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Status of Road Network of North Eastern Region of India: An Application of Shortest Path Approach

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Abstract

This paper has attempted to investigate the present status of road transport network of north eastern region of India (NER) which lost its traditional road network connectivity during partition of India in 1947. All the state capital has been considered as different nodes except for Sikkim. For Assam, due to its geographical characteristics, five other important places have been considered as nodes; and after which, the Internal Road Network is extended by incorporating Siliguri which connects the NER with its mainland. In the third stage, the Land Custom Stations of NER are included as nodes. In the fourth stage, the network is recreated to its pre-partition stage through Bangladesh. In the final stage, Mandalay in Myanmar is incorporated as a node to construct the External Road network of NER. Based on the Floyd-Warshall's algorithm, the shortest distance matrices are calculated under different scenarios. Finally, this study concluded that network proposed under last scenario found to be the optimal which can reconnect this region to its traditional road network connectivity available in 1947, in one hand and opening of connection through Mandalay as a part of Act East Policy of Government of India, on the other hand will create a new vista for the NER.

1. Introduction

The North Eastern Region (NER) of India has a geographical advantage for boosting trade relations with countries of East Asia. However, the inadequate transport network within the region has resulted in high transactions cost which is one of the major reasons behind the inadequate exploitation of trade opportunities both internally and

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externally and also underdevelopment of this region. What has led to this inadequacy in the transportation network is the partition of India in 1947. During the British period, the eastern part of India, Nepal, Bhutan, Myanmar and the present Bangladesh were under a common road transportation network which catered the need of this region without any obstacles. However, the demarcation of India has isolated NER not only from the mainland but also from its external neighbours. After partition, NER emerged as a geographically sequester region encompassed with ethnic and bio-geographic location(Barkakati, 1985; Bhattacharyya, 1989). The region was left partially land locked as it is connected only by tenuous *Siliguri Corridor*[1]. As a matter of fact, partition has made NER a partially landlocked region and Sen et al. (2013) has termed this as a pseudo landlocked region since it is not landlocked at least geographically but the actual road distance from the nearest sea port i.e., Kolkata port is more than three and half times the aerial distance from the same on an average may be identified as synonymous to economically landlocked.

Of the many reasons behind the underdevelopment of this region, lack of adequate connectivity with the rest of the country as well as with the neighbouring countries is one of the prime reasons. Furthermore, presence of hilly terrains all over the region is a hindrance to smooth transportation. Accordingly, this study laid emphasis on the underdevelopment of this region from the accessibility and road transportation point of view. The road transport and connectivity can be viewed as networks and could be dragged towards network study for analysis by considering different terminals as network nodes and their connection as edges or arcs.

To assess an integrated road network, a proper evaluation of road network structure is otherwise essential. It is a useful initial process to prioritize sections of the network so that the allocation of limited funds can be optimized to maximize benefits to the region as a whole. Network planning assists in the development of a broad vision of how the road network could be improved to enhance connectivity and accessibility in the future. This also helps to identify relative deficiencies on the road network and justify the assumptions often reached by intuition and dialogue alone. It serves as a means of gaining an understanding of the whole regional road network and how different parts are connected in comparison with each other(Bianco, 1987). Network measures provide a means to comparethe feasibility of a node both spatially and temporally, and can form a basis for developing strategies in the future. An important issue in formulation of transport policy is the trade-off between maximizing the socioeconomic efficiency and developing regional equity (Nijikamp, 1986).

1.1. Related Studies

The NER of India is bestowed with richnatural resources and is at the door-step of

[1] The NER of India is connected with rest of the country with 18 kilometers tenuous chicken neck shaped corridor in the state of West Bengal, popularly known as the Siliguri corridor.

the East Asia. In spite of these advantages, the NER has remained economically laggard which accounts for a mere 2.6 per cent of India's Gross Domestic Product (GDP) in 2019-2020. High transport costs arising out of inadequate transport systems connecting NER both domestically and internationallyentangled with lack of other essential infrastructure have rendered the region economically in underdeveloped state (De, 2008). The sudden isolation of the region due to partition resulted in political and economic crunch. Therefore, integrating the NER with the rest of India and neighbouring countries could help in reducing imbalances in the region (Chaube et al., 1975). The geo-political distancing of the region from its main port of Kolkata coupled with economic isolation has caused immense structural damage to the economy of NER (Ganguli, 1969).

