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Research Article

Transport Network Planning based on Connectivity to Institutions: A Case Study of Galkot Municipality, Nepal

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ABSTRACT

Road network planning is a crucial task that involves multiple dynamics to be considered for effective planning. The roads should be planned in such a way that they operate as a unified system, which is resilient and cost-effective in terms of construction and maintenance. The overall performance of road networks depends on their geometry as well as traffic characteristics. Due to a lack of resources at the municipal level, considering the entire road network for planning, upgrading, and maintenance is not possible. Therefore, this study analyzes the buffer areas of institutions within the municipality that must be connected through all-weather roads for a reliable network structure. Based on these buffer areas, sufficient road links were selected to ensure connectivity among institutions and other key areas, which will be prioritized for future investment and intervention.

Keywords: Transport, Institutions, Network, Planning, Poverty

Introduction

The economic progress of a nation hinges significantly on its rural road networks. Particularly in developing countries, these roads are crucial for transporting agricultural goods, reducing poverty, and enhancing access to fundamental amenities like markets, educational institutions, and healthcare services.[1,2] Nonetheless, insufficient rural road infrastructure, characterized by substandard road conditions and limited accessibility and connectivity, can impede the socio-economic progress of rural communities. Rural road development faces numerous challenges, as extensively outlined in prior research. These encompass, but are not confined to, a shortage of financial resources, a dearth of technical expertise within local governmental entities, geographical constraints, feeble governance, and a deficiency in transparency.[3] The allocation of resources for road construction frequently hinges on impromptu determinations and subjective evaluations by local government officials. Consequently, this frequently results in the ineffective and unequal dispersion of finite resources, as well as the neglect of local perspectives and concerns.

Nepal has six metropolitan cities, eleven sub-metropolitan cities, two hundred seventy-six municipalities and four-hundred sixty rural municipalities.[4] The construction and upgrading of road networks in rural Nepal are primary concerns for the federal and provincial government. This is crucial for the efficient delivery of goods and services. The absence or poor condition of rural roads typically hinders access to these necessities, leading to a diminished quality of life for rural residents. Furthermore, transportation plays a pivotal role in fostering growth, development, and poverty alleviation.[3] Nevertheless, simultaneous construction or upgrading of the entire road network is hindered by financial and technical limitations. In Nepal, overcoming technical challenges is becoming increasingly demanding due to its distinctive topography. Approximately 33 percent of the population in Nepal resides in rural municipalities [5] a figure expected to decline based on past trend if the road networks fail to facilitate access to essential services like health posts, schools, and markets for rural residents. Accessibility refers to the convenience with which goods can reach different locations, gauged in factors such as time, expense, seasonal availability and the quality of transportation services offered.[6]

Transport, which is simply defined as the movement of people and goods covering some geographical spaces, is one of the major components to improve people's access to services. It not only increases the accessibility to the remote places, but also increases the mobility scenario, and hence results in better linkages with market centers/agricultural production pocket areas and other opportunities in the district as well as Municipality. Adequate roads network in any Municipality can reduce isolation, encourage availing public services, and help to transfer technology. Road construction has been seen to bring about notable enthusiasm and visible changes in life. However, in the absence of rational criteria and professional guidelines, road constructions and upgrading are carried out in an "ad hoc manner" in major places, be it be municipalities or Municipalities.

A study delved into the role of traffic planning in rural areas, examining its contribution to sustainable land use planning as a resolution to the dilemma of balancing accessibility with environmental sustainability.[7] A study conducted in 2003 put forth a computer-assisted methodology for the planning and prioritization of transportation networks at the district level, both in developed and underdeveloped regions. The study concluded that the GIS-supported and spreadsheet-based approach proves beneficial in planning district-level road networks not only in Nepal but also in other developing countries.[8] Murawski and Church introduced a model that addresses the complementary aspect of the location/transportation equation, focusing on enhancing health service accessibility by upgrading transport network links to all-weather roads while considering existing facility locations as fixed.[9]

