Road network connectivity and spatial pattern of Dispur city.

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ABSTRACT

Road network is considered to be one of the keys to regional development of a region. It plays a vital role in modernization, sustainable development and human daily activities in both ancient and modern times. But the road network in many urban areas develops in an organic growth pattern. Hence a great emphasis needs to be given to the connectivity pattern and accessibility of the road network. Urban road network has less theoretical research. Only some developed countries have carried out the evaluation of urban road network and hence it has great potential for development and application prospects. In this study an attempt has been made to analyze the road network connectivity and spatial pattern existing in Dispur city in India, and hence to determine if the network connectivity can explain significant variance in the spatial pattern of the network structure.

Keywords : Transportation Networks, Connectivity , Accessibility and T- matrix.

1. Introduction

Road transport network is primarily designed to connect local resources and people to distant markets and population centers. Thus it provide support to urban system development. An efficient transport network is essential for maintaining and improving the quality of life within cities and ensuring sustainable development. Because of the huge developmental cost of the road transport network, effective utilization is essential, which can be attained only when there is proper connectivity and orientation. Hence, a great emphasis needs to be given to layout and pattern of the urban road transport network. Urban road transport network evaluation has less theoretical research, and relative project cases are also not enough. Only some developed countries have carried out urban road network evaluation and hence it has great potential for development and application prospects. Extraction of the basic connectivity indices, which provide fundamental information to delineate a given network character had been the focus of many studies. Very few studies concentrated on finding the spatial pattern of the network and to understand its structural attribute. Interaction between network connectivity and the structural attribute of the road network is not clearly understood. To increase the understanding of this interaction we explore the concepts of Connectivity and Development. Also Fractality, which help in characterizing and understanding the spatial pattern of road network is focused. Hence the main idea of this study is to determine if the road characteristic variables indicating connectivity can explain significant variance in the spatial pattern of the network structure. Dispur region of Guwahati city has been chosen as the study area for preparing the road network. Ribeir and Silva [1] discussed the integrated development of any region depends fundamentally on the accessibility in general and the transport infrastructure in particular. Road networks, as one of the oldest infrastructures of transport in the world, it is play a key role in the urban spatial structure. One of the most important problems in road network is how to evaluate the accessibility found in Weiping and Chi [2]. Besides to the accessibility, the connectivity is important network Analysis techniques. This research attempts to find the accessibility and connectivity of road networks in Dispur of Guwahati city. The accessibility of study area is determined by the T- matrix. The connectivity extracted from indices Alpha, Beta and Gamma depending on the degree of completeness link between streets (linkages) and vertices (nodes).

2. Literature review

A network is a framework of links, connected within nodes. Several network based indicators have been developed to analyze the transport network since 1960 and these indicators can be classified as connectivity, cyclic property, efficiency measures. Garrison [4] and Kansky [6] developed graph theory measures to quantify the spatial structure of road network and to verify their relationship with regional economic characteristics. Traditional interest in understanding network structure has been limited to geographers who view the spatial nature of the road network as a vital input to regional development found in Rodrigue et al. [7]. In recent years, Gastner et al. [5] and Xie [8] discussed the considerable interest to understand the topology of transport networks that connects points in geographic space. Xie and Levinson [9] investigated the potential application of proposed network measures namely, heterogeneity, connection patterns and continuity, in quantifying the structure of road networks. Erath et al. [3] investigated the network measures applied to trace the changes in network characteristics over time . In short, various spatial metrics provide quantitative information for urban transport network analysis.

3. Objectives

1. To understand the connectivity and development of the existing road network of the study area.
2.To characterize the connectivity and accessibility of the spatial structure of the road network .

4. Characteristics of road network

Road network displays both topologic and geometric variations in their structure. There are a variety of indices, proposed in earlier studies applicable for evaluating road network properties. These measures find further application in planning and transportation practice. Selected measures used in this paper are discussed below.

