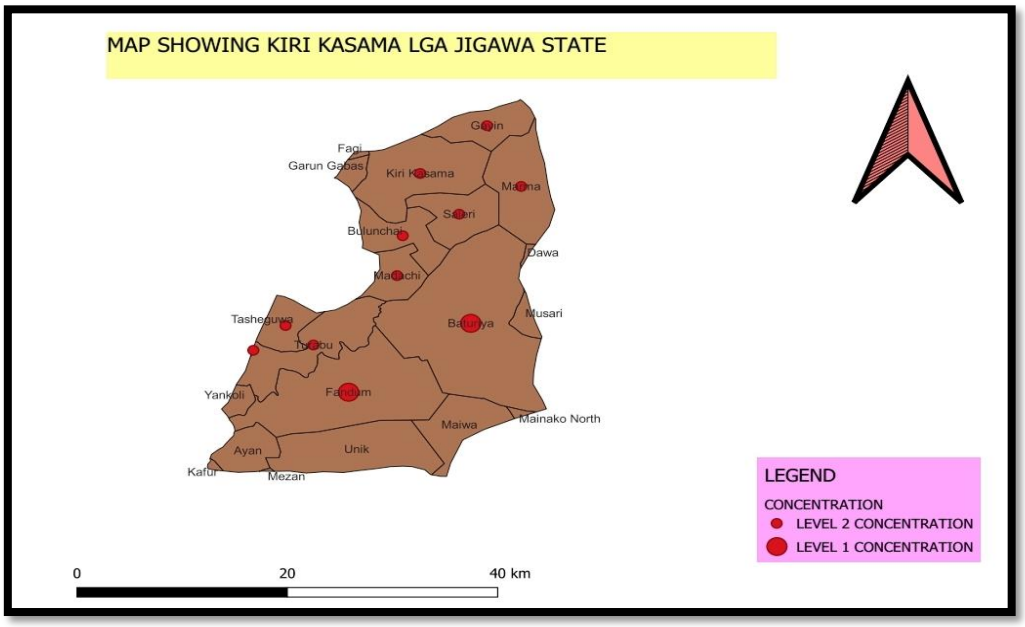

Fig. 3: Map showing various ward as nodes and their level of concentration

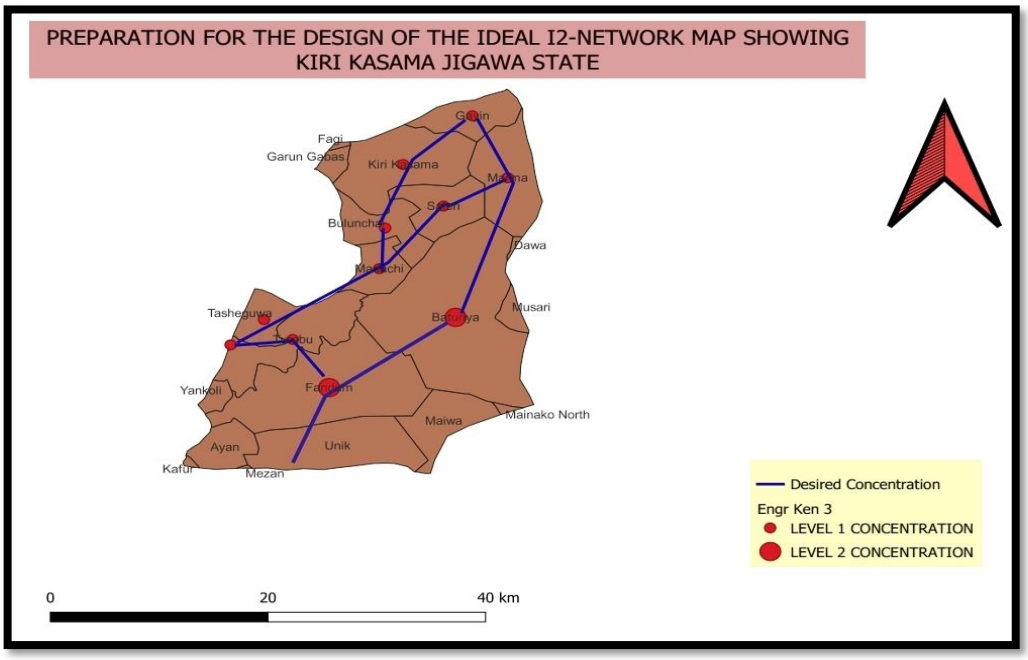

Fig. 4: Map showing level of concentration and ideal road network design in progress

