

Interaction between Road Network Connectivity Pattern and Development in Darjeeling District of West Bengal, India

Biswajit Paul^{1*} and Subir Sarkar²

Abstract : Road transportation system is one of the key elements of a society that directly or indirectly affects the developmental process of any place or region. An efficient road network links the resource deficient areas with resource surplus areas. Thus, making it a necessary consideration to understand the connectivity pattern of the road network of any place. The northernmost district of West Bengal, Darjeeling is been selected to perform the analysis of road network connectivity, to understand the level of regional development within the district and to find the prevailing correlation between them. Four network connectivity indices (Beta, Alpha, Gamma, and Cyclomatic Number) and levels of regional development are computed depending on ten selected demographic and socio-economic parameters such as household density, population density, effective literacy rate, total work participation rate, level of urbanization, villages electrified, road density, health facilities, the density of the educational institutes, and percentage share of net sown area. The study is primarily based on secondary information analyzed in the SPSS platform and finally presented by cartographic techniques using ArcGIS. To examine the relationship between road connectivity and regional development, Spearman's Rank Correlation technique is used, prior to that, all the parameters of regional development are normalized using the z-score method. The result shows, there is a positive correlation (Spearman's rho = 0.683) between the road connectivity and the regional development in the study area although the relationship is moderately strong.

Keywords : Road connectivity, Development, Z-Score, Spearman's Rank Correlation, Composite score.

Introduction

Road transportation network is considered as the lifeline of human civilization because it helps to distribute the natural resources as well as the human resources from a resource surplus area to deficient areas. Transportation is referred to the movement of people, goods, services, and information between places. (Kansky, 1963) has defined the transport network as 'a set of graphical locations inter-connected in a system by several routes'. As per the India Transport Report: Moving India to 2032 of the National Transport Development Policy Committee (NTDPC) transport system

¹ Junior Research Fellow, ²Professor, Department of Geography & Applied Geography, University of North Bengal, West Bengal, India

* Corresponding author: biswajit.geo@nbu.ac.in

are of five types : Railways, Roads and Road Transport, Civil Aviation, Port and Shipping, and Urban Transport. India is one of the leading countries in the world in terms of its total road network having 5.6 million kilometers of road length (Basic Road Statistics of India, 2015-16) and jointly the states of West Bengal, Maharashtra, Uttar Pradesh, Karnataka and Assam shares 43.11% of total road length of the country. Road network directly or indirectly affects the developmental process of a place. The huge cost of road construction demands an effective utilization and it is possible by the proper connectivity and orientation (Sreelekha, Krishnamurthy, & Anjaneyulu, 2016). Thus, it is necessary to understand the connectivity pattern of the road network of a place. Connectivity generally means the degree of completeness of the arcs between the vertices (Robinson & Bamford, 1978). The network connectivity evaluates the intensity of the connections between the road segments. A well-connected road network will have numerous nodes, short links, and the minimum number of dead-ends (Sreelekha, Krishnamurthy, & Anjaneyulu, 2016), (Hurst, 1974). Connectivity of a network can be measured by the uses of 'graph theory'-a branch of typology which is concerned with the elementary structure in which the 'locations (nodes) are reckoned in terms of their position on the geometric net and not by their actual locations. There are several measures or indices available in the literature for the evaluation of the road network connectivity such as Beta, Alpha, Gamma, and Cyclomatic Number (Kansky, 1963). Whereas, development is a positive change in the economy, infrastructure, and society of a region, regional development is the provision of aid and other assistance to regions that are less developed. The transportation/development relationship is a two-way interaction process, and the results of the interaction depend upon the type of economy involved and upon the level of development at which transport improvements are affected (Hoyle, 1973).