Real world systems can be represented using graph theoretic methods. In this paper we focus on undirected graphs. An undirected graph G = (V, E) consists of a set V of nodes or vertices and a set E of edges. An edge e(i, j) connects two nodes i and j where e(i, j) ϵ E. The neighbors N(i) of node i are defined to be a set of directly connected nodes to node j. The degree d(i) of a node i is the number of the edges connected to node j. A path is defined as a sequence of nodes (n_1,...,n_k) such that from each of its nodes there is an edge to the successor node. The length of a path is the number of edges in its node sequence. A shortest path between two nodes, i and j, is a minimal length path between them. The distance between two nodes, i and j, is the length of its shortest path. Our model, a transportation network as an undirected graph which is represented by (V, E) with node set V and edge set E. Here V represents the stations and E represents the connection between stations.

5. Methodology

Network analysis of Road networks, as one of the oldest infrastructures of transport in the world, occupy a significant locality in modernization, sustainable development, and human daily activities in both ancient and modern times. The road network of a high quality increases a nation’s economic output by reducing journey times and costs, making a region more attractive economically found in Rogers [10]. The connection and arrangement of a road network is usually abstracted in network analysis as a undirected planar graph G (V, E), where V is a collection of nodes (vertices) and E is collection of links (edges). Xie and Levinson [11] investigated a two-way road consists of two adjacent and opposite one-directional links. Many techniques have been used in the transportation network and for characterizing different ways are there found in Levinson [12]. Connectivity and Accessibility are the most important Network Analysis Techniques.

5.1 Connectivity

The most fundamental properties of a Transportation network are measured by the Alpha Index, Beta Index and Gamma Index. For extraction of connectivity index it requires edges and vertices of a road network. These indices can be useful for change detection system in network structure and also for traffic analysis.

Alpha Index: This is a ratio of circuits to the number of maximum possible circuits in the network. It gives possible values from 0.0 to 1.0, higher the value of index, higher the degree of connectivity within the network.

$$\alpha = (e - v + 1) / (2v - 5) \text{ -------- } (1)$$

where e = Number of edges (Line) , v = Number of Vertex (Node).

Beta Index: The Beta Index Measures the connectivity relating the number of edges to the number of nodes. It is more useful for simple network where no circuits are involved. Greater is the beta index value, then the network is well connected discussed in Nagne [14].

$$\beta = e / v \text{ ----------- } (2)$$

where e = Number of edges (Line) , v = Number of Vertex (Node).

Gamma Index: The Gamma Index is a Ratio of actual number of edges to the Maximum possible number of edges in the network.

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

where e = Number of edges (Line), v = Number of Vertex (Node). It is a useful ratio in evaluating the relative connectivity of an entire network. Gama index can be used to categorize those networks that fall between minimal and maximal connection. A classification used by engineers consists of three basic network configurations: spinal, grid and delta found in Taafe et al.[13] and Nagne et al.[14].

5.2 Accessibility

There are many definitions of accessibility in the literature. However, a general definition is that accessibility is the easy (or difficulty) that opportunities (e.g., employment) or services can be reached from a location. Accessibility captures the effort required to overcome the spatial separation of two locations, and usually reflects the utility (e.g., travelling from home to a job) associated with travelling between these locations .This network analysis involves spatial, social and economic aspects with detail data, and involves a large amount of computation. Accessibility analysis is the collection, processing, and analysis of spatial and non-spatial data.

The following five important aspects of network analysis can be determined by the accessibility matrix of a network, which are not effectively treated by full network measures:

1. Placement: It gives the total number of linkage and where they are located within a given network.
2. Direct and in direct linkages: We can identify the both direct and indirect connection.
3. Attenuation: the differences between direct and in direct linkages should be treated.
4. Redundancy: It should be made corrections for meaningless round trips.

5. Unequal linkages: in some cases, linkages should be assigned different weight instead of assuming that all are equivalued.

