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| Items | Description of Module |
|---|---|
| Subject Name | Geography |
| Paper Name | Quantitative Techniques in Geography |
| Module Name | Measurement and Analysis of Planar Network System |
| Module ID | QT 27 |
| Pre- Requisites | Basic knowledge of measurements of simple algebra and concept of network are necessary to understand the Network analysis |
| Objectives | (i) to understand the procedure of calculation of different indexes related to planar network system, and (ii) to show its uses with relevant examples. |
| Key words | Planar network system, network design, connectivity, alfa index, detour index, Pi index, Diameter of network, eta index |

## Measurement and Analysis of Planar Network System

Madhushree

### 1.0: Introduction:

Network analysis is an important aspect of spatial organization of socio economic activities. groups, organizations and circuits of networkwhich are associated with graph theory, are part of network analysis. Such aspects are useful for study of diffusion of innovations, spread of diseases, political movements, traffic analysis, drainage network and computer networking. Graph theory is mostly based of two elements of space: **Vertex** of network (that is called **nodes)**and **edge**(or **arcs**) which connects two vertexes in the network. Network problems that involve finding an optimal way of doing something are analysed through graph theory.

### 2.0: Network Description

The analysis of transport network has become an important part of geographical studies only in relativity recent years. Formerly transport network tended to develop in a somewhat random and often unrelated fashion but post-war changes and developments in transport focused attention upon the analytical study of networks; for instance, in Britain (and indeed, elsewhere in the world), the construction of motor ways the nationalization of railways and growth in air transport as well as development in communications, led to the development of network analysis, if only because of economic considerations. When route ways such as motor ways cost much as $ 1 million per kilometer to construct; it becomes especially important that the proposed motor way network pattern should be subjected to careful and critical scrutinyto ensure costs and maximum benefits should be achieved.

Networksvary greatly. For example, they must geometrically be planar (two-dimensional) or non-planar (three dimensional). They vary in their size, connectivity, and complexity; they may have relatively fixed channels of movement, such as railways, or relative freedom of movement, as with ships or aircrafts. The figure below shows the topological classification of networks (after P. Haggett).

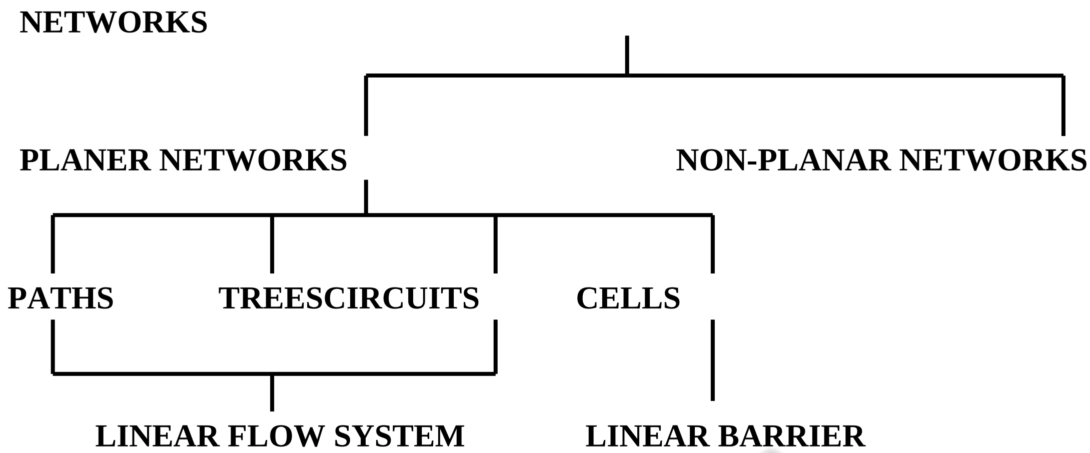



**Fig.-1: Topological Classification of Networks**

Network description involves the description of the disposition of nodes and their relationship and line or linkage distribution. Such a description is valuable not only because it helps to measure accessibility but also it allows comparisons to be made between regional networks within a country and between one country's networkswith another. Such variations may be related to other variation, i.e. mean income per head, and thus it becomes possible to use them as indicators of economic development. Fitzeraldhas said that variations in the characteristics of networks may be considered to reflect certain spatial aspects of the socio economic system.