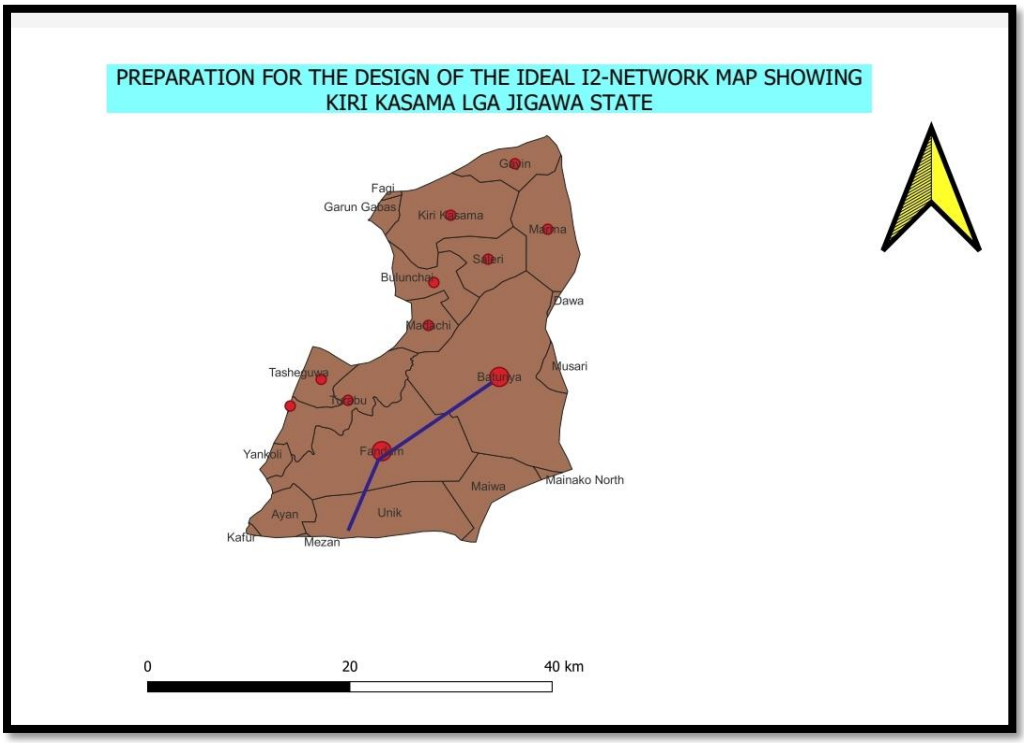

Fig. 5: Map showing level of concentration and ideal road network design in progress