Hasan et al. proposed a methodology for Rural Road Planning and Prioritisation Model (RPPM) that comprises two major components. The first involves developing a core network in collaboration with local stakeholders, while the second focuses on prioritizing roads based on Cost Benefits Analysis (CBA) and Multi Criteria Analysis (MCA).[10] A group of researchers addressed the issue of upgrading the rural road network in the hilly regions of Nepal. They employed a multi-objective optimization model to assist decision-makers in selecting which roads to prioritize for improvement.[11] In 2017, Shrestha et al. introduced a pragmatic method for delineating rural road networks in mountainous areas of developing nations. This approach hinges on the use of Geographic Information System (GIS) technology, enabling the pinpointing of crucial nodes within the road infrastructure. These nodes guarantee essential access to communities within a specified maximum walking duration.[12] Modinpuroju et al. conducted a spatial analysis within the study area, utilizing ArcGIS software, to determine the facility's maximum coverage distance for designing the village facility index, taking into account link weight through the application of the gravity formula.[13] Luitel and Tiwari conducted an evaluation of the serviceability coverage of facilities including hospitals and fire brigades, accounting for factors like distance and walking time impedance, within Lalitpur Metropolitan City, Nepal.[14] Acharya and Paudel investigated how the selection of administrative centers in any area, using the case study of Province no. 1, Nepal, is influenced by two primary factors: the distribution of population and the layout of transportation networks [15] Basnyat and et al. suggested a network architecture designed to efficiently and reliably manage regular traffic flow while also being capable of accommodating traffic in extraordinary circumstances.[16]

In this paper, the major road networks within the municipality are identified, followed by an analysis of present mobility and accessibility situations. The study delves deeper into planning an efficient municipal road network layout based on the current situation, which plays a major role in connecting various institutions such as schools, heathpost and other administrative offices within the municipality. This network can serve as a lifeline for future, cost effective development of the road network.

Study Area

Galkot Municipality is situated in Baglung District, Gandaki Province, Nepal, covering an area of 194.39 sq. km. It is bordered by Baglung Municipality to the east, Burtibang to the west, Myagdi District to the north, and Gulmi District to the south (Figure 1). The municipality has a population of 30,503.[17] Although the population appears to be decreasing, it is expected to grow after the construction of the Puspalal Highway, which goes through east to west connecting mid hill section of the roads.

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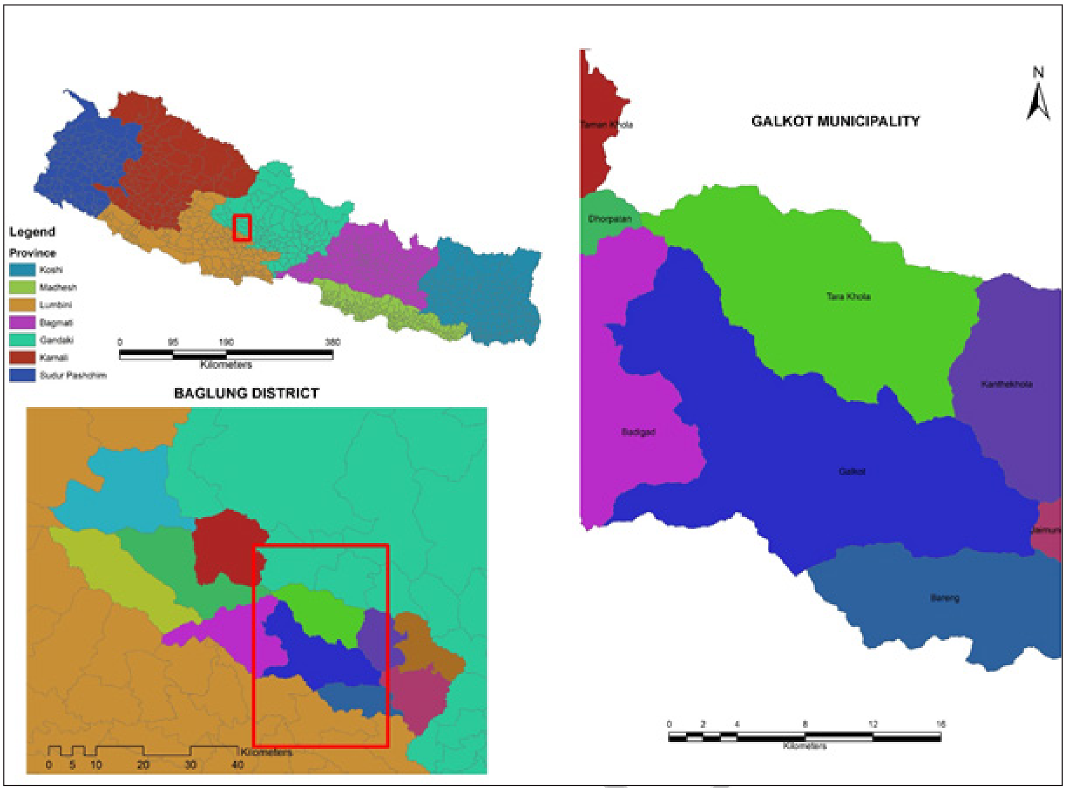