Literature Review

Since the year 1960, many works have been done by various researchers and several indicators are introduced for analyzing the transport network including the connectivity, accessibility, efficiency and cyclic properties. Garrison(1960), has investigated the connectivity of the highway system. Kansky (1963), has studied the structural properties of the transportation network and developed graph-theoretical measures. He has also analysed the interaction between regional character and transport geometry. In the year 2009, an analysis of the Swiss road and railway networks were carried out using graph theoretical measures (Erath, Löchl, & Axhausen, 2009). Similar works have also been done by Xie, F., & Levinson, D. in the year 2007 and Sarkar in 2013. Saxena (1980), has examined the relationship of road connectivity of Rajasthan with the economic development of the state. In the year 1983, the level of urbanization has been analysed in relation to the road transportation system of Rajasthan. Sreelekha, Krishnamurthy, & Anjaneyulu (2016), have emphasized the interaction of road network connectivity and spatial pattern of the roads in Calicut city. The spatial analysis has been carried out by Dorosh, Wang, You, & Schmidt (2010) in the Sub-Saharan African region to correlate crop production and road connectivity. Similarly, Mukerji (1974), has made an attempt to correlate road connectivity and level of urbanisation in Rajasthan.

LOCATION OF THE STUDY AREA

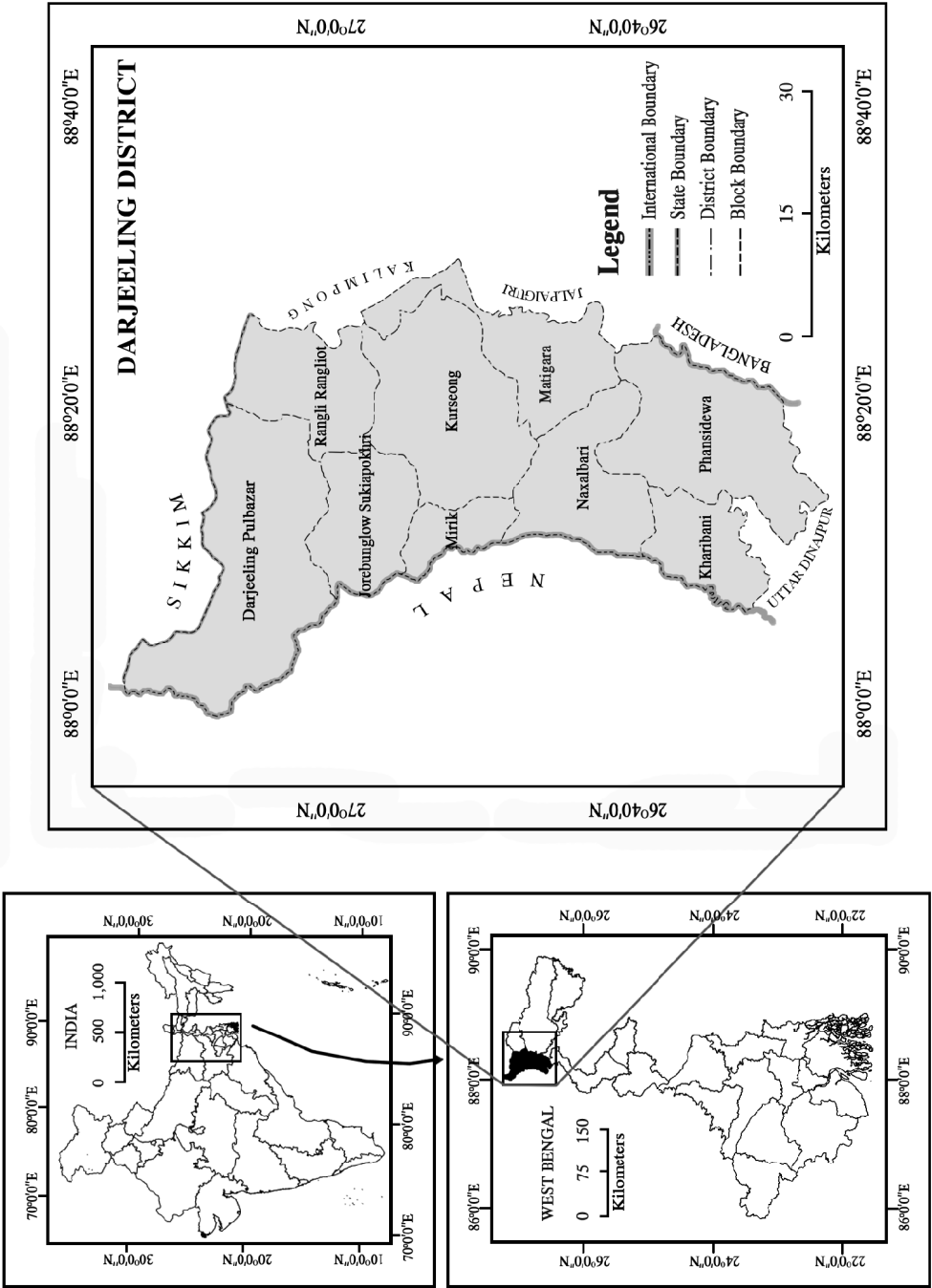


Fig.1: Location map of Darjeeling district

The Study Area

Darjeeling district is selected as a study area to carry out the present research. It is the northernmost district of the state of West Bengal having an elongated shape, geographically the northern part of the district is of Great Himalayas (300 – 12000 ft. above MSL) and the southern part lies in the Tarai region.

The district extends between 26°26'47" to 27°13'17" north latitude and 87°59'27" to 88°29'30" east longitude and measures about 86 km in the north to south and 50 km in the west to east. The total area of the district is 2040 square kilometers with 9 blocks ; Darjeeling Pulbazar, RangliRangliot, Jorebunglow Sukiapokhri, Mirik, Kurseong, Phansidewa, Naxalbari, Matigara and Kharibari. The district has 4 urban local bodies which consist of 2 municipalities (Darjeeling, and Kurseong), one notified area (Mirik), and one municipal corporation (Siliguri). The district shares its common boundary with two neighbouring nations Nepal to the west, and Bangladesh to the south-east. According to LSS O'Malley, historically the hilly areas of Darjeeling district were inhabited by the Lepchas, Limbus, Bhutias, Tibetans, and various Nepalese castes and tribes since ancient time. Whereas, the plain region is covered by dense forest and inhabited by the indigenous tribal group of the population like Rajbangshi, Koch, Meche, Dhimal.

Objectives

