Trans. Inst. Indian Geographers
ISSN 0970-9851
Indexed in Scopus

An analysis of road network development in Darjeeling town, West Bengal

Pallabi Sarkar, Kolkata and Tuhin Kanti Ray*, Siliguri

Abstract

In recent years, Darjeeling has experienced a marked increase in population and faster pace of urbanization that has resulted in rapid growth of traffic volume within the city exasperating the existing problems of limited road space. Darjeeling being one of the most visited tourist places in eastern India has its own importance in road network not only for local mobility but also for the development of tourism and economic prosperity of the region. An attempt has been made in this paper to analyze the network efficiency and complex circuit pattern of road through connectivity and accessibility measures. Study of road infrastructure based on frequency, density and road hierarchical order has also been undertaken. Effort has been made to assess the transport services of the area to find out ways to improve the road condition as well as quality of life in the district. It has been observed that though intra-urban connectivity seems to be adequate there is scope to enhance inter-urban connectivity of the town. Further there is a scope to develop alternative routes to improve the accessibility of the area and ensure better mobility particularly at the time of natural calamity or heavy traffic.

Keywords: *Network efficiency, circuit pattern, connectivity, accessibility, road hierarchy.*

Introduction

Infrastructure is one of the key necessities for proper urban growth. It is of utmost importance to satisfy the growing travel demands of the ever-increasing population. Moreover, a flourishing tourism industry also requires the support of a good transport system. However, in hilly terrain, development of transport network as well as maintaining them is challenging, not only because of the physiographic limitations but also due to occurrence of frequent natural hazards. Darjeeling municipality has a mere 3.2 percent of road space and there is very little scope of expansion of roads or even road width. In order to cater to the growing demands of population and increasing demands of tourism in the region, it is necessary to improve connectivity and accessibility through the existing road network. In this context, the present paper makes an attempt to assess the road network of the Darjeeling municipality and its surroundings for better efficiency.

Darjeeling, often addressed as the “Queen of Hills,” has a long colonial legacy not only as an exciting tourist spot but also as a sanatorium and health resort. The district headquarters of the northernmost district of West Bengal, Darjeeling attracts numerous tourists and nature lovers round the year. Darjeeling municipality was formed in the year 1850 making it one of the oldest Municipalities in the country. This municipal town has developed on a 'Y' shaped ridge with the base resting at Katapahar and Jalapahar and the two arms diverging north of the observatory hill. It is spread over an area of 7.43 km2. The area has steep slopes and loose topsoil leading to frequent landslides during the monsoons. Presently the total population of this municipal town is 1, 18,805 (Census, 2011) distributed in 32 wards (Fig-1). There has been a significant increase in population (about 66.23%) during the 1991 to 2001 decade. The paper aims at identifying the existing road network characteristics and road condition in relation to regional demand pattern in Darjeeling town as a whole.

Review of literature

Research in India about transport is heavily skewed in favour of the towns and its surrounding areas in the plains. Towns in hilly areas are generally neglected. Most studies on transport are related to network development of the region while others are related to regional transport problems and their solutions. Former category includes studies of Indian Highway Network as a complex system (Mukherjee, 2012) where the junction points are considered as nodes and the linkages by the existing road connection between them. A recent case of study to measure the transport network in peri-urban Burdwan also considered network analysis as an important analytical tool of transportation as it involves the depiction of the array of nodes and their relationships with the arcs (Arif et. al, 2020). Another case study conducted for Calicut considers road network and connectivity coverage in city center in order to assess the transport development. The paper identified the reasons for the restrained network performance of the city area with the distance from the city center (Sreelekha et.al 2020). In a case study of road transport in West Bengal, Bhaduri (1992) did a detail network analysis of roads in West Bengal. Network analysis of Darjeeling district was also carried out in the same book by using graph theory. Study of connectivity and accessibility was conducted using Shimbel and detour index. In the present study the same techniques have been followed to measure the connectivity and accessibility. In Bradbury's (1992) study, the inter district level variation of Darjeeling district has been depicted. But, the previous works rarely focused on the intra district or intra municipal level situation which constitutes the main focus in this paper. Beta index and Shimbel index had been adopted in another study to measure the connectivity and accessibility respectively which was carried out in Kolhapur city of Maharashtra (Patil et al 2014). Kolhapur has an undulating topography where these two techniques were applied to measure the intra urban connectivity and accessibility.

As regards the second category of research Dutta et.al (2012) highlighted environmental issues regarding road condition and transportation system, their causality and also found out some remedial plans for improvement of traffic and transport system in Burdwan Municipality. For a spatial analysis of the road network, different indices were used for measuring centrality, connectivity and accessibility in the municipal area. Nag et.al. (2016) emphasized on sustainable transportation options in Darjeeling by identifying critical problems threatening the sustainability of the existing transportation system. Sharma (2016) using multimodal transport network technique provided a smart