Figure 1.Study Area

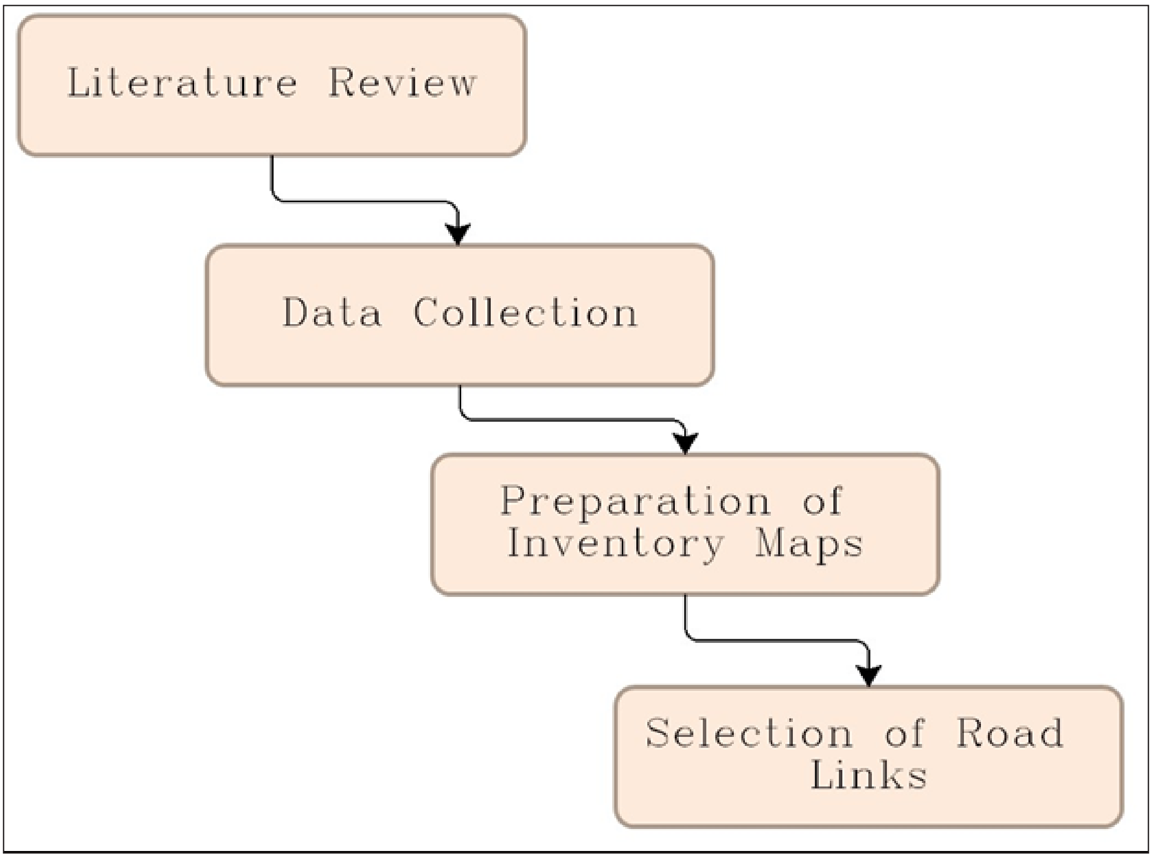

Figure 2.Methodological Framework of the Study

Methodology

This study aims to assist in the planning of roads to fulfill the stated objectives. Effective planning requires relevant and high-quality data, which can only be acquired through the use of properly selected survey methods. This section addresses the methodological framework adopted for data collection, encompassing survey methods, sampling techniques, data quality and quantity, as well as the methodology for data processing, analysis, and presentation. Figure 2 illustrates the methodological framework of the study.