5.3 The total accessibility (T-matrix)

Matrix tells us more than the indices (Alpha, Beta and Gamma), it does take into account the placement of linkage in the network. We construct a connectivity matrix where for each cell a value of 1 or 0 is used to denote in a connection exists between two node pairs. Then each cell of C^2 matrix is the summation of the product of each corresponding row and column in the C^1 matrix. This C^2 matrix indicates the two- linkages path between the two respective nodes. It will repeat the construction of the nth order connectivity matrices until the number of nth-linkages paths is equivalent to the diameter of the network. The total accessibility matrix produces from sum of multiplication series matrices that do show the number indirect connections or paths between individual nodes, this multiplication lasts until to have nonzero values in all cells .

$$T = \Sigma C^1 + C^2 + C^3 + \ldots + C^n \quad \text{-----------} \ (4)$$

where, $C^2 = C^1 * C^1$, $C^3 = C^1 * C^2$, ……, $C^n = C^1 * C^{n-1}$
T = Total accessibility matrix, C^1 = accessibility matrix power 1, C^2 = accessibility matrix power 2,...., C^n = accessibility matrix power n.

6. Study Area

Dispur is the largest city in Assam and one of the fastest developing cities in India. With the rapid growth of population in the city, the road traffic problems are also increasing at an alarming rate. The development of a city or town leads to the growth of the number of vehicles which is directly linked to increased traffic congestion and a growing number of accidents and fatalities. Road traffic problems like congestion, unpredictable travel-time delays and road accidents are taking a serious shape in the city. The main objective of this study is to analyze the potential of bridging centrality on transportation network, viz. Dispur city map. It is a well planned city and capital of Assam. We take 14 major bus stoppages of this Dispur area to analyze the connectivity and accessibility.