The major objectives of the present study include: (1) to measure the road network connectivity and level of development in the blocks of Darjeeling district, and (2) to find out the relation between them.

Data and Methods

The present study is based on the secondary sources of information collected from different government reports such as the District Information System for Education (DISE) report (2011-12), All India Survey on Higher Education (AISHE) report (2011-12), District Census Handbook (2011), and District Statistical Handbook (Department of Planning and Statistics (2010-11).

Road connectivity indices are calculated using different formulae explained in Table 1: **Formulae used in the study** from a transport map collected from Natural Resources Data Management System (NRDMS) center Jalpaiguri. To identify block-wise levels of development in the study area ten variables are selected and transformed into a standardized form using the z-score technique and finally, the Spearman's Rank Correlation technique is applied to identify the relationship between connectivity and development in the study area.

Results and Discussion

Road Network Connectivity

The district is well connected with the rest part of the country by several National and State Highways namely NH 31, NH 31A, NH 31C, NH 55, SH 12, and SH 12A (Old Numbering). The NH31 begins at Barhi in Jharkhand further more, goes through Darjeeling district to eventually end at

Table 1: Formulae used in the study

Measurements	Equations	Description
Beta index (β)	$\beta = \frac{e}{v}$	e = Number of edges or links between the nodes. v = Number of vertices in the road network. g = Number of not-connected subgraphs in the network.
Alpha Index (α)	$\alpha = \frac{e-v+1}{2v-5}$	
Gamma Index (γ)	$\gamma = \frac{e}{3(v-2)}$	
Cyclomatic Number (μ)	$\mu = e - v + g$	
Z-Score	$Z = \frac{(x - \bar{x})}{\sigma}$	x = Individual observation $\bar{x}$ = Mean. σ = Standard deviation
Spearman's Rank Correlation (r_s)	$r_s = 1 - \frac{6 \sum d^2}{n^3 - n}$	$\sum d^2$ = Sum square of the difference between ranks n = Number of variables

Guwahati, in Assam. NH 31 has two tributaries namely NH31A and NH31C. The first one extend from Gangtok in Sikkim to NH 31 at Sevoke of Matigara block (Darjeeling district) and the second one connects Galgalia in Kharibari block of Darjeeling district to Bijni in Assam. NH31 meets with NH 34 at Dalkhola in Uttar Dinajpur and NH 34 stretches up to Dum Dum near Kolkata, the state capital of West Bengal. Besides these, there are NH 55 (connecting Siliguri city and Darjeeling town), West Bengal State Highways 12 (connecting Alipurduar and Galgalia), 12A (connecting Alipurduar and Siliguri), and numerous other roads maintained by Zila Parisad and Gram Panchayats. The average road density of the district is 1.19 kilometers per square kilometer (District Statistical Handbook, 2010-11). Road connectivity indices (β , α , γ , and μ) for all the blocks are calculated using a detailed transportation map of Darjeeling district collected from Natural Resources Data Management System (NRDMS) centre Jalpaiguri.