Literature Review

The literature review served as the initial step in this research, involving the collection and review of various published articles, reports, and other documents related to transportation and road network analysis. The aim of the literature review was to identify criteria and methods used globally, with a focus on determining suitable and feasible methods for the upcoming tasks of the study. Following the literature review, preparations for subsequent phases were undertaken. Initially, the study area was delineated using Google Maps, and topographic features were examined in Google Earth Pro. Network maps covering the chosen area were then collected. Shapefiles for the road network of Nepal were downloaded and extracted from OpenStreetMap. Utilizing the export data tool in ArcGIS, the road network map of the study area was exported. Corrections to the map were made using a satellite image layer.

Data Collection

The required data were collected using various techniques. The road network layout and datasets were digitized from Google Earth Pro, and a comprehensive field survey was conducted to gather information on road properties, such as width and surface type. Any missing road data in the satellite image from Google Earth was verified on-site during the fieldwork. SW Maps served as the primary data collection tool during the fieldwork. A template was created on SW Maps, capturing data such as Road Name, Width, and Surface Type. Additionally, various facilities like schools, hospitals, major market centers, and government offices were recorded as point data. The data collection was carried out using a motorcycle.

Preparation of Inventory Map

The road inventory data, collected from field surveys and other secondary sources, were compiled and processed using software. Current road inventory maps were then prepared, focusing on road characteristics such as surface type, road width, institutions, and cross-drainage structures. The processed road inventory data exclude the Strategic Road Network (SRN) and Provincial Road Network (PRN) which basically includes District Core Road Network (DRCN), as they fall under the jurisdiction of federal and provincial planning.

Selection of Road Links

Based on the processed municipal road inventory data, network was planned in such a way that the nearest road to a facilities (School, hospital, offices) is within 10 minutes of walking distance. A buffer areas were created in the vicinity of these institutions following with selection of road links that must be prioritized in order to ensure connectivity among institutions within the municipality.

Road Status of Galkot Municipality

Table 1 provides information on road surface types and their respective lengths in kilometers, along with the percentage distribution. Total length of all type road in the municipality is 450.38 km. The main surface types include Black Top (39.53 km, 8.78%), Earthen (403.64 km, 89.62%), and Gravel (7.21 km, 1.60%). The spatial layout of these roads is depicted in Figure 3.

Table 2 illustrates the hierarchy of the road network within the municipality. The roads are categorized into three main tiers: Strategic Road Network (SRN) comprising 7.76%, DRCN covering 11.68%, and Municipal Roads constituting the majority at 80.5%. Notably, only Municipal Roads fall under the jurisdiction of the municipality. The spatial layout of these networks is depicted in Figure 4.

Table 1.Roads classification based on surface type

S.N	Surface Type	Length (KM)	Percentage
1	Black Top	39.53	8.78%
2	Earthen	403.64	89.62%
3	Gravel	7.21	1.60%
4	Total	450.38	100%