The NER of India occupies a vital location and position both geographically and strategically from the angle of Act East Policy (earlier Look East Policy) adopted by the Government of India. However, a considerable infrastructure development is imperative in order to promote this region with a potential to influence neighbouring economies (Kazi, 2013). Also, in order to effectively execute the Act East Policy and making this region the gateway to South-East Asia, road connectivity within this region and with the neighbouring countries need to be well established (Ziipao, 2018). Furthermore, to aid India's strategy on regional cooperation and also as an alternative access to this pseudo landlocked region, connectivity particularly through road transport with Myanmar and Bangladesh is crucial (Yhome, 2015). However, a sound regional connectivity is not characterized by single mode transportation but by a multi modal transport system (Singh, 1984). In this study, road transportation has been taken into consideration to investigate the issue of accessibility and connectivity under different Scenarios which are presented and discussed later.

Accordingly, the aim of this research is to explore the possibilities of constructing a practical road network that can take action in regard to (a) the demand for proper means of communication by the people of this region, (b) the efficiency of the existing road transport network of this region and (c) the viability of establishing new economically efficient road transport network in and around the region being considered. Accordingly, the specific objective of this study is to investigate the shortest routes from among the different nodes within the region's road transport network.

Choosing an efficient route in real road network is a critical task in transportation network analysis. The existing literature on transportation network is mainly concerned with the identification of shortest path algorithm (Zhan & Noon, 1996) and computation of appropriate shortest path in real road network in terms of distance or cost (Wang & De, 2007). Zhan (1995) compared a set of three shortest path algorithms on real road networks to identify the fastest among them. These three algorithms are the graph growth algorithm, the Dijkstra algorithm implemented with approximate buckets, and the Dijkstra (1959) algorithm implemented with double buckets. However, in the literature of Transport Economics, the Floyd-Warshall's Algorithm[2] is an improvement over and above the Dijkstra algorithm in the sense that the former is considering the shortest distances between each and every node of a network under study whereas the latter is concentrating on the shortest route between any two nodes of that network(Floyd, 1962). In this sense, Floyd's algorithm may be taken as a generalization of the Dijikstra algorithm (Rardin, 2003). Accordingly, the alternative proposals have been evaluated in terms of a Floyd's shortest path algorithm in the real road network of NER.

2. Theoretical Framework of the Study

It is a fact that after partition of India, the NER is connected with its mainland only through the tenuous Siliguri corridoras mentioned earlier. This study first identified the nodes to be incorporated for analysis on the basis of administrative and strategic importance. The NER comprises of eight states including Sikkim. However, for this study Sikkim has been excluded assuming that it is well connected with West Bengal. Accordingly, the study area covers the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. Other than Assam, all the state capital has been considered as different nodes. For Assam, due to its geographical characteristics, along with its capital city, Guwahati five other important places namely Naogaon, Lumbding, Dibrugarh, Tinsukia and Silchar have been considered as nodes to construct the Internal Road network of NER. After which, the Internal Road Network is extended by incorporating Siliguri as another node since the whole NER is connected with its mainland only through Siliguri. In the third stage, six more nodes are included namely the Dawki, Sutarkandi, Sabroom, Zokwarthar, Moreh and Pangsu pass. These are the Land Custom Stations (LCS) declared by the Government of India through which trade takes place between NER of India with its external counterpart. In the fourth stage, the network is further extended by incorporating the possibility of Port connection for this region namely Kolkata (within India) and Chittagong in Bangladesh with one more node Dhaka in Bangladesh. In the final stage, the Mandalay in Myanmar is incorporated as a node to construct the External Road network of NER. Mandalay is selected because of its strategic location in implementing the Act East Policy of Government of India. Mandalay has been declared by the Government of India as the most important node for connecting the South Asian economies as a part of the Act East Policy.

Accordingly, this study determines the shortest distance matrix among the all nodes using the shortest path algorithm; and on the basis of such derived result the existing route is compared with the proposed route for the different Scenarios mentioned above. Accordingly, this study has identified the five different Scenarios mentioned above, on the basis of which analysis has been carried out. These are as under:

[2] Floyd-Warshall's Algorithm was developed during 1962 independently from each other by Floyd and Warshall.

Table 1: Description of different Scenarios proposed in the Study

Sl No.	Scenarios	Number of Nodes	Description of the Scenario
1	Scenario 1	13 Nodes	Internal Road Network of NER
2	Scenario 2	14 Nodes	Internal Road Network of NER with domestically connecting node at Siliguri
3	Scenario 3	20 Nodes	Scenario 2 with 6 LCS as different node
4	Scenario 4	23 Nodes	Scenario 3 with Port connectivity with Kolkata and Chittagong, Bangladesh via Dhaka
5	Scenario 5	24 Nodes	Scenario 4 with Mandalay since it is the most important node through which connectivity under Act East Policy is declared by the Government of India.

Source: Prepared by the authors

The details of the selected nodes are presented below as Table 2.