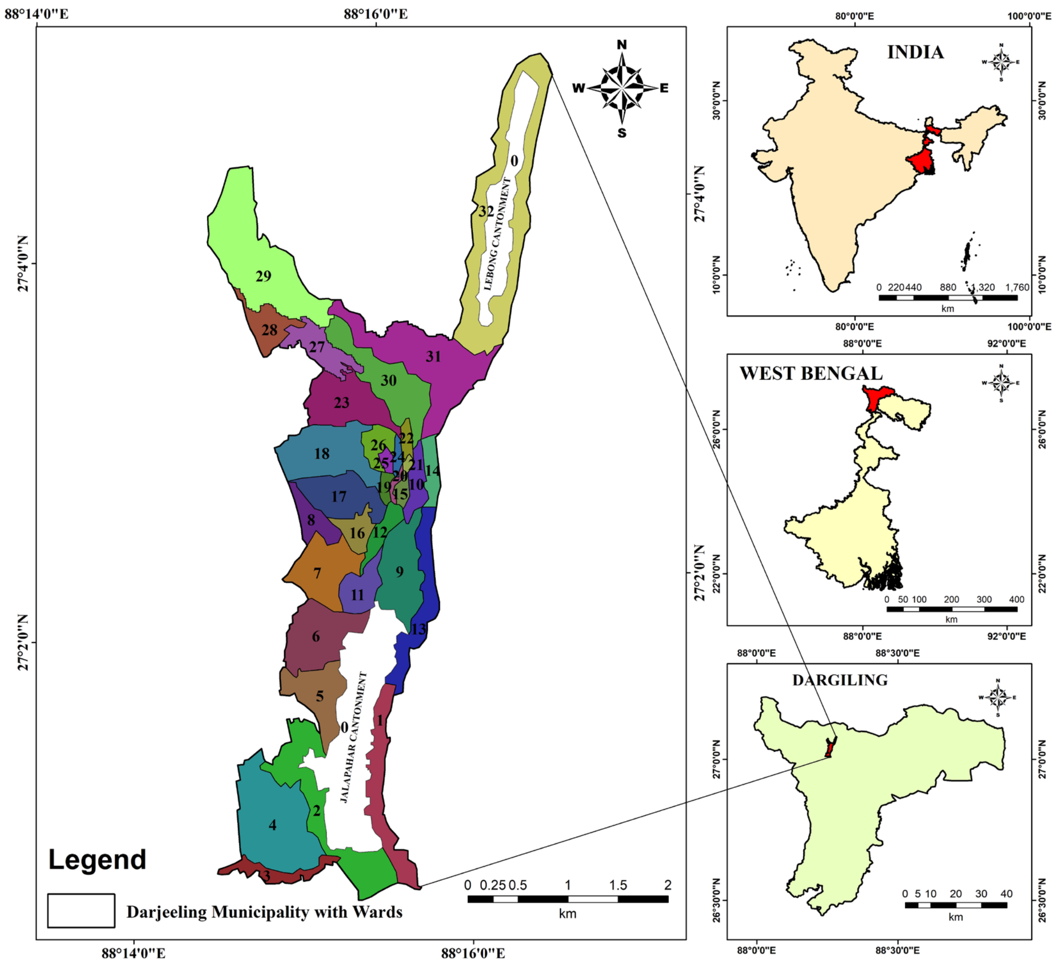

Fig. 1: Darjeeling municipality showing different wards and cantonment area

and sustainable solution for transportation in Shimla city with respect to its future tourism prospect. Multimodal movement finds alternative transport solution from environmental and energy saving point of view for smart city approaches in the hill area.

Statement of the problem

Road infrastructural development of a hilly region has unique challenges. Increasing inhabited population and advancement in tourism in Darjeeling town and its surroundings has enhanced the transportation activity and traffic load along the roads in the city. However, unplanned expansion of tourist accommodations, resorts and shopping areas are largely responsible for the narrower road space. Scope for widening of roads or development of new roads in a hilly area is highly limited due largely to physical constraints. Further, there are frequent occurrences of geomorphological hazards which make movement difficult. Therefore, to solve the traffic bottlenecks and to cater to increasing mobility demand it is necessary to focus on the present road connectivity of the area and to enhance accessibility of these roads as well as the alternative roads.

Objectives

Road network development in relation to existing transport infrastructure influence the mobility pattern of Darjeeling town. Hence the prime concern of the present research is to identify the level of transport infrastructure that influences the mobility pattern of this town. In this context the main objectives of this paper are:

a. To analyze the existing road network pattern of the region in terms of road frequency, road density, and road hierarchy and road characteristics.

b. To determine the present intra town as well as inter town network connectivity and assess the degree of accessibility of the road network.

Methodology

Transport network in Darjeeling municipality has been categorized into two parts. Firstly, for analyzing the connectivity and accessibility of nodes along the major transportation routes, a number of topological measures of network structure have been developed based on elementary concepts of graph theory which is the study of graph and graph is constituted by nodes and edges. Networks are highly complex spatial systems and substantial simplification is needed to study them. Idealization of the network into the form of a graph is a prerequisite for analyzing a transport network (Taaffe and Gauthier, 1973), (Patil, 2014). Secondly for assessing the nature of road characteristics, measures of road density, frequency and hierarchy have been used.

Connectivity of the network refers to the degree of connection between all vertices (Taaffe and Gauthier, 1973) or the degree of completeness of the links between nodes (Robinson and Bamford, 1978). The greater the degree of connectivity within a transportation network, the more efficient is the system. The inter-town connectivity and accessibility of Darjeeling is computed to determine the degree of connectivity and accessibility of Darjeeling town with respect to the other major nodes of the district (Table 1). As Darjeeling is one of the most important towns and tourist spots, it is important to identify the degree to which it has been linked with the other towns or of

Table 1: Selection of the nodes

Inter-town nodal point (within district)		**Intra town nodal point (within town)**	
V1 - Sukhiapokhri	V7 - Garubathan	V1 - North point	V7 - Phulbari
V2 - Darjeeling town	V8 - Matigara	V2 - Mall	V8 - West point
V3 - Ghoom	V9 - Siliguri	V3 - Jailkhana Baste	V9 - Jorbanglo
V4 - Kalimpong	V10 - Naxalbari	V4 - Chowk Bazar	V10 - Ghoom
V5 - Kurseong	V11 - Kharibari	V5 - Kalyan Gram	
V6 - Mirik	V12 - Phansidewa	V6 - Limbugaon	

Source: Selected by the authors

the district. Twelve nodal points have been selected within the district which is either a tourist spot or a major sub-divisional headquarter of the district. Intra-town connectivity and accessibility of Darjeeling municipality is to show the interconnection among the places within the town area (Table 1). In this case ten nodes which are either a major intersection points or important settlement within the municipality have been selected (Fig 2 and 3).