It is possible to describe networks in a variety of ways and here we may consider:

i. The connectivity of networks
ii. Centrality within networks
iii. The spread and diameter of networks
iv. Detours

**3.0 The Connectivity of Networks**

The connectivity of a network may be defined a degree of completeness of the links between node. It will be clearly apparent that the more areas there are in any transportation network, the more complete will be the linkage between the various nodes. The greater the degree of connectivity within a transportation network, the more efficient will be the system. In studying real transportation systems it becomes necessary for the transport geographer to be able to measure the degree of connectivity of the network in an order that constitute comparisons of efficiency vis-à-vis different networks and also consider and elicit the reasons for the difference between them.

K.J. Kansky, an American scientist who has studied the structure of transportation networks developed different indices for measuring the connectivity of networks, which includes a. cyclomatic number, b. alpha index, c. beta index and d. gamma index. These structural elements of network are interpreted below.

**3.1 Cyclomatic Number**: Aunique way of measuring connectivity is by means of cyclomatic number. The cyclomatic number may be formulated as:

Cyclomatic Number = a-(n-1), … … …(1)

Where a= number of arcs and n= number of nodes.

This equation is more commonly written as (a-n+1) as it is algebraically a simple term of the same. Thus, the cyclomatic number may be formed by subtracting the number of nodes from the no. of arcs. This formula can also bewritten substituting 1 by x in order to connect it to graph, where there happens to be two or more sub graphs, x.Then the formula for the cyclomatic number is written as:

Cyclomatic Number = a- n+x, … …(2)

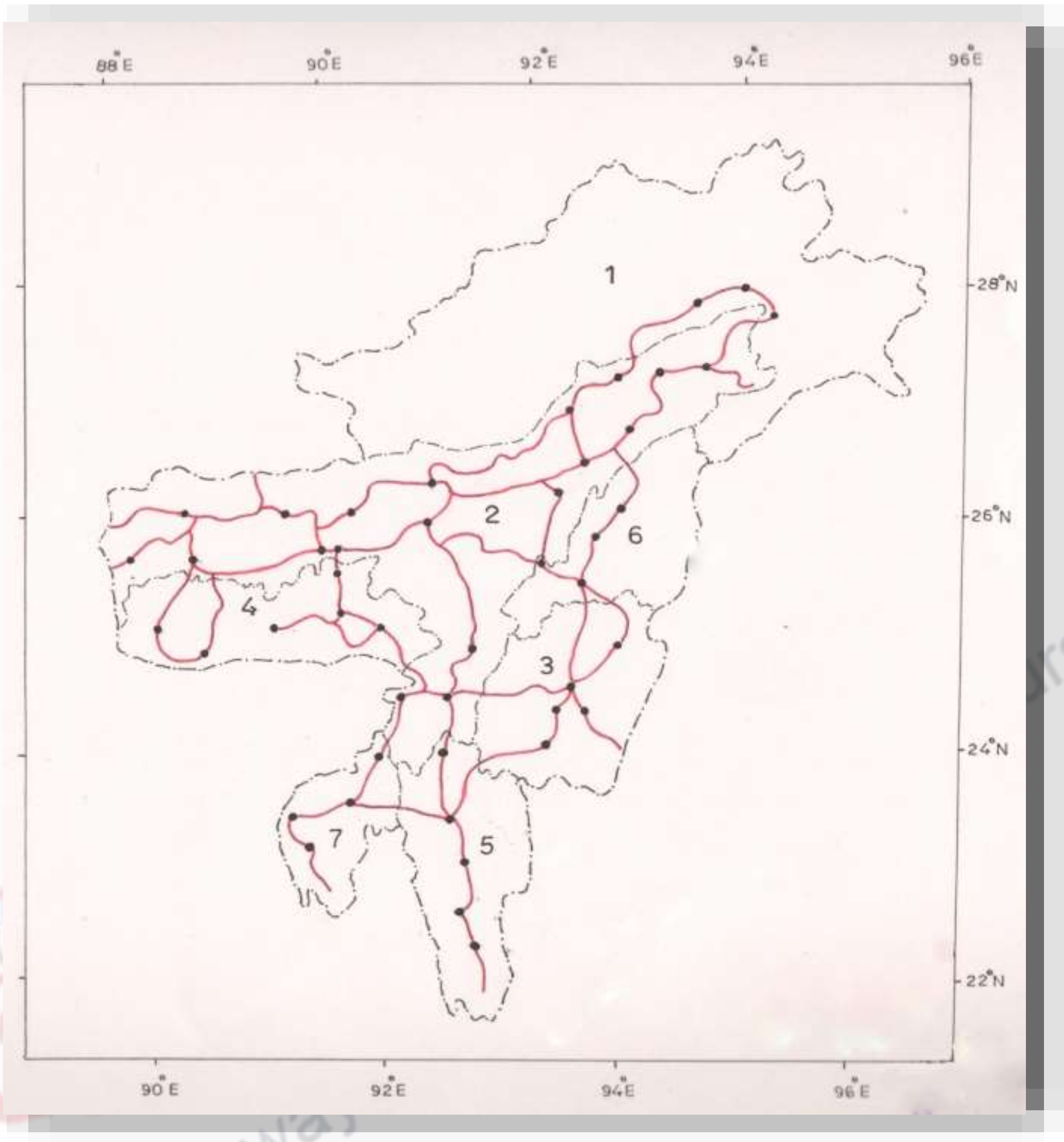
where,x= no. of sub graphs.