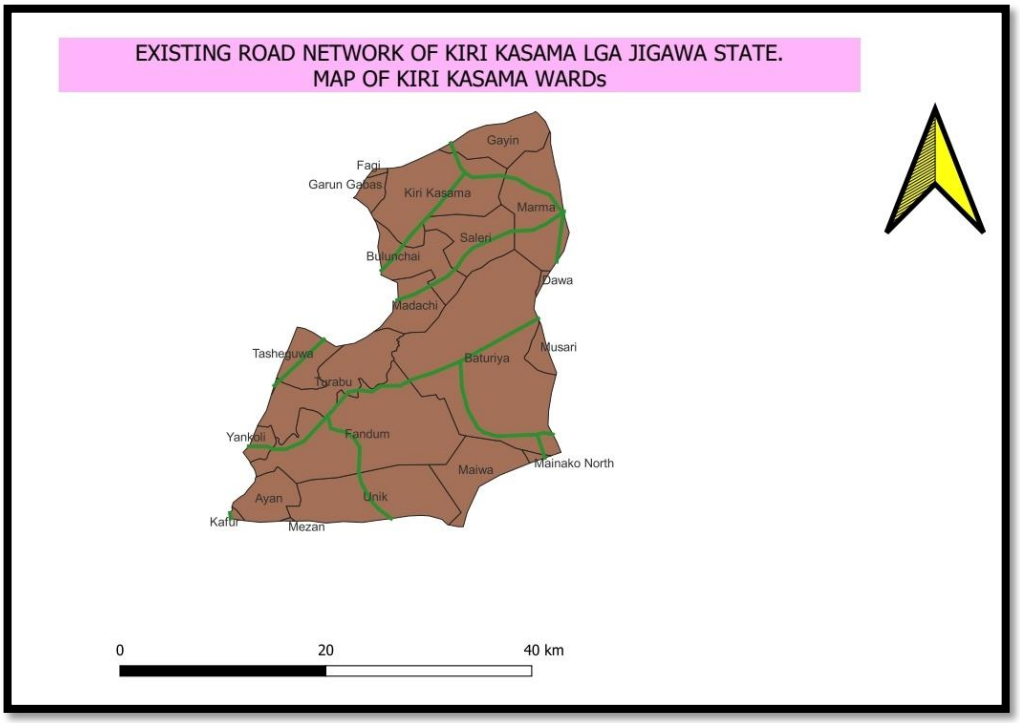

Fig. 6: Map showing existing road network of Kiri Kasama LGA Jigawa State

ISSN No:-2456-2165

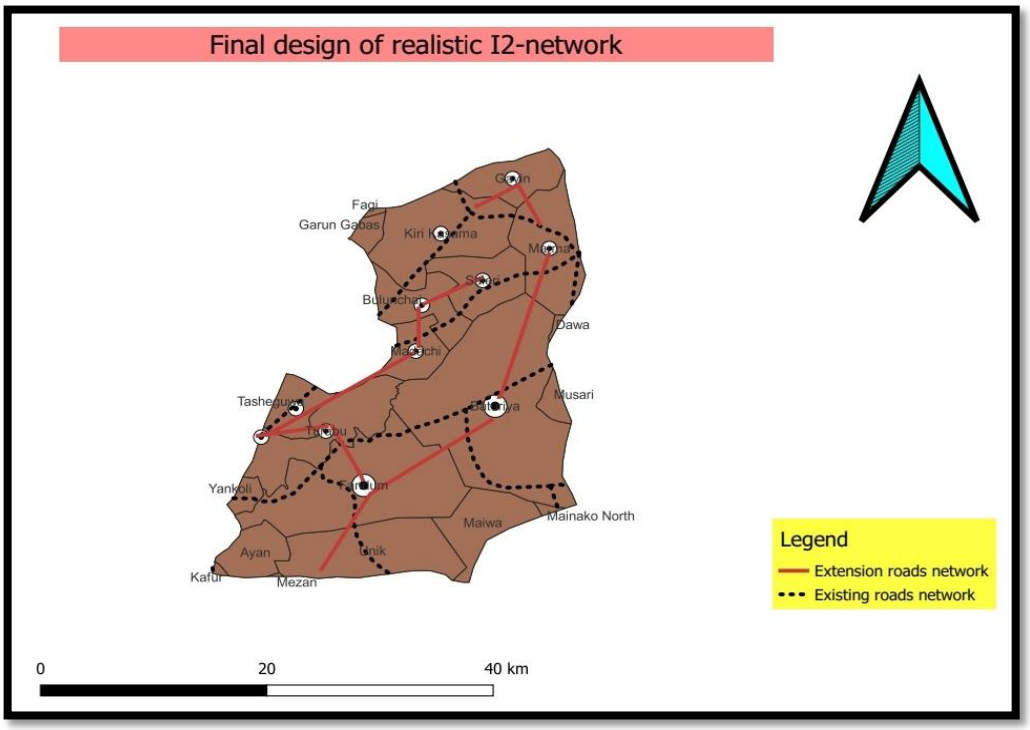

Fig. 7: Map showing final design of realistic I2 network Kiri Kasama LGA Jigawa State