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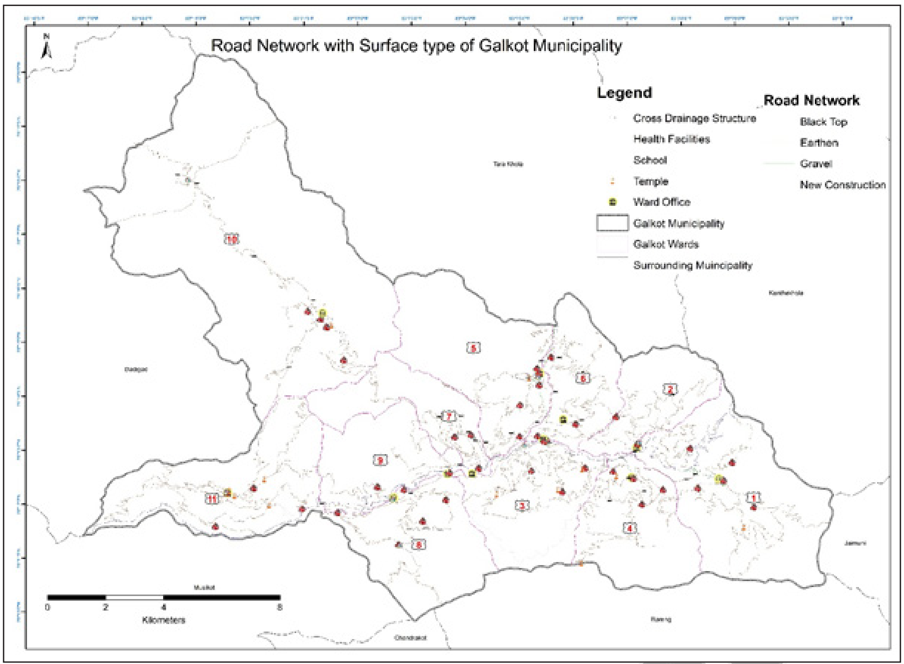

Figure 3.Road distribution based on surface type

Table 2.Road classification based on hierarchy of road type

SN	Road Type	Length (KM)	Percentage
1	SRN	34.95	7.76%
2	DRCN	52.59	11.68%
3	Municipal Road	362.84	80.56%
4	Total	450.38	100%

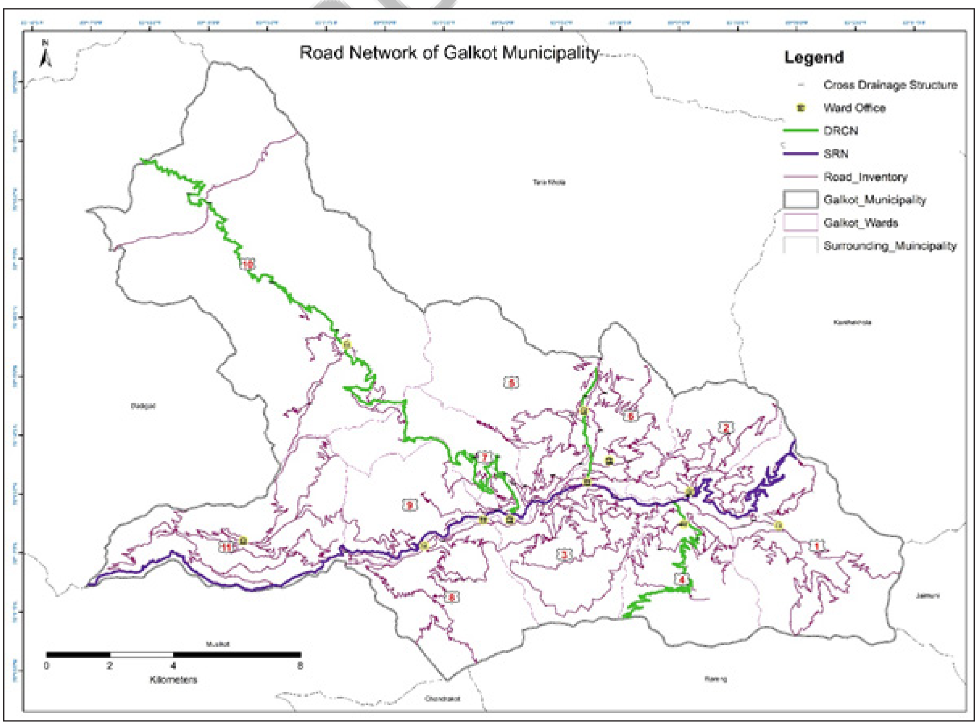

Table 4.Road Network of Galkot Municipality

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Table 3 outlines the distribution of various institutions across different wards in the specified area. Health Posts are located in wards 2, 3, 4, 6, 7, 8, 9, and 10, amounting to a total of 7. Hospitals are present in wards 1 and 11, with a total count of 2. Schools are distributed throughout all wards, ranging from 2 to 10 in each ward, resulting in a cumulative total of 52. Sub-Health Posts are situated in wards 2 and 10, totaling 2. Religious Places can be found in wards 2, 3, 4, 5, 9, and 11, with a total count of 13. Urban Health Centers are located in wards 7 and 8, amounting to 2. Ward Offices are established in every ward, with 1 in each, totaling 11. Lastly, the Municipality Office is situated in ward 10. The overall tally of institutions across all wards is 89. The spatial layout of these institution in the municipality is depicted in Figure 5.