The cyclomatic number is of little value in distinguishing between networks possessing low levels of connectivity. But where the networks are more complex nature, the cyclomatic numbers tells how many fundamental circuits are present in the transportation network.

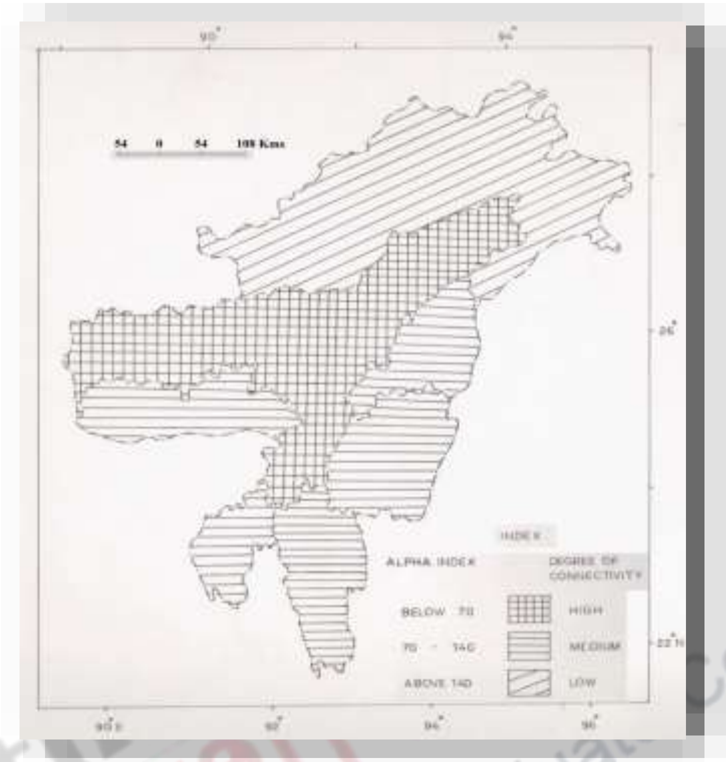
**3.2Alpha Index:**It shows the degree of connectivity.The alpha index ($\alpha$) is the ratio of the actual number of circuits in a network to the maximum possible number of circuits in that network. It is of the most useful and perhaps the best measure of connectivity of a network, particularly a fairly complex network. This consists of the ratio of the number of fundamental circuits to the maximum possible number of which may exist in a network. This index is also called Meshedness Coefficient in the literature on planar networks. The formula of alpha index is:

$$\alpha = \frac{a-n+1}{2n-5} \quad \text{...} \quad \text{...} \quad \text{...(3)}$$

If the index is multiplied by 100, this will be converted into percentage thereby giving the number of fundamental circuits as the percentage of maximum number possible.



88°E
90°E
92°E
94°E
96°E
28°N
26°N
24°N
22°N
1
2
3
4
5
6
7




1.Arunachal Pradesh
2. Assam
3. Manipur4. Meghalaya
5. Mizoram
6. Nagaland
7. Tripura

**Fig.-2: Road map of North East India for the calculation of connectivity indices**

The value of alpha index ranges from 0 to 1, or from 0 to 100 if it is converted into percent. The higher the index, the greater is the degree of connectivity in the network and vice versa. Here, 0 indicates no circuits and value of 1 or 100 percent indicates completely interconnected network in which every possible link between various nodes exists. Simple network such as tree network has nil value.

Let us examine the degree of road connectivity in North East India using the Alpha Index.

**Table-1:Calculation of alpha index for the states of North-East**

| States | Arcs | Nodes | Alpha Index |
|---|---|---|---|
| Assam | 37 | 19 | 57.57 |
| Arunachal Pradesh | 4 | 3 | 200 |
| Nagaland | 7 | 4 | 133.3 |
| Manipur | 8 | 5 | 80 |
| Mizoram | 8 | 5 | 80 |
| Tripura | 6 | 4 | 100 |
| Meghalaya | 9 | 5 | 100 |



**Figure 3**: **Degree of road network connectivity in North East India using Alpha Index**

**3.3Beta Index:**It indicates arcs of road network per node. The beta(β) index is a simple measure of connectivity whichiscalculated by dividing the total number of area in a network by the total number of nodes. Thus,

Beta index (β) = $\frac{arcs}{nodes}$. … … (4)

The beta index is very useful for measuring the connectivity of simple networks. The beta index ranges from 0.00 for network which consists just of nodes with no arcs through 1.00 and greater where networks are well connected. For instance very simple networks and trees possess values less than 1.0, a connected network involving a single circuit has a rule of 1.0, while networks of greater complexity which include several circuits have higher than 1.0. The beta index is of less value for complex networks than for simple ones. Now let us examine the degree of road connectivity in North East India using the Beta Index.

**Table-2:Calculation of beta index for the states of North-east**

| States | Arcs | Nodes | Beta Index |
|---|---|---|---|
| Assam | 37 | 19 | 1.95 |
| Arunachal Pradesh | 4 | 3 | 1.33 |
| Nagaland | 7 | 4 | 1.75 |
| Manipur | 8 | 5 | 1.6 |
| Mizoram | 8 | 5 | 1.6 |
| Tripura | 6 | 4 | 1.5 |
| Meghalaya | 9 | 5 | 1.8 |