Beta index (β) is the ratio of edges and vertices of a network. Whereas the alpha index (α) is the ratio of an actual number of circuits i.e. the number of cycles (μ) or a cyclomatic number and the maximum possible number of a circuit in a graph. Gamma index (γ) measures the relation of the

actual number of edges present in a graph and the maximum possible number of edges in the same graph. The descriptive figures of different connectivity indices are given in Table 2.

Table 2: Descriptive Statistics of road connectivity in Darjeeling district

	β	α	γ	μ
Minimum	1.00 (Phnasidewa)	0.02 (Phnasidewa)	0.35 (Phnasidewa)	1.00 (Mirik)
Maximum	1.24 (Darjeeling Pulbazar)	0.15 (Mirik)	0.48 (Mirik)	11.00 (Matigara)
Average	1.15	0.10	0.41	6.11
Std. Deviation	0.07	0.04	0.04	3.03

Source: Computed by the authors

A Composite Connectivity Score (CCS) for all the blocks have been computed by summing up the calculated index values of β , α , γ , and μ (Saxena H. M., 1980). All the blocks are ranked in order from the highest level of connectivity to the lowest. According to composite connectivity scores, the district has been categorized (Figure 2 Figure 3) into three zones, based on Natural Breaks (Jenks).

High Connectivity Zone: The highest connectivity is observed in Matigara block (12.75) followed by Darjeeling Pulbazar block (11.82). The early settlement had come up in Darjeeling and Siliguri, and the access to the Darjeeling town located in the Darjeeling Pulbazar block was through

Table 3: Block-wise levels of road connectivity

Sl. No.	Name of the Blocks	Beta Index (β)	Alpha Index (α)	Gamma Index (γ)	Cyclomatic Number (μ)	Composite Connectivity Score (CCS)	Ranks (r_i)
1	Darjeeling Pulbazar	1.24	0.14	0.44	10.00	11.82	2
2	Rangli Rangliot	1.18	0.13	0.43	4.00	5.74	6
3	Jorebunglow Sukiapokhri	1.16	0.10	0.41	6.00	7.66	5
4	Mirik	1.11	0.15	0.48	1.00	2.74	9
5	Kurseong	1.06	0.04	0.37	4.00	5.48	7
6	Matigara	1.21	0.12	0.42	11.00	12.75	1
7	Naxalbari	1.14	0.09	0.40	7.00	8.63	4
8	Phansidewa	1.00	0.02	0.35	4.00	5.37	8
9	Kharibari	1.21	0.12	0.42	8.00	9.75	3