Table 3.Institution distribution in Galkot

Institution	Ward											Total
	1	2	3	4	5	6	7	8	9	10	11	
Health Post	2	-	1	-	1	-	-	1	-	1	1	7
Hospital	-	-	1	-	-	-	-	-	-	-	-	1
School	10	6	5	4	5	4	3	5	2	4	4	52
Sub-Health Post	-	2	-	-	-	-	-	-	-	-	-	2
Religious Place	2	-	3	2	1	-	-	-	-	1	4	13
Urban Health Center	-	-	-	-	-	-	-	1	-	1	-	2
Ward Office	1	1	1	1	1	1	1	1	1	1	1	11
Municipality Office	-	1	-	-	-	-	-	-	-	-	-	1
Total	15	10	11	7	8	5	4	8	3	8	10	89

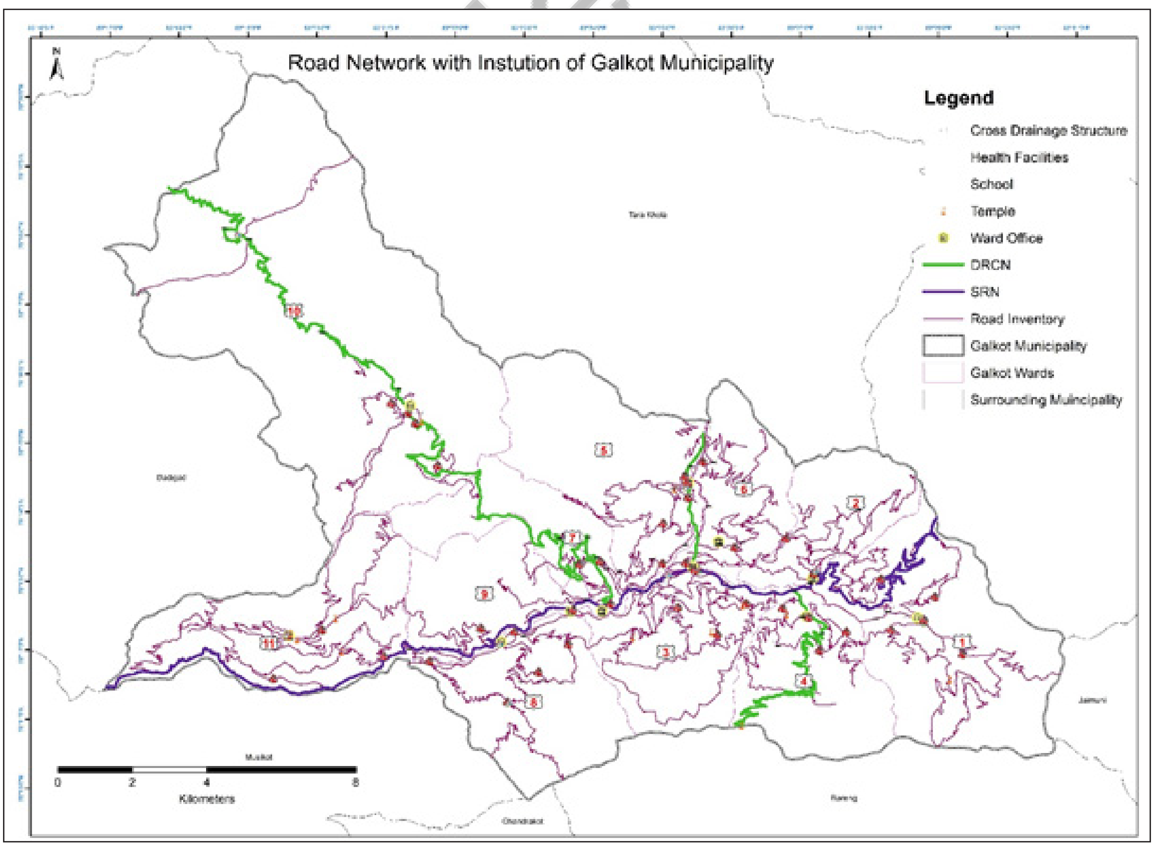

Figure 5.Road Network with institution of Galkot Municipality

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Results and Discussion

Road network planning was done using ArcGIS. Network planning is done such that the nearest road to a facility (school, hospital, offices) is within 10 minutes