Three indices are used to measure the connectivity and two indices are used for measuring accessibility of the of the study area. (Deniel et.al. 2021)

1. Alpha Index (α): A measure of connectivity which evaluates the number of cycles in a graph in comparison with the maximum number of cycles. The higher the alpha index, the more a network is connected. The value of α index indicates the number of fundamental circuits as a percentage of maximum number possible.

$$\alpha = \frac{\text{Actual Circuit} \quad (e-v+1)}{\text{Maximum Circuit} \quad (2v-5)}$$

where e = No. of Edges (links)

v= No of nodes (vertices)

2. Beta Index (β): It measures the level of connectivity in a graph and is expressed by the ratio between the numbers of links (e) over the number of nodes (v). Value ranges between ‘0’ to ‘1’. Beta index ‘0’ represents presence of node without arcs. A connected network with one cycle has a value of 1. More complex and well-connected networks have a value of greater than 1 (Rodrigue, 2020, Saxena, 2005, Ahmed et.al, 2018)

$$\beta = e/v$$

where e = No. of Edges (links)

v= No of nodes (vertices)

3. Gamma Index (γ): Defined as the relationship between the number of observed links and the number of possible links (Rodrigue, 2006, p.66). The value of gamma ranges between 0 and 1, where value 1 indicates a completely connected network.

$$\gamma = \frac{e}{3(v-2)}$$

where e = No. of Edges (links)

v= No of nodes (vertices)

Accessibility is the measure of the capacity of a location to be reached by, or to reach different location (Rodrigue, 2006). The structure of a network, changes in response to the increase of new linkages or the betterment of existing linkages. These alterations are reflected in changes in nodal accessibility (Taffee-Gauthier, 1973). Topologically, nodal accessibility is measured using Shimbel index. It can be derived from the shortest path matrix. The minimum number of links required to connect two nodes is called the shortest path. It indicates the minimum number of linkages needed to connect farthest node in the network by the shortest path (Saxena, 2005) (Daniel et. al. 2020). The methodology adopted in this study is applicable for a hilly region like Darjeeling as it is clearly mentioned that “in idealizing any network as a graph, we are treating only the topological properties of the transportation system, not the whole range of properties that are identifiable with any given region” (Taffee-Gauthier, 1973). Therefore at the time of measuring connectivity, irrespective of the terrain characteristics researcher can apply this graph theory based measurement of connectivity and same is applicable for

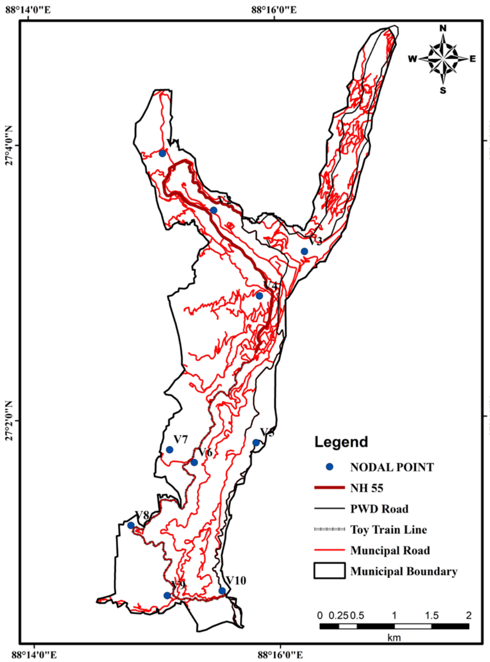

Fig. 2: Road network map of Darjeeling Municipality

accessibility. Moreover, no such an assumption or precondition exist as to the application of these techniques an isotropic surface.

Detour index is also a measure of accessibility, which determines the efficiency of a transport network in terms of how well it overcomes distance or the friction of space. It is the ratio between the straight distance (DD) and the actual distance (DT) of two nodes. The detour index in most cases is more than 100. The complexity of the topography is often a good indicator of the level of detour (Rodrigue, 2006, Saxena, 2005)

$$\text{Detour Index} = \frac{\text{DT (Actual Road Distance)}}{\text{DD (Straight line distance)}} \times 100$$