Source: Computed by the authors

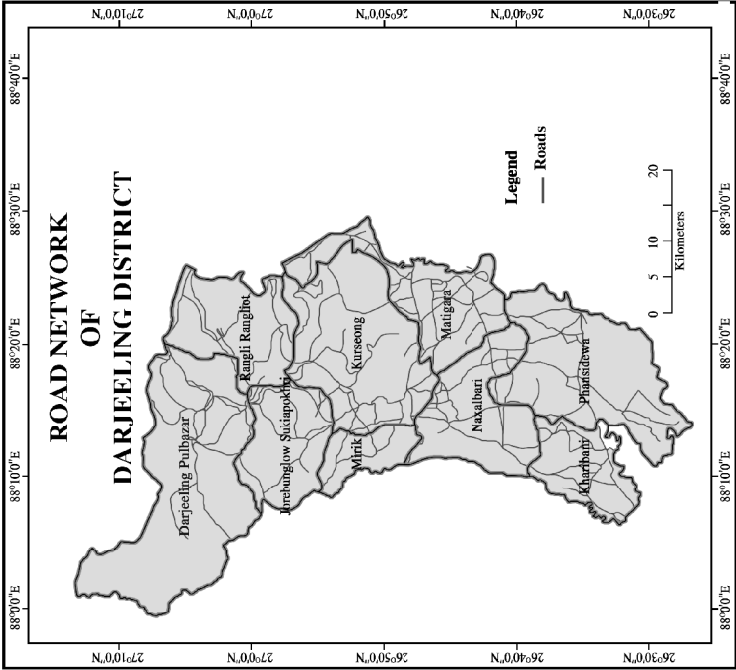


Figure 2

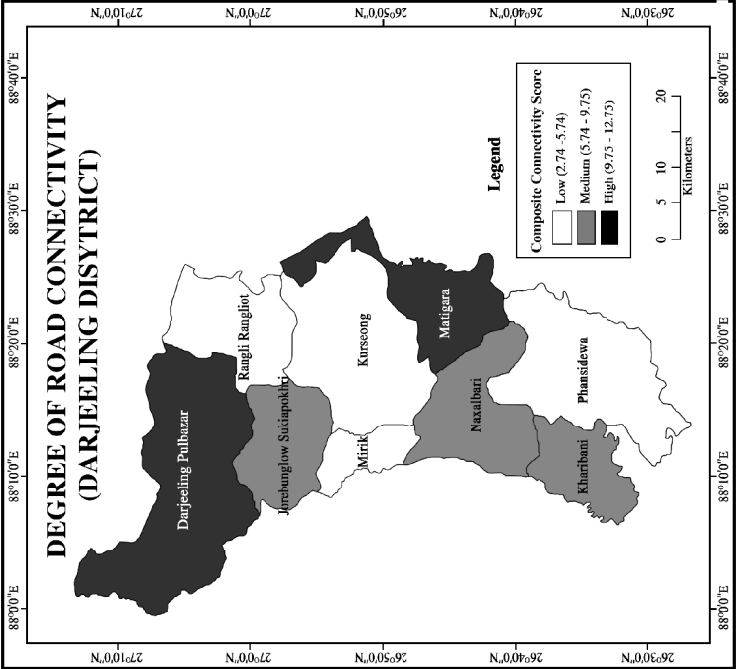


Figure 3

Matigara block as a result of which they had built roadways connecting the plains to the hills to carry them and their goods to the hills.

Medium Connectivity Zone: In the blocks of Jorebunglow Sukiapokhri (7.66), Naxalbari (8.63), and Kharibari (9.75) moderate connectivity scores are observed.

Low Connectivity Zone: The lowest road connectivity is observed in Mirik block (2.74), and the other three blocks of this low connectivity zone include Rangli Rangliot (5.74), Kurseong (5.48), and Phansidewa block (5.37).

Levels of Development

Development is a process of growth, expansion, or realization of potential, bringing regional resources to full productive use. It is a kind of positive change in the economy, infrastructure and society. To determine the level of development in the blocks of Darjeeling district ten parameters are selected including socio-demographic and infrastructural aspects because the development is a multidimensional approach. The selected indicators include:

- a) X1= Household density / sq. Km.
- b) X2= Population density / sq. km.
- c) X3= Effective literacy rate (%)
- d) X4= Total work participation rate (%)
- e) X5= Rate of urbanization (%)
- f) X6= Electrified villages (%)
- g) X7= Road density / sq. km.
- h) X8= Health facility / 1000 population
- i) X9= Number of educational institutes / 1000 population
- j) X10= Net sown area (%)

The levels of development in each block are calculated using a Composite Development Score obtained through the z-score method and ranked into order to perform Spearman's Rank Correlation. Considerable disparities are found in the levels of development across the blocks of the Darjeeling district. The extent of disparities is portrayed by three distinct categories of the high, medium and low and the categorization (Figure 4) is carried out by following Natural Break (Jenks) Method in a GIS platform.

Highly Developed Zone: Based on the composite development score only the Matigara block (10.52) is recorded a high level of development and the reason include positive performance in Household and Population Density, Literacy Rate, Total Work Participation Rate, Rate of Urbanization, Village Electrification, Road Density, and concentration of Healthcare facilities. The block comes

under the proximity zone of Siliguri city resulting high rate of urbanization and the block is also connected by several important roads.