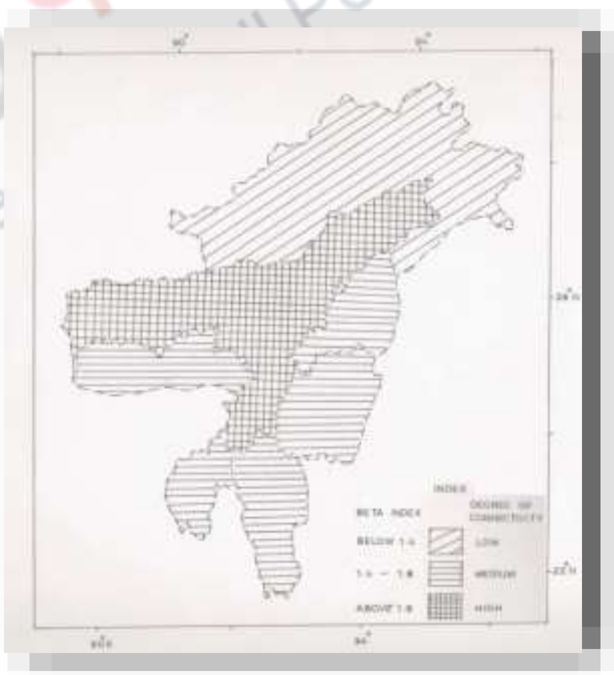


**Fig.-4**: **Degree of road network connectivity in North East India using Beta Index**

**3.4 Gamma Index:** The Gamma (γ) index describes in numerical terms the connectivity of a network. It is a measure of connectivity that considers the relationship between the number of observed links and the number of possible links. The value of gamma is between 0 and 1 where a value of 1 indicates a completely connected network and would be extremely unlikely in reality. Gamma is an efficient value to measure the progression of a network in time. The formula for gamma index is:

$$\text{Gamma index } (\gamma) = \frac{arcs}{3(nodes-2)} \quad . \qquad \ldots \qquad \ldots \qquad \ldots(5)$$

Now let us examine the degree of road connectivity in North East India using the Gamma Index.

**Table-3:Calculation of gamma index for the states of North-east**

| States | Arcs | Nodes | Gamma Index |
|---|---|---|---|
| Assam | 37 | 19 | 72.54 |
| Arunachal Pradesh | 4 | 3 | 133.33 |
| Nagaland | 7 | 4 | 116.66 |
| Manipur | 8 | 5 | 88.88 |
| Mizoram | 8 | 5 | 88.88 |
| Tripura | 6 | 4 | 100 |
| Meghalaya | 9 | 5 | 100 |

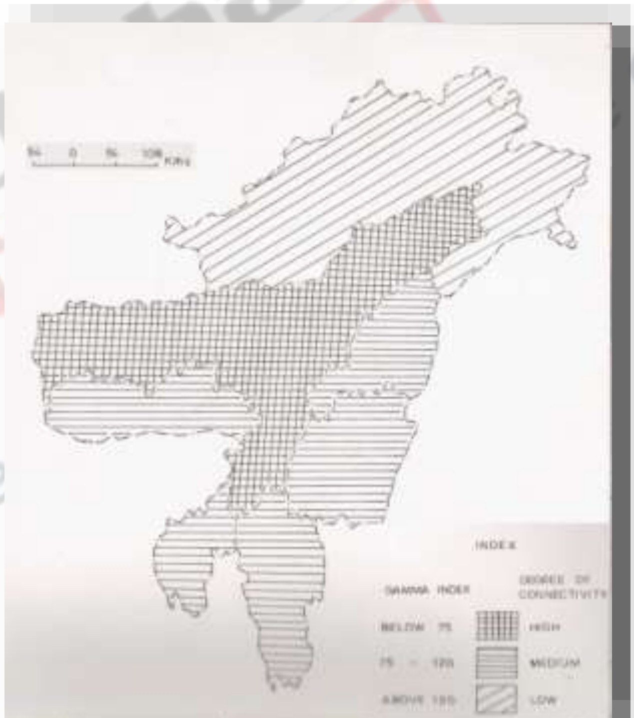


**Fig.-5: Degree of Road Network Connectivity in North East India using Gamma Index**

## 4.0 Centrality Within Networks

The degree of centrality of any node on a network may be described in terms of its Konig number, an index developed in 1936 by D. Konig. The Konig number of each node is calculated by adding up the number of arcs from each other node using the shortest path available. For example, in **Fig.-6**, point E has the lowest number and is, therefore, the most central node in the network.