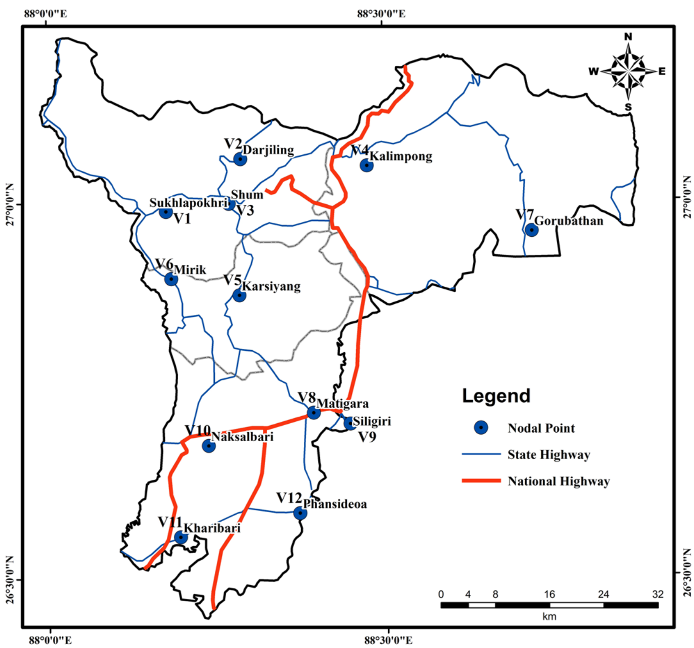

Fig. 3: Road Map of Darjeeling with major nodes

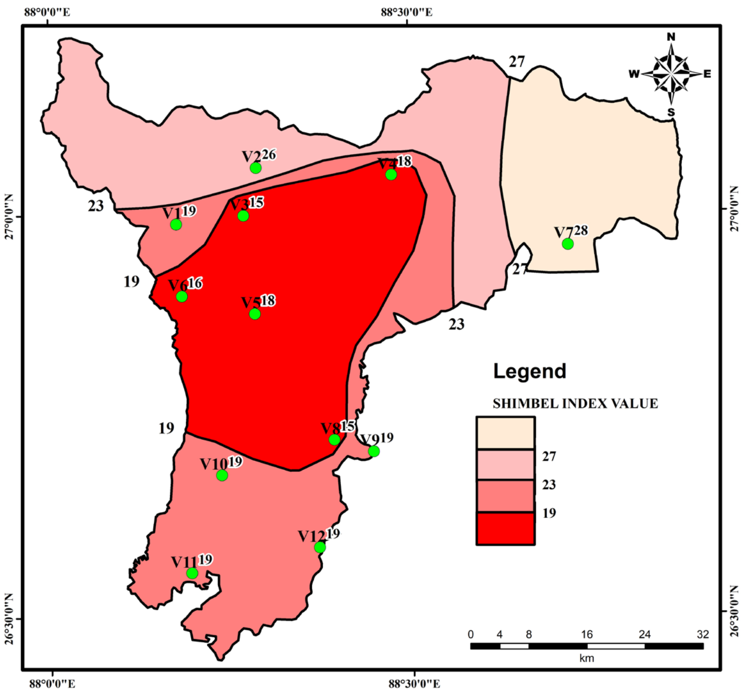

Fig. 4: Accessibility map based on Shimbel Index: Darjeeling district

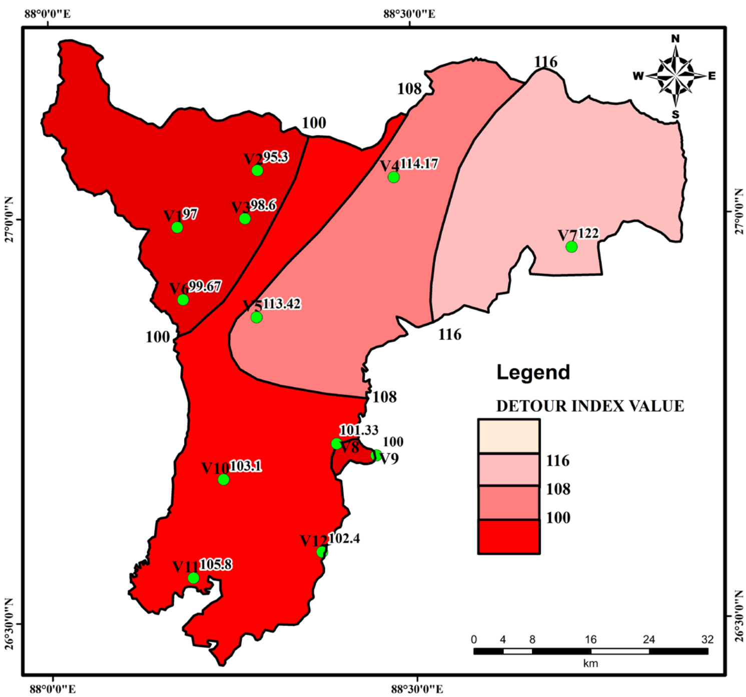

Fig. 5: Accessibility map based on Detour Index: Darjeeling district

Table 2: Determination of Connectivity for Darjeeling District

Measurement	Formula	Value	Remarks
Gamma index (γ),	$\gamma = \frac{e}{3(v-2)}$ $\frac{20}{3(12-2)}$ =20/30	0.66 or 66 %	indicates the degree of inter connection among the nodes is moderately high.
Beta index (β),	$\beta = \frac{\text{Arcs (e)}}{\text{Nodes (v)}}$ 20/12	1.66	means the network has more than one circuit or forms a complex pattern.
Alpha index (α),	$\alpha = \frac{e-v+1}{2v-5}$ $\frac{20-12+1}{(2*12)-5}$ = 9/19	0.474 or 47.4 %	reveals that the road circuit development is not so high in this given network. Thus, the degree of connectivity is moderate.