Moderately Developed Zone: In the moderate zone, there are three blocks from the plain i.e. Kharibari (-0.16), Naxalbari (1.91), Phansidewa (-0.79) and one block from the hill i.e. Darjeeling Pulbazar (1.60).

Least Developed Zone: Except Darjeeling Pulbazar block, all the other four blocks in the northern hilly part of the district namely Rangli Rangliot (-3.79), Jorebunglow Sukiapokhri (-3.09), Mirik (-2.45), and Kurseong (-3.75) which recorded the lowest performance in almost all the indicators because of the natural constraints. The blocks are mostly backward as far as transportation, health facilities, work participation rate, and electrification is concerned.

Table 4: Block-wise normalized measurements of selected parameters (Z-Score)

Sl. No.	Blocks	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	Composite Z-score	Ranks (r ₂)
1	Darjeeling Pulbazar	-0.81	-0.81	0.70	1.37	-0.04	-0.58	1.09	0.19	0.88	-0.40	1.60	3
2	Rangli Rangliot	-0.93	-0.94	0.66	-0.40	-0.94	-1.12	-0.67	-0.15	1.18	-0.48	-3.79	9
3	Jorebunglow Sukiapokhri	-0.21	-0.26	0.99	-1.77	0.17	-0.31	-0.46	-0.58	0.03	-0.70	-3.09	7
4	Mirik	-0.59	-0.59	0.71	-0.52	-0.94	-1.58	-0.20	0.42	1.69	-0.85	-2.45	6
5	Kurseong	-0.95	-0.96	0.76	-0.98	-0.34	-0.15	-0.83	0.18	0.13	-0.61	-3.75	8
6	Matigara	2.35	2.33	-0.27	0.65	1.61	0.31	2.39	2.49	-0.66	-0.68	10.52	1
7	Naxalbari	0.72	0.72	-0.16	-0.25	1.86	0.96	-0.23	-0.80	-1.09	0.18	1.91	2
8	Phansidewa	0.04	0.12	-1.94	0.55	-0.94	1.85	-0.76	-0.93	-0.95	2.15	-0.79	5
9	Kharibari	0.37	0.38	-1.47	1.36	-0.45	0.62	-0.33	-0.82	-1.20	1.38	-0.16	4

Source: Computed by authors based on District Census Handbook (2011), DISE and AISHE report (Darjeeling and Siliguri, 2011) and District Statistical Handbook (Department of Planning and Statistics (2010-11)).

Correlation analysis: The correlation coefficient of Spearman's rho between the levels of road connectivity and the levels of development of Darjeeling district is 0.683 indicating a moderately positive correlation. Hence the result exhibit that the level of development in the study area is closely associated with the degree of road connectivity and the correlation is statistically significant.