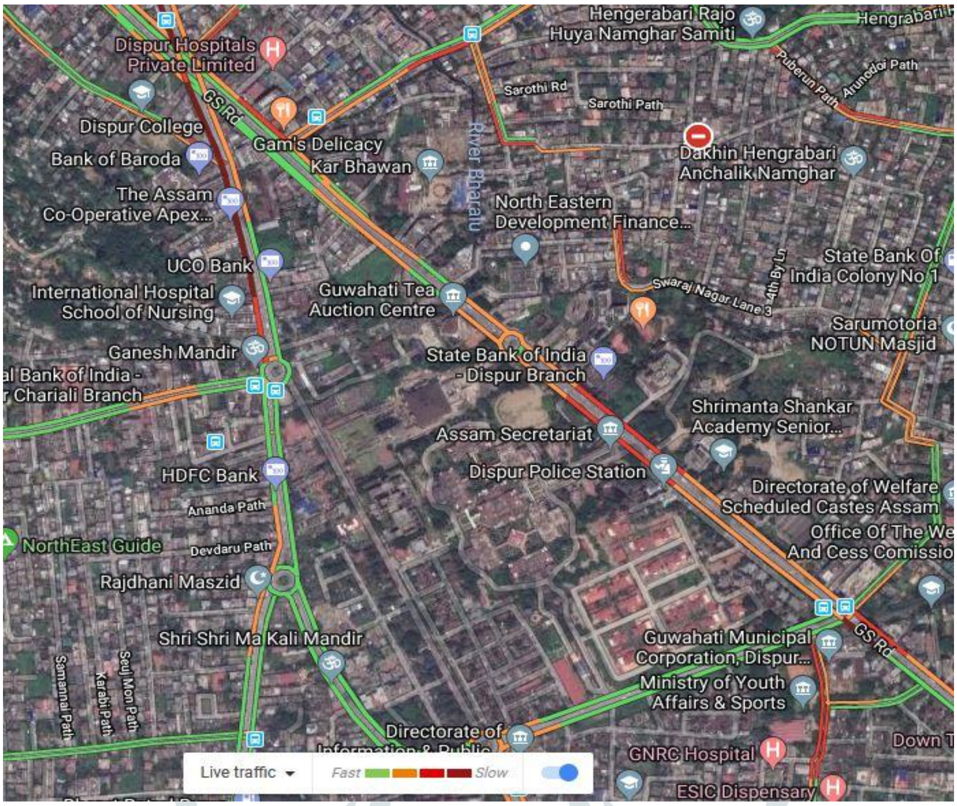


Figure.1 The satellite image of study area

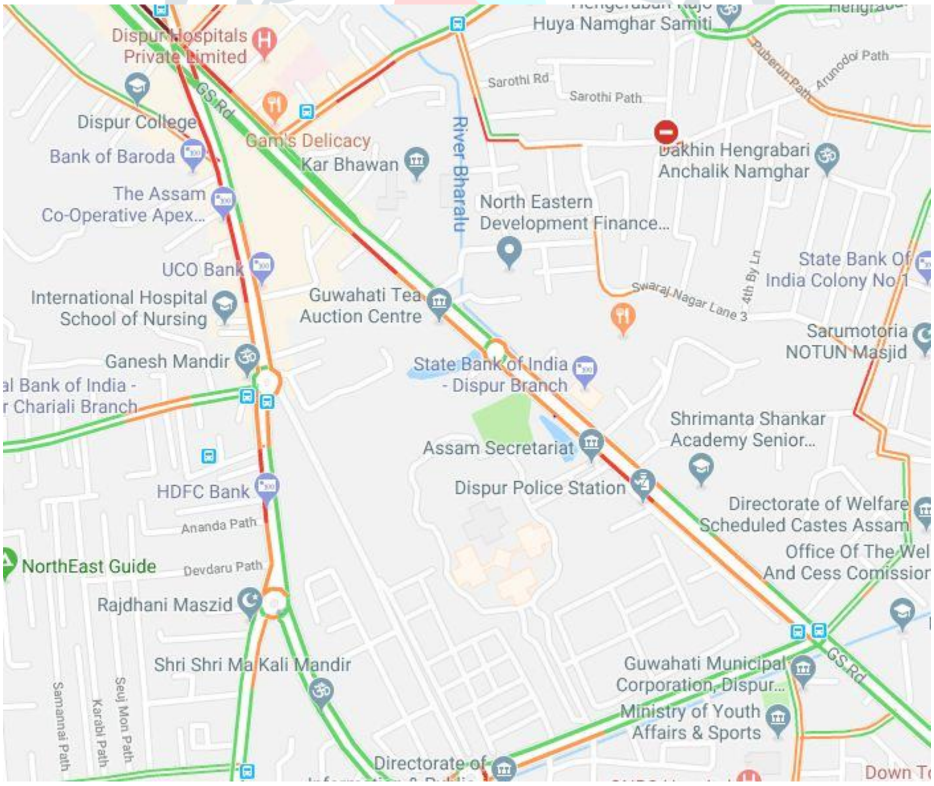
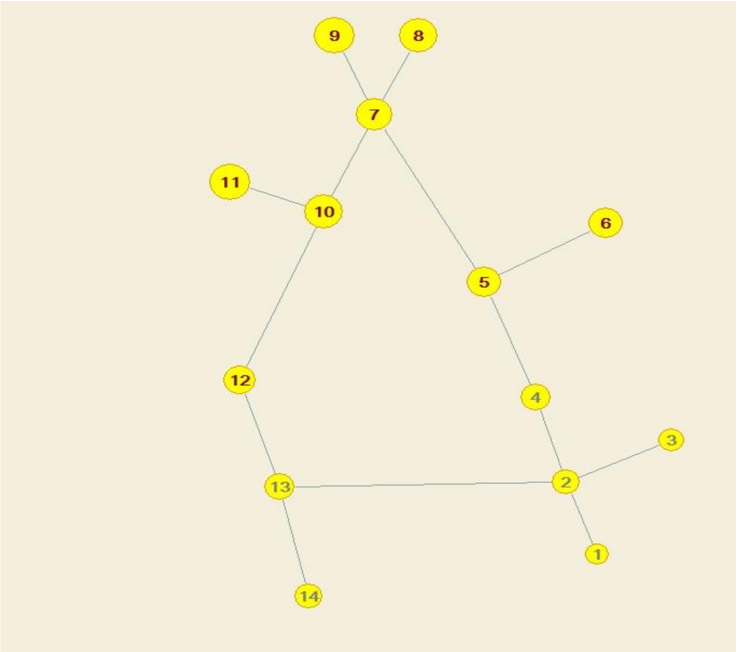