Table 2: Description of the selected Nodes in the study

Nodes	Nodes Names	Location of Selected Nodes	Nodes	Nodes Names	Location of Selected Nodes
N1	Guwahati	Guwahati,Assam, India	N13	Tinsukia	Tinsukia, Assam, India
N2	Shillong	Shillong, Meghalaya, India	N14	Siliguri	Siliguri, West Bengal, India
N3	Silchar	Silchar, Assam, India	N15	Dawki	Dawki, Meghalaya, India
N4	Agartala	Agartala, Tripura, India	N16	Sutarkandi	Sutarkandi, Assam, India
N5	Aizawl	Aizawl,Mizoram, India	N17	Sabroom	Sabroom, Tripura, India
N6	Imphal	Imphal, Manipur, India	N18	Zokhawthar	Zokhawthar,Mizoram, India
N7	Kohima	Kohima, Nagaland, India	N19	Moreh	Moreh, Manipur, India
N8	Dimapur	Dimapur,Nagaland, India	N20	Pangsu Pass	Pangsu Pass, Arunachal Pradesh, India
N9	Lumbding	Lumbding,Assam, India	N21	Kolkata	Kolkata, West Bengal, India
N10	Naogaon	Naogaon, Assam, India	N22	Dhaka	Dhaka, Bangladesh
N11	Itanagar	Itanagar, Arunachal Pradesh, India	N23	Chittagong	Chittagong, Bangladesh
N12	Dibrugarh	Dibrugarh,Assam, India	N24	Mandalay	Mandalay, Myanmar

Source: Prepared by the authors

As mentioned above, the first thirteen Nodes (N1 – N13) are considered under Scenario 1. Scenario 2 consists of fourteen Nodes (N1-N14) i.e., first thirteen nodes from Scenario 1 with Siliguri (N14) as another node. Scenario 3 consists of twenty nodes (N1- N20) i.e.,Scenario 2 plus six LCS (N15 – N20) available in this region. Under Scenario 4, the issue of Port connectivity is considered. Hence, two ports namely Kolkata (N21) in India along with Chittagong (N23) via Dhaka (N22) in Bangladesh is considered along with twenty nodes already considered under Scenario 3. Finally, under Scenario 5, one new node namely Mandalay (N24) is considered.

This studyattempts to evaluate the economic viability of internally efficient road connectivity in NER in terms of an appropriate shortest path algorithm available in the existing literature. Accordingly, this study deals with the following research questions that need to be answered. These are as following:

1. How the region suffered in the disruption of its road transportation network after partition of India during 1947?
2. What is the nature of the internal road transportation network of NER?
3. Whether the internal road transportation network of NER is cost effectively connected with the rest of the country through the Siliguri corridor?
4. Whether the opening of different LCS within the NER really improves the existing road transportation network of the region?
5. Whether the opening of Bangladesh route can significantly improve the efficiency of the internal road transportation network of NER?
6. What is the best possible solution to connect the NER externally in the light of Act East Policy initiated by the Government of India?

This study attempts to answer these research question raised here in the following subsections one after another.

3. Data & Methods

3.1. Data

This proposed study is basicallyempirical research and the data has been collected from secondary sources for investigating the present land-way network system of India's NER after Partition of 1947; and for calculation of shortest path from the different nodes of the NER's transport network using Floyd's algorithm; the different nodes on the region's transport network are selected on the basis of economic and administrative importance. The secondary data in identifying the actual distance matrix were collected from the Bing map portal, from where again; the shortest route distance matrix was determined by using the Floyd's algorithm.

3.2. Methods

Network can be represented as a graph g= {N, E} where N represents the set of nodes or vertices and E represents the set of Edges or links. The broad objective is to find the best possible route considering the alternative proposals in the real road network of NER. To find the best possible alternative in real road network, it is necessary to considering the economic efficiency of such routes. The technical efficiency in route choice is related to determination of shortest path through applying appropriate shortest path algorithm. If heedlessly applied, this shortest path algorithm may result a situation where the best alternative may satisfy the technical efficiency in the real road network but the economic importance of nodes in the real road network may be compromised. These are discussed in detail in the following.

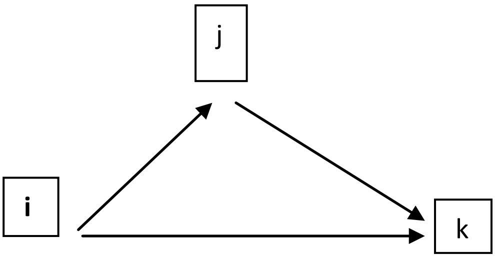
3.2.1. Floyd's Algorithm

This study applied Floyd's algorithm to find the shortest path within the road transportation network of NER under five different Scenarios.Suppose G = (N, A) be the road transportation network consisting of a set of 'N' number of nodes and a set 'A' of arcs with associated numerical values. In this study, associated numerical values are nothing but the actual road distances (in km). The Floyd's algorithm works on n-node network as a square matrix with 'n' rows and 'n' columns. Entry (i, j) of the matrix, denoted by dij, gives the distance between the source node 'i' to destination node 'j', which is finite if node 'i' is directly connected to node 'j', and infinite otherwise.