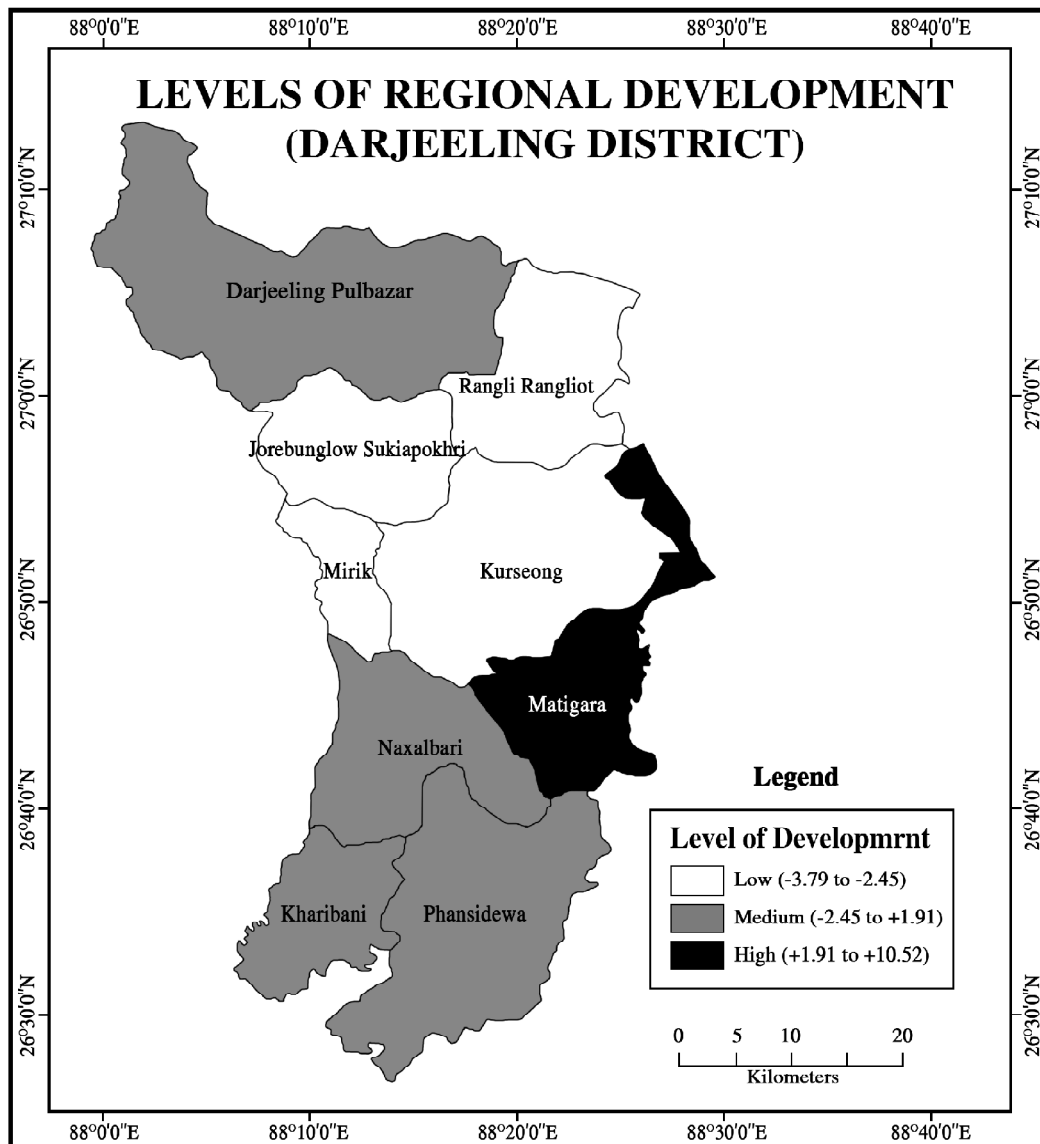


Figure 4

Table 5: Spearman's rank correlation

Correlations ^a				
			Road Connectivity	Regional Development
Spearman's rho	Road Connectivity	Correlation Coefficient	1.000	.683*
		Sig. (2-tailed)	.	.042
	Regional Development	Correlation Coefficient	.683*	1.000
		Sig. (2-tailed)	.042	.
*. Correlation is significant at the 0.05 level (2-tailed).				
a. List wise N = 9				

Source: Computed by authors

Conclusion

The analysis reveals that the levels of development in Darjeeling district are directly varying with respect to the road network connectivity in the majority of the blocks. From the comparative observation of Figure 2, Figure 3 and Figure 4, it is found that only the Matigara block accounted for high performance in road connectivity as well as in the development score. Similarly, Rangli Rangliot, Kurseong and Mirik block is recorded a low level of development as well as low connectivity score and for the medium category of road connectivity, Naxalbari and Kharibari block record moderate level of development. But in the blocks of Darjeeling Pulbazar, Jorebunglow Sukiapokhri, and Phansidewa block there is no such one to one relationship between connectivity and development. The study also reveals that most of the hilly blocks come under the low category of development as well as the lower category of road connectivity because of the natural limitations. Within the blocks of the plain region also the inequalities are considerable. Naxalbari, Kharibari Phansidewa blocks come under the medium category of development due to poor rural transportation, low literacy rate, the inadequacy of Health and educational infrastructural facilities. Although these three blocks are in the first row in terms of Agricultural production and net sown area but other infrastructural and socio-economic facilities are lacking. Thus, the improvement in other socio-economic, and infrastructural facilities are expected to ensure balanced development.

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