walking distance. Galkot being hilly municipality a 300 meters radius buffer zone is created shown in Figure 6. Since the road are not straight the buffer zone is created. The roads under the liability of the Federal government (SRN – Strategic Road Network) and Provincial Government (DRCN- District Road Core Network) are not taken under consideration.

Based on the above criteria 8 road links can be identified which serve individual institutions shown in Table 4. The details of road links can be seen below. Link 1 is the longest at 19.35 kM and serves maximum 9 institutions while link 6 is the shortest serving 6 institutions.

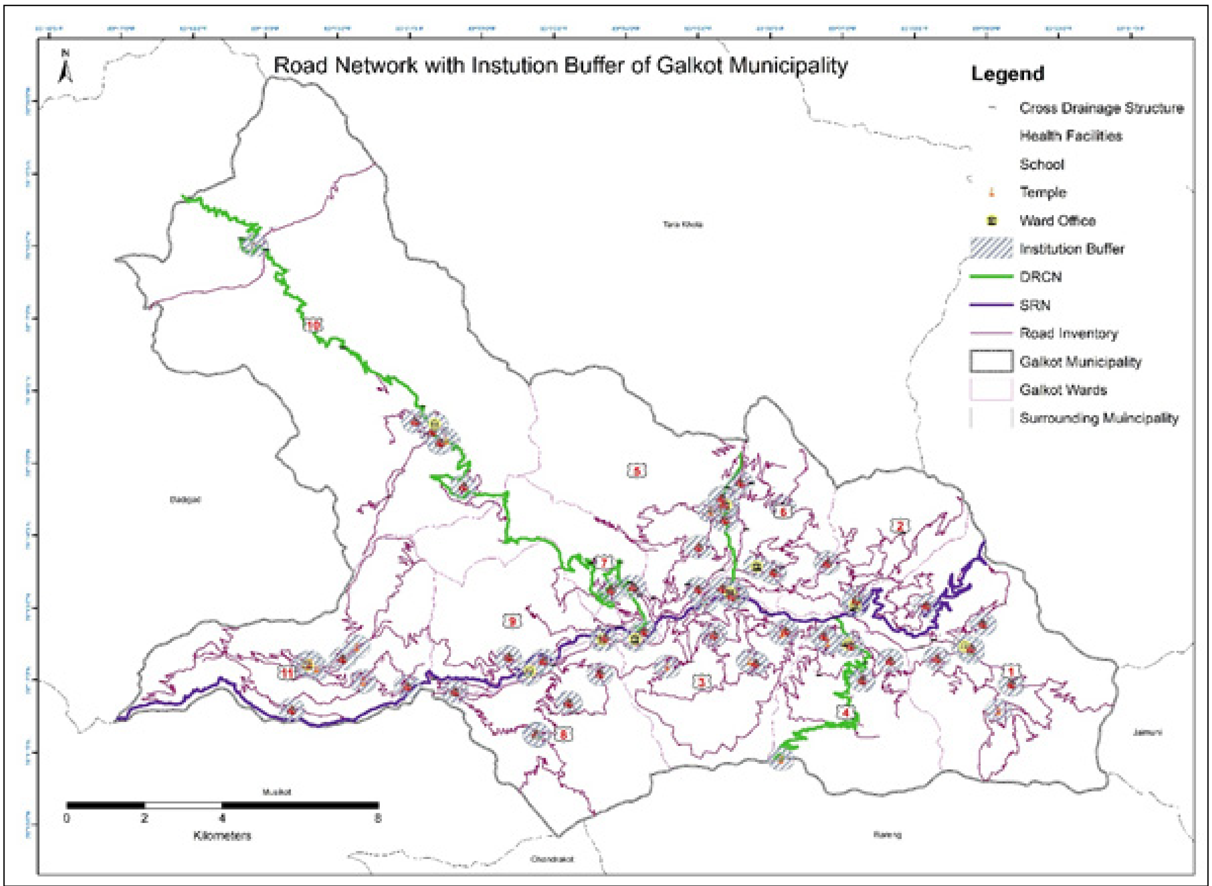

Table 6.Road Network with institution Buffer

Table 4.Road link Based on Institution served and Length.