Source: Computed by the authors

Table 3: Determination of connectivity within Municipality

Measurement	Formula	Value	Remarks
Gamma index (γ),	$\gamma = \frac{e}{3(v-2)}$ $\frac{22}{3(10-2)}$ = 22/24	0.9166 or 91.6%	indicates the degree of inter connection among the nodes is very high or a very well-connected network.
Beta index (β),	$\beta = \frac{\text{Arcs (e)}}{\text{Nodes (v)}}$ 22/10	2.2	means the complex network pattern having more than one circuit or forms a well-connected network.
Alpha index (α),	$\alpha = \frac{e-v+1}{2v-5}$ $\frac{22-10+1}{(2*10)-5}$ =13/15	0.86 or 86%	reveals that the road circuit development is very well in this given network and the degree of connectivity is very high.

Source: Computed by the authors

The road infrastructure is shown by using ward wise road frequency and road density measurement. Number of roads in each ward is counted and categorized in four groups with high, medium, low and very low values. Road density for each ward is measured by the ratio of total length of road and area of that particular ward and the categorized in four groups for assessment of road infrastructure.

$$\text{Road density} = \frac{\text{Length of road in each wards (Km)}}{\text{Area of the ward (Sq. Km)}} \quad (\text{length(km)/ Km}^2)$$

Road connectivity

A topology of the roads has been created connecting the selected 12 nodes of Darjeeling district. Here according to γ index, maximum number of possible links is 30 but the actual number of linkages is 20 and as per γ index the maximum numbers of possible circuits is 19 but only 9 circuits have been formed (Table 2).

In order to determine the spatial pattern of connectivity within Darjeeling Municipality, the topology was formed on 10 selected nodes. Here actual number of linkages is estimated at 22 and possible linkage is 24 and the maximum numbers of possible circuits are 15 and actual number of circuits formed is 13 (as per γ and α index Table 3).

The overall study from all the selected indices reflected a higher level of intra town connectivity in comparison to the inter town connectivity. It also shows higher level of travel demand and mobility within the town as compared to the travel demand among various towns of the district. Levels of interaction depend on the size of population and inter nodal distance. Therefore, it is logical that the level of intra town interaction must be higher than the inter town.

Accessibility (Inter- and Intra-town)

Accessibility (both for Darjeeling district and the municipality) has been computed based on Shimbel index and Detour index where higher value indicates lower level of accessibility and vice-versa. According to the calculated values

Table 4: Determination of Shimbel Index (inter-town)

Range	Type	Nodes
<19	High	V3, V4, V5, V6, V8
19-23	Moderate	V1, V9, V10, V11, V12
23-27	Low	V2
>27	Very Low	V7

Source: Computed by the authors

Table 5: Determination of Detour Index (inter-town)

Range	Type of Zone	Nodes
<100	High	V1, V2, V3, V6, V9
100-108	Moderate	V9, V10, V11, V12
108-116	Low	V4, V5
>116	Very Low	V7

Source: Computed by the authors

Table 6: Determination of Shimbel Index (intra-town)

Range	Type of Zone	Nodes
<14	High	V3, V4
14-16	Moderate	V2, V5, V6, V9
16-18	Low	V1, V7
>18	Very Low	V8, V10

Source: Computed by the authors

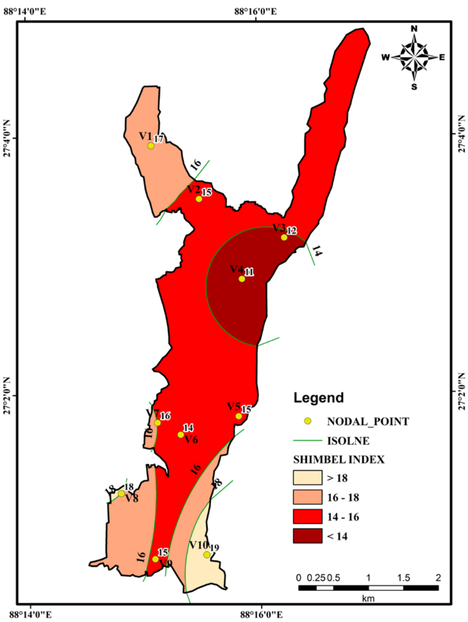

Fig. 6: Shimbel Index- Darjeeling (M)

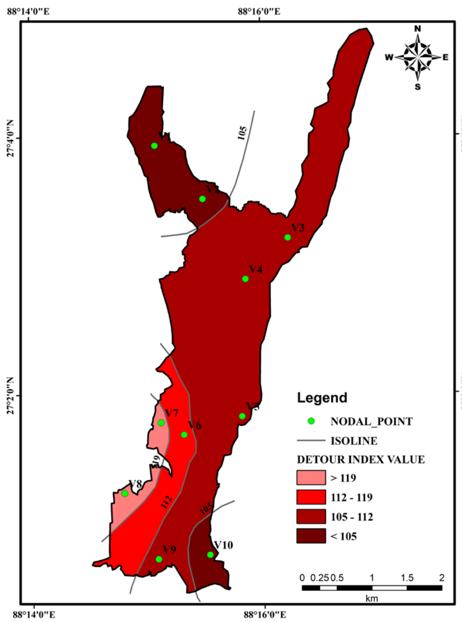

Fig. 7: Detour Index – Darjeeling (M)

we categories the area into four zones and prepared zonation map (Fig 4 and 5).

Darjeeling town (V2) is situated in the third accessibility zone according to Shimbel index based on shortest path matrix that means accessibility is much less than other selected nodes (Table 4 and 6).

The result obtained from detour index is somewhat different from the findings based on 'Shimbel' index. The lower the detour index the more direct is a given route. The map illustrates (Fig 5) that Darjeeling town (V2) is situated in higher value zone in respect of Detour index.

The study of intra-town accessibility has been done based on the same exercise to show the degree of interconnection among various nodes within Darjeeling town.