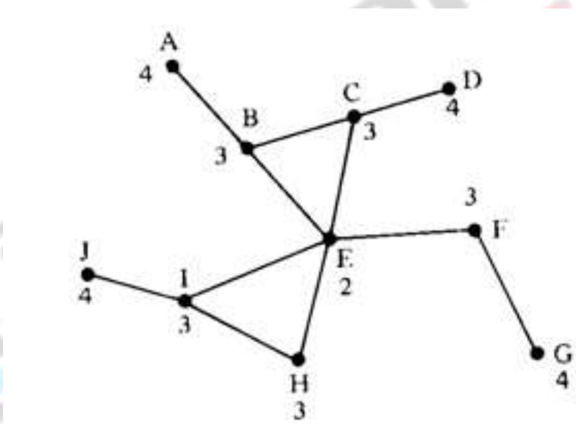


**Fig.-6: The centrality of nodes on a network in terms of their Konig number** ( E has the lowest Konig number thus is the most central)

### 5.0 The Spread And Diameter of the Network

The diameter of network was examined by Kansky who developed two useful indices to measure the spread of network. The description of a network in terms of its diameter involves the counting of the number of arcs on the shortest possible path between the two nodes lying farthest apart on the network. In general terms, the diameter increases with increasing size of the network, although any addition of connecting areas may result in the diameter being decreased. These two indices are: a. Pi (π) Index and b. Eta (η) Index.

a. **Pi Index**: It shows the relationship between the total length of the graph *(c)* and the distance along its diameter *(d)*. It is labeled as Pi because of its similarity with the real Pi value (3.14), which is expressing the ratio between the circumference and the diameter of a circle. A high index shows a developed network. It is a measure of distance per units of diameter and an indicator of the shape of a network. It is expressed as:

$$\pi = \frac{c}{d}, \quad \ldots \quad \ldots \quad \ldots(6)$$

where *c* is the total length of the network and *d* is the distance along its diameter

b. **Eta Index**: The Eta (η) Index a similar index to the π index of Kansky, which also gives some idea of the spread of the network. Average length per link. Adding new nodes will cause a decrease of Eta as the average length per link declines. The eta index is given by the formulae:

$$\eta = \frac{c}{a}, \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

Where c is total distance of the network and a is the number of arcs

### 6.0 Detour Index

In the opinion of Robinson and Bamford (1978), owing to topography and other obstacles the direct paths are deflected or deviated. Such deviations can be measured with the help of the Detour Index. Thus, we can use route distances and straight line distances to determine the efficiency of a specific route as compared with another. The formula is:

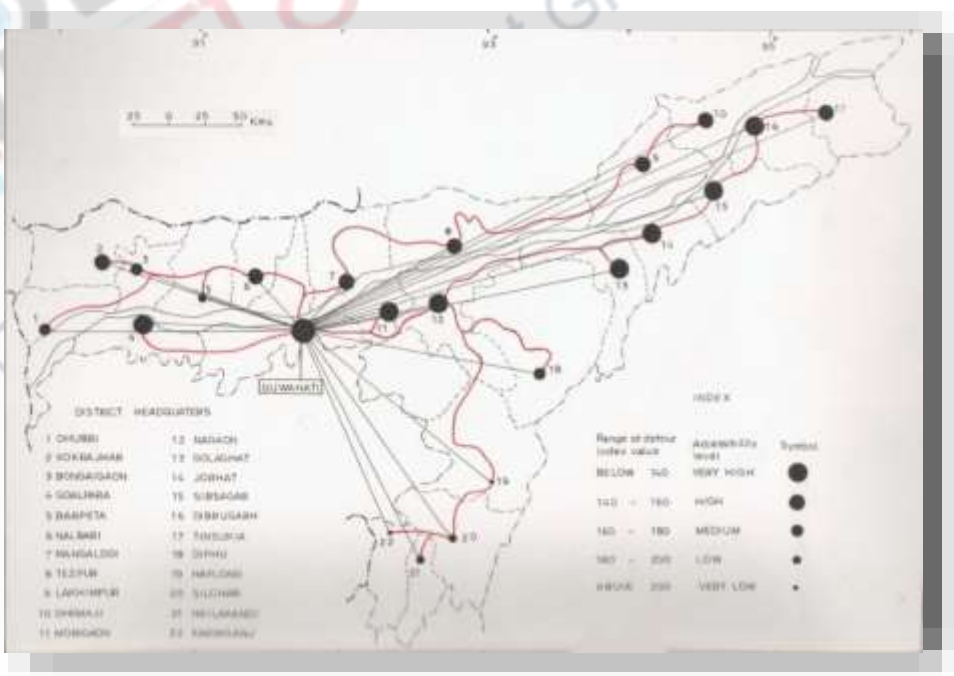
$$\text{Detour Index} = \frac{Actual route distance}{Straight line distance} \times \frac{100}{1} . \quad \ldots \quad \ldots(8)$$