Figure.2 The road network map of study are



ID	Label
1	Down Town Hospital
2	Super Market
3	LP School
4	State Bank of India
5	Prasar Bharati
6	Housing Colony
7	Ganesh guri Chariali
8	Statefed Bus
9	International Hospital
10	Ganesh Mandir
11	Jatiya
12	Rajdhani Masjid
13	Last Gate
14	Housefed

Figure.3 Topological road network map of study area

7. Data Analysis.

Table 1. Descriptive Statistics of Connectivity Indices.

No of Vertices(v)	No of Edges(e)	β	α	ɣ
14	14	1	0.043478	0.388889

Table.2 The accessibility matrix for the study area(C^1 Matrix)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	1	0	0	0	0	0	0	0	0	1	0
3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	0	1	0	0	1	0	0	0	0	0	0	0	0	0
5	0	0	0	1	0	1	1	0	0	0	0	0	0	0
6	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7	0	0	0	0	1	0	0	1	1	1	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	1	0	0	0	1	1	0	0
11	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12	0	0	0	0	0	0	0	0	0	1	0	0	1	0
13	0	1	0	0	0	0	0	0	0	0	0	1	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Table.3 Accessibility matrix C^5 for the study area.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

1	0	19	0	0	7	0	1	1	1	1	1	7	0	6
2	19	0	19	26	1	7	10	1	1	9	1	1	32	0
3	0	19	0	0	7	0	1	1	1	1	1	7	0	6
4	0	26	0	0	20	0	1	7	7	9	1	8	1	7
5	7	1	7	20	0	13	33	0	0	1	8	9	9	1
6	0	7	0	0	13	0	0	6	6	8	0	1	1	1
7	1	10	1	1	33	0	0	20	20	33	0	1	9	1
8	1	1	1	7	0	6	20	0	0	0	6	7	1	1
9	1	1	1	7	0	6	20	0	0	0	6	7	1	1
10	1	9	1	9	1	8	33	0	0	0	13	19	1	6
11	1	1	1	1	8	0	0	6	6	13	0	0	6	0
12	7	1	7	8	9	1	1	7	7	19	0	0	19	0
13	0	32	0	1	9	1	9	1	1	1	6	19	0	13
14	6	0	6	7	1	1	1	1	1	6	0	0	13	0

Table. 4 The total accessibility (T-matrix)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	5	24	5	6	8	1	2	1	1	2	1	8	7	7	**78**
2	24	23	24	32	9	8	12	2	2	11	2	9	39	7	**204**
3	5	24	5	6	8	1	2	1	1	2	1	8	7	7	**78**
4	6	32	6	11	25	5	9	8	8	11	2	10	9	8	**150**
5	8	9	8	25	16	17	40	7	7	10	9	11	11	2	**180**
6	1	8	1	5	17	4	7	7	7	9	1	2	2	1	**72**
7	2	12	2	9	40	7	24	25	25	40	7	9	11	2	**215**
8	1	2	1	8	7	7	25	5	5	7	7	8	2	1	**86**
9	1	2	1	8	7	7	25	5	5	7	7	8	2	1	**86**
10	2	11	2	11	10	9	40	7	7	16	17	24	8	7	**171**
11	1	2	1	2	9	1	7	7	7	17	4	5	7	1	**71**
12	8	9	8	10	11	2	9	8	8	24	5	10	24	5	**141**
13	7	39	7	9	11	2	11	2	2	8	7	24	16	17	**162**
14	7	7	7	8	2	1	2	1	1	7	1	5	17	4	**70**