For a better understanding of the local accessibility of the town, four different zones have been identified (Table 6). According to the Fig 6, Chawk bazar is in the most accessible zone while Mall is in moderately accessible in the Municipality. These two areas have high accessibility mainly because of their commercial land use.

On the basis of detour index (Table 5 and 7) the same area is divided into another four zones. The detour index value clearly depicts that the maximum nodes of the municipal area belong to high and moderately accessible zone. Both the indices (Shimbel and detour) reveal that the Mall (V3) and Chowk Bazaar (V4) area fall under moderate to high accessibility as most tourists visit these two areas. (Fig-7)

Road infrastructure development

The district has a network of several major connecting roads and national highways (NH). NH 31, 31C, and 55 connecting

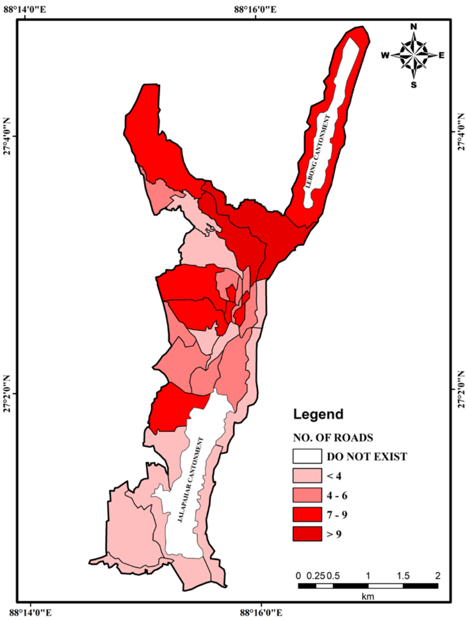

Fig. 8: Road frequencies – Darjeeling (M)

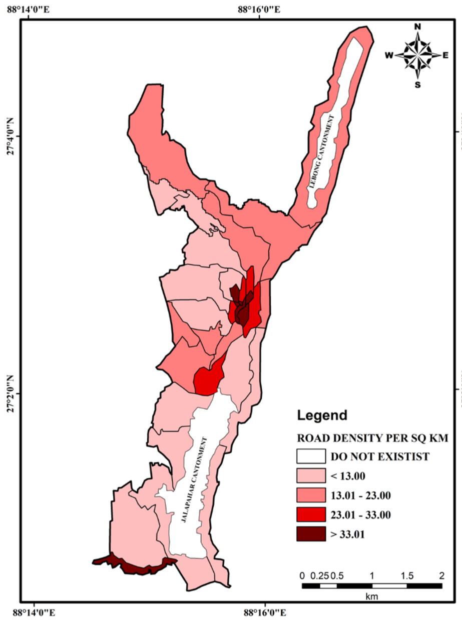

Fig. 9: Road densities – Darjeeling (M)

Table 7: Determination of Detour Index (intra-town)

Range	Type	Nodes
<105	High	V1, V2, V10
105-112	Moderate	V3, V4, V5, V9
112-119	Low	V6
>119	Very low	V7, V8

Source: Computed by the authors

Table 8: Ward wise road frequency

Road frequency (no. of roads)	Range	Total wards covered
< 4	Very Low	5
4-6	Low	16
7-9	Moderate	9
> 9	High	2

Source: Computed by the authors

Darjeeling district with the other parts of West Bengal and the rest of the country. Siliguri is an important transit town for the hilly regions of the district, and for Sikkim and other northeastern states. The NH 31 passing through Siliguri connects the district to Jharkhand, Bihar and ends at Guwahati in Assam. It also connects Gangtok in Sikkim. NH 31C passing through Bagdogra and Naxalbari connects Bijni district in Assam. NH55 connects Siliguri to Darjeeling.

As per UDPFI standard for hill areas Darjeeling Municipality is classified under large city (over 80,000 population). The Municipal area has approximately 4.87 percent roads, which is fairly low as per UDPFI standard (6-8%) for any large hill town. Due to the rapid growth in urbanization, the present roads will not be able to cope with this population pressure (Draft Development Plan, Darjeeling Municipality, 2012-13). Major arterial roads in the Municipality area are Bazaar Cart Road, Bhanu Sarani (East & West), Forest Road, Gandhi Road, Ghoom Monastery Road, H.D.Lama Road, Jawahar Rd (East & West), Kutchery Road, Laden-La Road, Lebong Cart Road, N.C.Geonka Road etc. The Municipality is also served by a number of medium and small lanes and bye-lanes with different categories of vehicles plying on them. Most of the roads have an average width of 3.5m, with a very little scope of widening. Concept of public transport system is not developed here. Darjeeling is connected with rest of the West Bengal mainly through NH-55 known as Hill Cart Road.

The existing road infrastructure in Darjeeling municipality is examined counting the number of roads present in each ward from the road network map by preparing a zonation map based on ward wise road frequency. (Table 8)

Fig- 8 represents sixteen wards that have a low frequency of roads ranging from four to six whereas only two wards have high road frequency (more than nine). In the city center, the frequency of road is moderate to high, but in the southern part of the municipality the frequency of road is very low in contrast.

Ward wise road density has been calculated by dividing the total road length in each ward with the area of that ward and according to the value it has been divided into four classes (Table 9). Based on these classes a zonation map has been prepared. (Fig-9)

Very high level of road density has been observed at the central area of Darjeeling town because of its commercial use which reduces towards the periphery. The Chowk bazaar Mall and the Super market area at the central part of the town are the places of high road density. In this respect it may be mentioned that the areal extent of these wards is very small which demonstrates a high road density, even though the total length of the road is less.