The logic of Floyd's algorithm is very simple, Consider the following figure where we consider three nodes i, j and k with the weights (distance) shown on the three arcs. It is always shorter route to reach k from i passing through j if

$$d_{ij} + d_{jk} < d_{ik}$$

This is presented as following:



Assuming, d_{ij}, the actual road distance between i[th] sources to j[th] destination', and d_{ij}*, the Shortest Road distance in the same route following Floyd's Algorithm, this study defines, $(d_{ij} - d_{ij}^*)$ as the net reduction in road distance if the existing traffic flow is routed through the shortest path network. To find the technical efficiency of available routes in the existing network,this study has applied the Floyd's algorithm to find the shortest path for the whole network. The net reduction in road distance when the existing traffic flow is routed through the alternative routes is compared to find the technical efficiency through shortest path methods.

After finding the technical efficiency of each route through appropriate shortest path methods (this study utilizes Floyd's algorithm to find the shortest path in real road network of Tripura), a close look towards the economic efficiency of such alternative route is necessary. To correct this bias, this study modified the results related to technical efficiency of the existing road network by considering the economic weights of each node in terms movement of vehicle. When the vehicles are actually routed through the shortest paths, the reduced distance matrix will show a positive value.

It may be noted that the concept of technical efficiency and economic efficiency of choice of route in the real road network is not substitute in nature. Rather, technical efficiency of such route is calculated independently of economic efficiency of routes. But economic efficiency of route is derived by modifying the concept of technical efficiency of routes through shortest path method. Hence, it may be argued that technical efficiency is necessary but may not sufficient to achieve the economic efficiency of choice of appropriate route in the real road network. The result of technical efficiency is modified as below to identify the economic efficiency of choice of appropriate route.Following Sen et al. (2013), the actual distance matrix and the shortest distance matrix in real road network may be defined as:

$$D = ((d_{ij})) = \begin{pmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & d_{nn} \end{pmatrix} \text{ and } D^*=((d_{ij}^*)) = \begin{pmatrix} d^*_{11} & \cdots & d^*_{1n} \\ \vdots & \ddots & \vdots \\ d^*_{n1} & \cdots & d^*_{nn} \end{pmatrix}$$

Where again,

$$d_{ij} = d_{ji} \text{ for all i,j= 1, 2, ...n}$$
$$\text{and } d_{ij} = 0 \text{ for all i=j}$$

Hence, both the matrices are square symmetric matrices.

Accordingly,
$$\Omega = (D - D^*) = \begin{pmatrix} d_{11} - d^*_{11} & \cdots & d_{1n} - d^*_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} - d^*_{n1} & \cdots & d_{nn} - d^*_{nn} \end{pmatrix}$$

This may be taken as an indicator of level of economic efficiency of alternative routes. Note in this context that, Floyd's algorithm does not take traffic density into account. This study deals with the accessibility issue and hence, distance is more important than that of traffic density in the existing road.Accordingly, a lager value of such indicator clearly implies higher economic efficiency.

Results & Discussions

As mentioned above, the analysis has been carried out with five different Scenarios. Scenario 1 represents a 13 by 13 sub-matrix representing the internal road network of NER. Scenario 2 represents a 14 by 14 sub-matrix representing the internal road network of NER and connection of NER with the rest of the country through Siliguri (N14) corridor. Scenario 3 is the extension of Scenario 2 with inclusion of six more LCS (N15-N20). Scenario 3 is represented by the sub-matrix of order 20 by 20. Scenario 4 is the next extension of Scenario 3 with the option of port connectivity either through Kolkata (N21) or through Chittagong (N23) via Dhaka (N22), Bangladesh. It may be recalled that Scenario 4 is synonymous to traditional connectivity of NER before partition in 1947 mentioned above. Scenario 3 is represented by the sub-matrix of order 23 by 23. Finally, Scenario 5 is formed by extending Scenario 4 with one more node Mandalay (N24) to analyses the impact of Act East Policy on the efficiency of road transportation network of NER. Scenario 5 is represented by the matrix of order 24 by 24. This is presented below in Table 3.In the matrix, the initial direct distance between any two nodes isgiven. The 'na' signifies that there is no direct link between the nodes. After which, this study applied the R Package "sna" to determine the shortest distance matrix under different Scenarios mentioned above.