8. Discussion

8.1 Connectivity of Road Networks in Study Area

To find out the connectivity of road networks in the study area, a map is considered contains number of nodes = 14 and number of linkages =14. The degree of connectivity is explained from Alpha, Beta and Gamma Index by using equation (1), (2) and (3) above as in the Table.1.These indices are determined by relations between number of edges and number of nodes in network.

Here α = 0.043478 means there are 4.3478 % of all possible circuits. β = 1 means there are 1 roads per place and γ = 0.388889 means there are 38.8889 % of the possible routes in the network.

8.2 Accessibility of Road Networks in Study Area

Accessibility is another important characteristic of transportation network. To evaluate the accessibility of individual nodes we must look carefully at the internal structure of the network. Here we make a connectivity matrix .If two locations (vertices) are directly connected by a link (edge) then we code with a 1 and if two locations (vertices) are not directly connected by a link (edge)then we denote 0. The accessibility matrix of the network for the study area consists of 196 cells, as shown in Table 2. It shows the sample of accessibility matrix consists of 14rows and 14 columns, for the study area. The first matrix is the direct linkage accessibility matrix and C^2 , C^3 , C^4 and C^5 are indirect connection or path of the linkages from node i to node j . If we sum all the matrices recording indirect paths between the nodes, the result is a matrix specifying all direct and indirect connections between the nodes of the network, as Table. 4 in which the matrices as C^1 ,C^2 , C^3 , C^4 and C^5 are summed to give a matrix T that enumerates the total of all direct and indirect connections of the network. This matrix has diameter 5 . So, we now must stop the powering process upto 5 of the connection matrix, which is called 5-linkages matrix. Now we add these matrices from first matrix to matrix power five to produce a useful single matrix (total accessibility matrix (T-matrix)). In fact matrix T is a representation of the accessibility surface of the network. Using the row sums of the matrix T, we can rank nodes in terms of their relative position (accessibility) on the network. The higher the value of the row sum the greater the accessibility of the node. Here the least accessible node is 14 (ID 14, Housefed) with 70 connections. The most accessible node is 7 (ID 7, Ganesh guri Chariali) with 215 connections.

8.3 Spatial pattern.

This measure is used to capture the spatial pattern, which describe the structural attribute including compactness, shape, fragmentation and irregularity of the network. Taafe et al. [13] and Nagne et al. [14] investigated a classification used by engineers consists of three basic network configurations: spinal, grid and delta. A relative measure to an analysis of the network configuration is based on the value of gamma index. Spinal pattern is the characteristic of a minimally connected network, where every node is connected to at least one another node in the network, and it is possible for flow to occur between any two nodes in the network.

Table 4. Pattern of the network.

Sl. No	γ	Pattern
1	$1/3 \leq \gamma \leq 1/2$	Spinal
2	$1/2 < \gamma < 2/3$	Grid
3	$2/3 \leq \gamma \leq 1$	Delta

9. Conclusion

This study investigates road network characterization of Dispur region of Guwahati city based on various aspects as connectivity, Accessibility and spatial pattern and hence to quantify variation in the spatial structure of the network. A measure of connectivity evaluates network based on intensity of connections between the road segments while the spatial pattern measure describe the structural attributes of complicated road networks. Further, the study examines how road network characteristics as connectivity and development indices impact the spatial pattern of the road network. The indicators undertaken for measuring the spatial structure of road networks can be applied to identify its effect on the performance of the road transport system, as well as its subsequent effects on land use and urban form. The quantitative relationship identified between the spatial pattern and arrangement of urban road network and network density provides an empirical guide for the planning and policymaking of urban development and road construction.

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