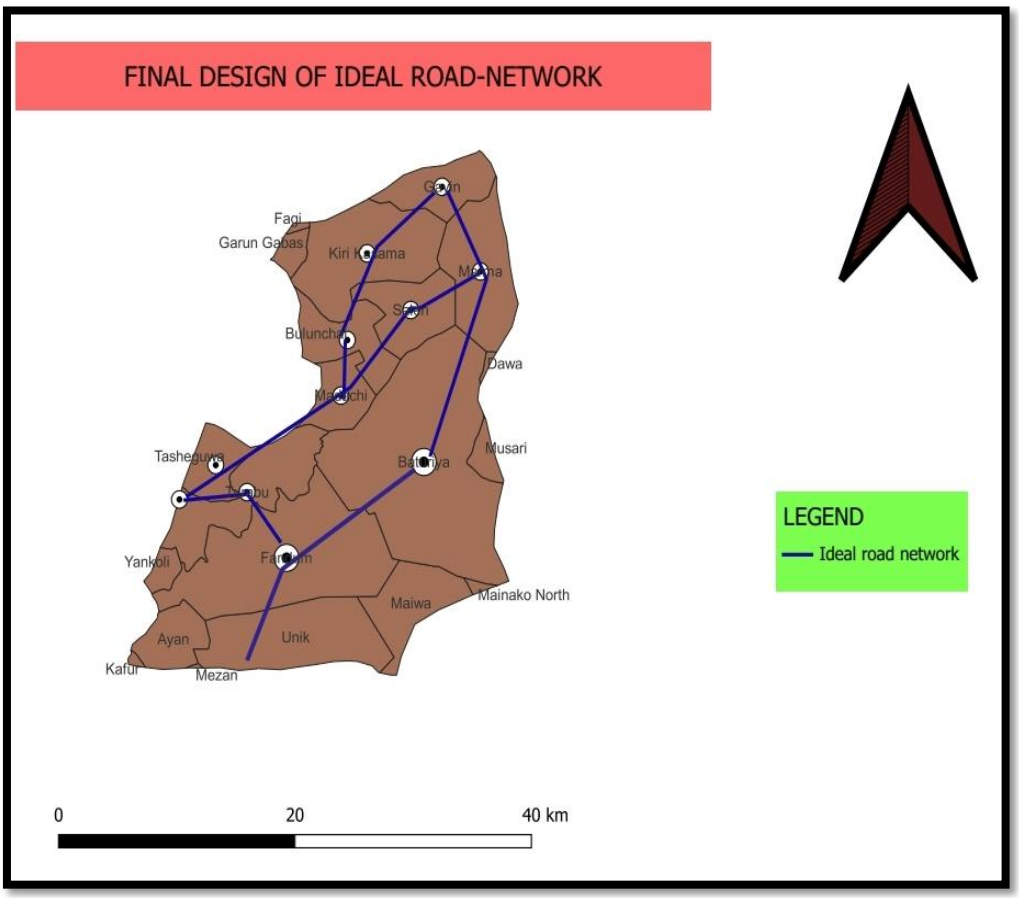

Fig. 8: Map showing final design of ideal road network Kiri Kasama LGA Jigawa State

VI. CONCLUSION

From observation there is no existing connecting link between some wards therefore some extension route networks should be provided for future development of Kiri Kasama Local Government Area, Jigawa State as shown in the final design of realistic network map.

The conclusion summarizes the findings of the study and emphasizes the importance of a well-designed road network for the future development of Kiri Kasama LGA, Jigawa State. It highlights the need for establishing connecting links between wards to address the challenges faced by rural communities and promote socio-economic growth. The conclusion also emphasizes the significance of efficient, sustainable, and adaptable road networks in shaping the future of transportation systems.

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