Table 3: Combined Initial Distance Matrix of Selected Nodes under different Scenarios

Names	Nodes	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	N24
Guwahati	N1	0	100	na	na	na	na	na	na	na	123	na	na	na	436	na	na	na	na	na	na	na	na	na	na
Shillong	N2	100	0	208	na	na	na	na	na	275	na	na	na	na	na	81	na	na	na	na	na	na	na	na	na
Silchar	N3	na	208	0	284	176	267	na	na	273	na	na	na	na	na	na	66	na	na	na	na	na	na	na	na
Agartala	N4	na	na	284	0	345	na	na	na	na	na	na	na	na	na	na	na	129	na	na	na	na	135	na	na
Aizawl	N5	na	na	176	345	0	414	na	na	na	na	na	na	na	na	na	na	na	216	na	na	na	na	na	na
Imphal	N6	na	na	267	na	414	0	137	na	na	na	na	na	na	na	na	na	na	na	108	na	na	na	na	na
Kohima	N7	na	na	na	na	na	137	0	138	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dimapur	N8	na	na	na	na	na	na	138	0	92	165	na	271	na	na	na	na	na	na	na	na	na	na	na	na
Lumbding	N9	na	275	273	na	na	na	na	92	0	98	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Naogaon	N10	123	na	na	na	na	na	na	165	98	0	197	320	na	na	na	na	na	na	na	na	na	na	na	na
Itanagar	N11	na	na	na	na	na	na	na	na	na	197	0	188	na	na	na	na	na	na	na	na	na	na	na	na
Dibrugarh	N12	na	na	na	na	na	na	na	271	na	320	188	0	48	na	na	na	na	na	na	na	na	na	na	na
Tinsukia	N13	na	na	na	na	na	na	na	na	na	na	na	48	0	na	na	na	na	na	na	121	na	na	na	na
Siliguri	N14	436	na	na	na	na	na	na	na	na	na	na	na	na	0	na	na	na	na	na	na	588	492	na	na
Dawki	N15	na	81	na	na	na	na	na	na	na	na	na	na	na	na	0	na	na	na	na	na	na	297	na	na
Sutarkandi	N16	na	na	66	na	na	na	na	na	na	na	na	na	na	na	na	0	na	na	na	na	na	276	na	na
Sabroom	N17	na	na	na	129	na	na	na	na	na	na	na	na	na	na	na	na	0	na	na	na	na	na	168	na
Zokhawthar	N18	na	na	na	na	216	na	na	na	na	na	na	na	na	na	na	na	na	0	na	na	na	na	na	480
Moreh	N19	na	na	na	na	na	108	na	na	na	na	na	na	na	na	na	na	na	na	0	na	na	na	na	474
Pangsu Pass	N20	na	na	na	na	na	na	na	na	na	na	na	na	121	na	na	na	na	na	na	0	na	na	na	781
Kolkata	N21	na	na	na	na	na	na	na	na	na	na	na	na	na	588	na	na	na	na	na	na	0	314	na	na
Dhaka	N22	na	na	na	135	na	na	na	na	na	na	na	na	na	492	297	276	na	na	na	na	314	0	248	na
Chittagong	N23	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	168	na	na	na	na	248	0	na
Mandalay	N24	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	480	474	781	na	na	na	0

Source: Estimated by the author

Results & Discussions

Shortest Distance Analysis under Scenario 1

The Shortest Distance matrix under Scenario 1 is determined and presented as Table 4 below.

Table 4: Shortest Distance Matrix under Scenario 1

Names	Node	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13
Guwahati	N1	0	100	308	592	484	563	426	288	221	123	320	443	491
Shillong	N2	100	0	208	492	384	475	505	367	275	223	420	543	591
Silchar	N3	308	208	0	284	176	267	404	365	273	371	568	636	684
Agartala	N4	592	492	284	0	345	551	688	649	557	655	852	920	968
Aizawl	N5	484	384	176	345	0	414	551	541	449	547	744	812	860
Imphal	N6	563	475	267	551	414	0	137	275	367	440	637	546	594
Kohima	N7	426	505	404	688	551	137	0	138	230	303	500	409	457
Dimapur	N8	288	367	365	649	541	275	138	0	92	165	362	271	319
Lumbding	N9	221	275	273	557	449	367	230	92	0	98	295	363	411
Naogaon	N10	123	223	371	655	547	440	303	165	98	0	197	320	368
Itanagar	N11	320	420	568	852	744	637	500	362	295	197	0	188	236
Dibrugarh	N12	443	543	636	920	812	546	409	271	363	320	188	0	48
Tinsukia	N13	491	591	684	968	860	594	457	319	411	368	236	48	0