Such a detour index may be compared with various aspects of physical geography, such as the degree of dissection or drainage density of an area over which the routes run.The detour index may also be used to give some comparison between routes before and after improvement has taken place.For example, let us calculate the relative road transport accessibility from the district head quarters of Assam to Guwahati City using the detour index.

**Table-4:Actual and Straight road distances of the district headquarters of Assam from Guwahati to Different District Headquarters**

| District headquarters | Actual road distance (km) | Straight line distance (km) | Detour index |
|---|---|---|---|
| Dhubri | 290 | 180 | 161 |
| Kokrajhar | 236 | 147.5 | 160 |
| Bongaigaon | 210 | 122.5 | 171.4 |
| Barpeta | 140 | 75 | 186.6 |
| Goalpara | 150 | 112.5 | 133.3 |
| Nalbari | 71 | 47.5 | 149.4 |
| Mangaldoi | 68 | 42.5 | 160 |
| Tezpur | 181 | 117.5 | 147.7 |
| Lakhimpur | 396 | 260 | 152.3 |
| Dhemaji | 462 | 312.5 | 148 |
| Morigaon | 78 | 62.5 | 124.8 |
| Nagaon | 123 | 95 | 129.4 |
| Golaghat | 288 | 222.5 | 129.4 |
| Jorhat | 304 | 247.5 | 122.8 |
| Sibsagar | 363 | 297.5 | 122.01 |
| Dibrugarh | 443 | 340 | 130.3 |
| Tinsukia | 591 | 390 | 151.5 |
| Diphu | 271 | 165 | 164.2 |
| Haflong | 368 | 165 | 223.0 |
| Silchar | 343 | 177.5 | 193.2 |
| Hailakandi | 336 | 180 | 186.6 |
| Karimganj | 338 | 152.5 | 221.6 |

**Fig.-7:Relative road transport accessibility from the district headquarters of Assam to**




**Guwahati City using detour index**

**6.1Interpretation**:

Detour between Guwahati and Haflong districts is the highest as 223 percent. It isdue to undulating topography and higher density of drainage network between them which enhances the actual road distance. On the other hand, in the upper plains of Brahmaputra especially between Guwahati and Jorhat and between Guwahati and Sibsagar towns, the detour is very low as 122 and 123 percents respectively. It means that the curve-linearity in the road length is only the 22 percent due to gentle slope topography. Thus, topography and relief features of landscape are major factors for detour of road transport network in Assam.

## 7.0: Summary

In planar network system which is analysed by two-dimension graphs, the nodes and arcs are mail elements through which the physical aspects of network like connectivity, diameter and detour indexes are analysed. Cyclomatic number and alpha, beta, gamma are indexesrelated to network analysis. These are helpful in selecting the optimal routes and paths. However, the issues of optimal route designing and network impact on urban as well as agricultural landscapes are important aspects to be addressed separately in the next module.