Functional classification of urban roads has been identified according to hierarchical order of roads where over half of the municipal roads belongs to sub arterial category (Fig 10). While major arterial roads in the urban areas of Darjeeling municipality provide both city level and regional level connectivity, the sub-arterial roads are mostly narrow with open drains and provide local level connectivity. On the basis of length, width and material of construction, a road hierarchy within the

Table 9: Length and width of roads according to material of construction

Type of road (Street Network)	Construction Material	Length (km)	Width (meter)	Physical Condition
Pucca Road (85 %)	Motorable Bituminous	50 Km.	3.5 m (Average)	50 Mtr potholes/ Km Road, (average)
	Non-Motorable Bituminous	14.5 Km.	1.5m(Average)	
	Concrete Carriage Road-	9.50 Km.	2.5m(Average)	
	Concrete Stepped Road	2.50 Km.	1m(Average)	
Kutcha Road (15%)	Kutcha Road	13.50 Km.	2.5m(Average)	

Source: Darjeeling, DDP (2008-09 To 2012-13)

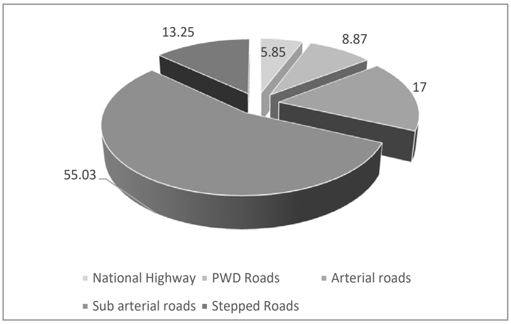

Fig. 10: Functional classifications of urban roads.
Source: Darjeeling, DDP (2008-09 to 2012-13)

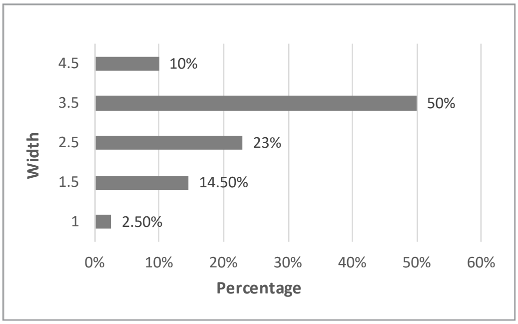

Fig. 11: Right of way width classification.
Source: Darjeeling, DDP (2008-2012)

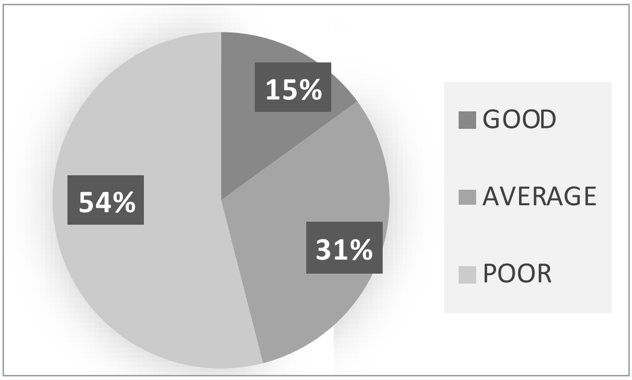

Fig. 12: Road condition at Municipal level
Source: Darjeeling, DDP (2008-2012)

Table 10: Ward-wise summary of feedback and plans on road network

Issues suggested by the Ward Committee	Ward Number
Poor condition of black top road	1, 7, 9, 11, 12, 13, 14
Narrow road stretches obstruct smooth movement of vehicles.	1, 2, 3, 5, 10, 11, 12, 13, 14, 18
Poor maintenance of existing road network	1, 7, 9, 11, 12, 13, 14
Excessive traffic load	7, 8, 10, 11, 12, 15, 16, 18, 19, 21, 23, 24, 25, 28, 29, 30, 31, 32
Upgradation of existing roads	1, 2, 7, 11, 12, 13, 14, 18, 19, 20
Removal of encroachment	1, 2, 3, 11, 12, 14 to 20
Erosion of road soil	1, 8, 10, 11, 13, 14
Strengthening of road (low capacity)	1, 2, 3, 7, 10, 11, 13, 14 to 19 (except 18)
Construction of link-road with adjoining GP	1, 2, 3, 4, 5, 6, 7, 8, 13, 14, 27, 28, 29, 31, 32

Source: Darjeeling, DDP (2008-09 to 2012-13)

municipality is presented in table 9.

Another notable feature of the urban roads is their right of way width. Figure 11 represents the width of the urban roads in the town. Only 10 percent roads have average width of 4.5 meter which is not so efficient for average traffic movement. Minimum width of a kerbed urban road is 5.5m including allowance for a stalled vehicle. Average width of the road in Darjeeling municipality is 3.5 meter which is recommended for single lane without kerbs and not capable to carry double way traffic which is resulting in huge traffic bottlenecks and travel delays. (Urban Roads Manual, PWD, Govt. of Delhi, 2014).

According to the feedback received through the household survey conducted by the municipal authority (Fig 12) 54 percent roads are in poor condition with average 50m or more potholes found per kilometer roads. The survey states that only 15 percent roads are in good condition which is basically the national highway and few major arterial roads. Another ward level survey, conducted by the Ward committees of Darjeeling Municipality a few problems regarding roads and traffic are identified by the people which are compiled in Table 10.