Source: Estimated by the author

From the Table 4, it is clear that distance between any two nodes varies in between 48 km to 968 km within the internal road network of NER. Maximal distance varies in between 557 km to 968 km. The interesting fact that both the lower and upper end of maximal distance is between Agartala (N4) to Lumbding(N9) and Agartala(N4) and Tinsukia(N13). The minimal distance within the road transportation of NER varies in between 48 km to 280 km. The least distance is identified as Dibrugarh (N12) to Tinsukia (N13) whereas upper most value is 284 km between Agartala (N4) to Silchar (N3) within the internal road network of NER. Guwahati (N1) is considered as the gateway of NER. The average distance of the different nodes from Guwahati (N1) is around 363 km with a spread in between 100 km to 592 km. Shillong (N2) is nearest node to Guwahati (N1) whereas Agartala (N4) via Silchar (N3) is the furthest node from Guwahati (N1).

Shortest Distance Analysis under Scenario 2

The Shortest Distance matrix under Scenario 2 is determined and presented as Table 5 below. From the below Table, with the inclusion of Siliguri (N14) as another node along with the internal road network of NER, it is found that distance between any two nodes varies in between 48 km to 108 km.

Table 5: Shortest Distance Matrix under Scenario 2

Names	Node	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14
Guwahati	N1	0	100	308	592	484	563	426	288	221	123	320	443	491	436
Shillong	N2	100	0	208	492	384	475	505	367	275	223	420	543	591	536
Silchar	N3	308	208	0	284	176	267	404	365	273	371	568	636	684	744
Agartala	N4	592	492	284	0	345	551	688	649	557	655	852	920	968	1028
Aizawl	N5	484	384	176	345	0	414	551	541	449	547	744	812	860	920
Imphal	N6	563	475	267	551	414	0	137	275	367	440	637	546	594	999
Kohima	N7	426	505	404	688	551	137	0	138	230	303	500	409	457	862
Dimapur	N8	288	367	365	649	541	275	138	0	92	165	362	271	319	724
Lumbding	N9	221	275	273	557	449	367	230	92	0	98	295	363	411	657
Naogaon	N10	123	223	371	655	547	440	303	165	98	0	197	320	368	559
Itanagar	N11	320	420	568	852	744	637	500	362	295	197	0	188	236	756
Dibrugarh	N12	443	543	636	920	812	546	409	271	363	320	188	0	48	879
Tinsukia	N13	491	591	684	968	860	594	457	319	411	368	236	48	0	927
Siliguri	N14	436	536	744	1028	920	999	862	724	657	559	756	879	927	0

Source: Estimated by the author

The maximal distance between any two nodes spread in between 591 km to 1028 km. The lower end of maximal spread is between Shillong (N2) and Siliguri (N14) whereas upper end of maximal distance is between Agartala (N4) and Siliguri (N14). The minimal spread between any two nodes under consolation 2 varies in between 48 km to 436 km. The lower end of minimal spread is between Dibrugarh (N12) to Tinsukia (N13); and the upper end of minimal distance between any two nodes is between Guwahati (N1) to Siliguri (N14). The average path length in between any two nodes under Scenario 2 lies in between 330 km to 771 km. The lower and upper end of average path length is for Lumbding (N9) and Siliguri (N14), respectively. In comparison to Scenario 1, under Scenario 2 the lower and upper end values increase due to the inclusion of Siliguri (N14) since this act as a dead-end node in the road transportation network graph. Siliguri (N14) is connected to Guwahati (N1) at a distance of 436 km which is the major reasons behind staggering transport cost described under Scenario1. Disconnection of traditional connectivity of the NER after partition in 1947 partially transforms this region to an economically backward region.

Shortest Distance Analysis under Scenario 3

The Shortest Distance matrix under Scenario 3 is determined and presented as Table 6 below. From the Table 6, with the inclusion six more nodes along with the nodes under Scenario 2, it is found that distance between any two nodes varies in between 48 km to 1218 km. The maximal distance between any two nodes spread in between 686 km to1218 km. The lower end of maximal spread is between Lumbding (N9) and Sabroom (N17) whereas upper end of maximal distance is between Sabroom (N17) between Pangsu-pass (N20). The minimal spread between any two nodes under consolation 3 varies in between 48 km to 436 km. The lower end of minimal spread is between Dibrugarh (N12) to Tinsukia (N13); and the upper end of minimal distance between any two nodes is between Guwahati (N1) to Siliguri (N14).