SN	Name	No of institution	Length (kM)
1	Link 1	9	19.35
2	Link 2	7	13.15
3	Link 3	7	17.44
4	Link 4	6	7.90
5	Link 5	6	12.39
6	Link 6	6	4.10
7	Link 7	6	4.59
8	Link 8	5	13.18
	Total	52	92.10

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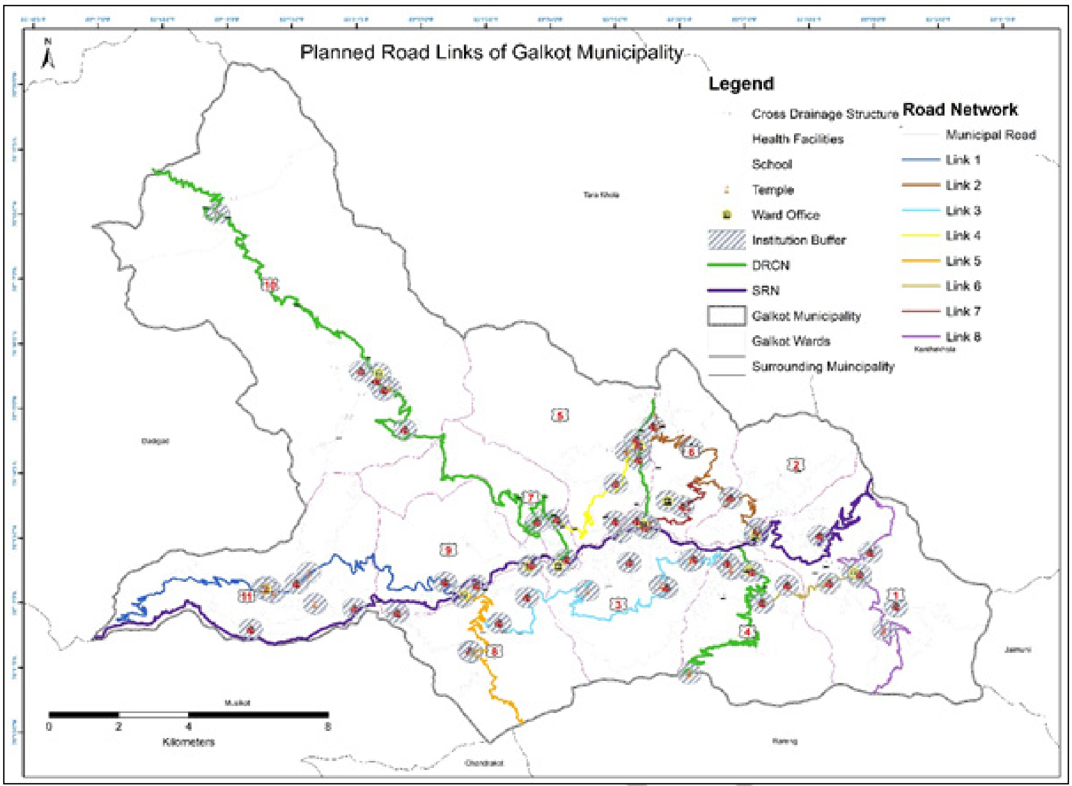

Figure 7.Planned road links of Galkot Municipality

Conclusion

This study explores the potential of GIS in effective transport network planning. Considering the challenge of managing the upgrade and maintenance of all roads, which is a daunting task due to the enormous resources required, especially beyond the capability of the municipality, a strategic approach was adopted. Institutions were identified as obligatory stations for planning purposes, leading to the creation of a buffer zone of 300 meters. Road links were then selected based on these buffer zones. Analysis reveals that the total length of links connecting all institutions within the municipality is 94.10 km out of the total municipal road network of 362.84 km. These road networks should be prioritized for future investment.

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