All these roads are not meant for heavy vehicles and most of them were constructed during pre-independence period and now due to plying of heavy vehicles and lack of maintenance, most of them are in bad shape as seen in table 11. The geology of the area compels all the roads to follow the contour lines and therefore, they are mostly meandering and sloping in nature and hence accident prone. That is why periodic maintenance is required in some black top roads like Bazar cart road covering Ward No - 24, 25, 23, 21 and Lebong cart road covering Ward No - 23, 28, 29, 30, 31, and 32. Construction of pedestrian step paths is also needed to remove the walking crowd from the main roadway. Construction of link roads is required for better connectivity of city core with adjoining Gram Panchayats (village clusters).

Conclusions

Darjeeling is an important tourist destination in the state of West Bengal. Thus, for the industry to flourish in the region, effective land use planning should be undertaken. For these purposes' scientific city zoning programmes should be introduced coupled with sustainable urban development principles and participation by stakeholders. Such kinds of planning related to structural changes need financial assistance as well as environmental impact assessment before their implementation and these will not be possible without the assistance of local governance. According to the study, there is an urgent need for further improvement of the connectivity and accessibility at the district level for efficient inter urban mobility. Though intra-urban connectivity is well developed and there is no need for further expansion, yet forming a better connectivity and easy accessibility of Darjeeling town with other major nodes of the district is necessary by developing alternative routes to reach other tourist destinations. Insufficient width of road intensifies the problem of slow-movement of vehicles and causes traffic snarls in most roads in the town. Potholes in many parts during rainy season make them accident prone. Regular maintenance of municipal roads every year after the rainy season as well as proper traffic management in the narrow roads can be effective to solve the road traffic issues. This study may be considered as a preliminary research which might be applicable for other hilly or mountainous towns of the country that have similar kind of road network and provide an approach to reduce congestion, improve mobility and better performance of the transport network.

References

Arif, M., & Gupta, K. (2020). Application of graph-based model for the quantification of transport network in peri-urban interface of Burdwan City, India. *Spatial Information Research*, 28. 447-457. Doi:10.1007/s41324-019-00305-w.

Bhaduri, S. (1992). *Transport and Regional Development- A Case of Road Transport of West Bengal*. Concept, New Delhi,123-124,126,138,141,144,160.

Daniel C. B., Saravanan S., & Mathew S. (2020). GIS Based Road Connectivity Evaluation Using Graph Theory. Mathew T., Joshi G., Velaga N., Arkatkar S. (eds) *Transportation Research*. Lecture Notes in Civil Engineering, vol 45. Springer, Singapore. https://doi.org/10.1007/978-981-32-9042-6_17

Daniel, C. B., Mathew, S. & Saravanan, S. (2021). Spatial interdependence of fractal dimension and topological parameters of road network: a geographically weighted regression approach. Spat. Inf. Res. https://doi.org/10.1007/s41324-021-00390-w

Dutta, S., & Mistri, D. (2012). Problems of transportation system in Bardhaman municipal area, West Bengal. Practicing Geographer; *Journal of Foundation of Practicing Geographers*, vol 16.67-78.

Mukherjee, S. (2012). Statistical Analysis of the Road Network of India; Pramana.

Nag, D., Saha, S. & Paul, S. (2016). Sustainable Transportation Options for A Tourist Hill

Town, Case Study: Darjeeling. *Conference: 9th Urban Mobility India Conference & Expo at Ahmadabad, India.*

Patil, P. T., Patil, A. A., Momin, M. M., & Mane, A. G. (2014). An assessment of accessibility and connectivity of some important places in Kolhapur city of Maharashtra: A Road network analysis. *Mathematical Theory and Modeling, 4*(12), 148-160.

Robinson, H., & Bamford., C. G. (1978). Geography of Transport. *Macdonald and Evans, ISBN 13: 9780712107303.*

Rodrigue, J. P., Comtois C. & Slack B. (2006). The Geography of Transport Systems. (2nd Ed.), Routledge, London. ISBN 978-0-415-48324-7.

Rodrigue, J. P. (2020). *The Geography of Transport Systems.* (5Th Ed.), Routledge, New York, P. 456. ISBN 978-0-367-36463-2

Saxena, H. M, (2005). Transport Geography. Rawat Publication, *New Delhi; ISBN-13: 978-8170339458.*

Sreelekha, M. G, Krishnamurthy. K, & Anjaneyulu. M. V. L. R (2020). Urban Road Network and its Topology, Case Study of Calicut, India. *European Transport \ Trasporti Europei, Issue 78, Paper no 6, ISSN 1825-3997.*

Taffee, E. J. and Gauthier, H. L., (1973). Geography of Transportation. *Prentice Hall, INC, Englewood Cliffs, N.J. ISBN 10:0133513874.*

Younes, A., Abdu, S. & Ali, H. (2018). Evaluating the connectivity level of Fayoum city roads network: a new method using GIS. Prace Komisji Geografii Komunikacji PTG. 21. 44-56. 10.4467/2543859XPKG.18.018.10776

Reports

Draft Development Plan, Darjeeling Municipality. Editions: 2008-2009 and 2012-13.

Urban Roads Manual (2014). Public Works Department, Government of Delhi, Edition: Second.

Pallabi Sarkar

Research Scholar,
Department of Geography, Adamas
University Kolkata, West Bengal

Tuhin Kanti Ray*

Assistant Professor,
Department of Geography,
Vidyasagar College, Kolkata

*Author for correspondence
E-mail: tuhinkanti2008@gmail.com