The average path length in between any two nodes under Scenario 3 lies in between 386 km to 836 km. The lower and upper end of average path length is for Lumbding (N9) and Siliguri (N14), respectively. In comparison to Scenario 2, under Scenario 3 the lower and upper end values increase due to the inclusion of six more LCS (N15-N20) available which are also Act as the dead-end node in the road transportation network graph. Moreover, as compared to Scenario 1 six more LCS namely Dawki (N15), Sutarkandi (N16), Sabroom (N17), Zokhawthar (N18), Moreh (N19) and Pangsu-pass (N20) as well as Siliguri (N14) which are all dead-end nodes which ultimately leads to increase in the spread of lower and upper end distances in a every situation. Hence, when compared to Scenario 2, Scenario 3 also hardly improved the connectivity issues in terms of lower end average path link. Another interesting fact is that the immediate neighbouring nodes namely Shillong (N2), Silchar (N3), Agartala (N4), Aizawl (N5), Imphal (N6), and Tinsukia (N13), respectively lies at a distance of 81 km, 66 km, 129 km, 216 km, 108 km, and 121 km, respectively. This is presented in Table 7 below.

Table 6: Shortest Distance Matrix under Scenario 3

Names	Nodes	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20
Guwahati	N1	0	100	308	592	484	563	426	288	221	123	320	443	491	436	181	374	721	700	671	612
Shillong	N2	100	0	208	492	384	475	505	367	275	223	420	543	591	536	81	274	621	600	583	712
Silchar	N3	308	208	0	284	176	267	404	365	273	371	568	636	684	744	289	66	413	392	375	805
Agartala	N4	592	492	284	0	345	551	688	649	557	655	852	920	968	1028	573	350	129	561	659	1089
Aizawl	N5	484	384	176	345	0	414	551	541	449	547	744	812	860	920	465	242	474	216	522	981
Imphal	N6	563	475	267	551	414	0	137	275	367	440	637	546	594	999	556	333	680	630	108	715
Kohima	N7	426	505	404	688	551	137	0	138	230	303	500	409	457	862	586	470	817	767	245	578
Dimapur	N8	288	367	365	649	541	275	138	0	92	165	362	271	319	724	448	431	778	757	383	440
Lumbding	N9	221	275	273	557	449	367	230	92	0	98	295	363	411	657	356	339	686	665	475	532
Naogaon	N10	123	223	371	655	547	440	303	165	98	0	197	320	368	559	304	437	784	763	548	489
Itanagar	N11	320	420	568	852	744	637	500	362	295	197	0	188	236	756	501	634	981	960	745	357
Dibrugarh	N12	443	543	636	920	812	546	409	271	363	320	188	0	48	879	624	702	1049	1028	654	169
Tinsukia	N13	491	591	684	968	860	594	457	319	411	368	236	48	0	927	672	750	1097	1076	702	121
Silliguri	N14	436	536	744	1028	920	999	862	724	657	559	756	879	927	0	617	810	1157	1136	1107	1048
Dawki	N15	181	81	289	573	465	556	586	448	356	304	501	624	672	617	0	355	702	681	664	793
Sutarkandi	N16	374	274	66	350	242	333	470	431	339	437	634	702	750	810	355	0	479	458	441	871
Sabroom	N17	721	621	413	129	474	680	817	778	686	784	981	1049	1097	1157	702	479	0	690	788	1218
Zokhawthar	N18	700	600	392	561	216	630	767	757	665	763	960	1028	1076	1136	681	458	690	0	738	1197
Moreh	N19	671	583	375	659	522	108	245	383	475	548	745	654	702	1107	664	441	788	738	0	823
Pangsu Pass	N20	612	712	805	1089	981	715	578	440	532	489	357	169	121	1048	793	871	1218	1197	823	0

Source: Estimated by the author

Table 7: Neighbourhood LCS Connection of NER under Scenario 3

Names	Guwahati	Shillong	Silchar	Agartala	Aizawl	Imphal	Kohima	Dimapur	Lumbding	Naogaon	Itanagar	Dibrugarh	Tinsukia
Nodes	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13
Existing Route	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri	Siliguri
Existing Distance	436	536	744	627	920	999	862	724	657	559	756	879	927
Min Distance	181	81	66	129	216	108	245	383	339	304	357	169	121
Difference	255	455	678	498	704	891	617	341	318	255	399	710	806
Optimal Route	Dawki	Dawki	Sutarkandi	Sabroom	Zokhawthar	Moreh	Moreh	Moreh	Sutarkandi	Dawki	Pangsu Pass	Pangsu Pass	Pangsu Pass

Source: Estimated by the author

Shortest Distance Analysis under Scenario 4

Under Scenario 4 (Table 8), with the inclusion of three more nodes along with the nodes under Scenario 3, it is found that distance between any two nodes varies in between 48 km to 1404 km. The maximal distance between any two nodes spread in between 712 km to 1404 km. The lower end of maximal spread is between Silchar (N2) and Kolkata (N14) via Dhaka (N22), Bangladesh whereas upper end of maximal distance is between Pangsu-Pass (N20) and Kolkata (N21). The lower end of minimal spread is between Dibrugarh (N12) to Tinsukia (N13) similar as that of previous two Scenarios and the upper end of minimum distance is between Guwahati (N1) to Siliguri (N14) similar to that of Scenario 1, 2 and 3.

The Average path length in between any two nodes under Scenario 4 lies in between 419 km to 843 km. The lower end of minimal spread is between Dibrugarh (N12) to Tinsukia (N13); and the upper end of minimal distance between any two nodes is between Silchar (N3) to Kolkata (N21), respectively.

In comparison to Scenario 3, under Scenario 4 the lower and upper end values increase due to the inclusion of three more nodes. It is a fact that as compared to Scenario 1, 2 and 3 under Scenario 4, lower and upper end distances increase slightly under Scenario 4. Previously under Scenario 1, 2 and 3 Siliguri (N14) was the only available gateway for the NER. But under Scenario 4 comparing the differences between the minimum distance from the six LCS to the corresponding the neighbouring nodes with the existing distance from Siliguri (N14) the optimal routs for the nodes under

Scenario 1 i.e., the internal road network of NER is presented above as Table 9.The optimal routs for the all 13 nodes under Scenario 1 proved to be economically efficient as compared to the existing gateway i.e., Siliguri (N14). This study further finds that, the geographical position of the six LCS (N15-N20) pave the way for connectivity of the internal network to its nearest port. This possibility of connecting the internal road network of NER under Scenario 1 is widening up gradually from Scenario 1, 2, 3 to Scenario 4.

Table 8: Shortest Distance Matrix under Scenario 4

Names	Nodes	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23
Guwahati	N1	0	100	308	592	484	563	426	288	221	123	320	443	491	436	181	374	721	700	671	612	792	478	726
Shillong	N2	100	0	208	492	384	475	505	367	275	223	420	543	591	536	81	274	621	600	583	712	692	378	626
Silchar	N3	308	208	0	284	176	267	404	365	273	371	568	636	684	744	289	66	413	392	375	805	656	342	581
Agartala	N4	592	492	284	0	345	551	688	649	557	655	852	920	968	627	432	350	129	561	659	1089	449	135	297
Aizawl	N5	484	384	176	345	0	414	551	541	449	547	744	812	860	920	465	242	474	216	522	981	794	480	642
Imphal	N6	563	475	267	551	414	0	137	275	367	440	637	546	594	999	556	333	680	630	108	715	923	609	848
Kohima	N7	426	505	404	688	551	137	0	138	230	303	500	409	457	862	586	470	817	767	245	578	1060	746	985
Dimapur	N8	288	367	365	649	541	275	138	0	92	165	362	271	319	724	448	431	778	757	383	440	1021	707	946
Lumbding	N9	221	275	273	557	449	367	230	92	0	98	295	363	411	657	356	339	686	665	475	532	929	615	854
Naogaon	N10	123	223	371	655	547	440	303	165	98	0	197	320	368	559	304	437	784	763	548	489	915	601	849
Itanagar	N11	320	420	568	852	744	637	500	362	295	197	0	188	236	756	501	634	981	960	745	357	1112	798	1046
Dibrugarh	N12	443	543	636	920	812	546	409	271	363	320	188	0	48	879	624	702	1049	1028	654	169	1235	921	1169
Tinsukia	N13	491	591	684	968	860	594	457	319	411	368	236	48	0	927	672	750	1097	1076	702	121	1283	969	1217
Silliguri	N14	436	536	744	627	920	999	862	724	657	559	756	879	927	0	617	768	756	1136	1107	1048	588	492	740
Dawki	N15	181	81	289	432	465	556	586	448	356	304	501	624	672	617	0	355	561	681	664	793	611	297	545
Sutarkandi	N16	374	274	66	350	242	333	470	431	339	437	634	702	750	768	355	0	479	458	441	871	590	276	524
Sabroom	N17	721	621	413	129	474	680	817	778	686	784	981	1049	1097	756	561	479	0	690	788	1218	578	264	168
Zokhawthar	N18	700	600	392	561	216	630	767	757	665	763	960	1028	1076	1136	681	458	690	0	738	1197	1010	696	858

Moreh	N19	671	583	375	659	522	108	245	383	475	548	745	654	702	1107	664	441	788	738	0	823	1031	717	956
Pangsu Pass	N20	612	712	805	1089	981	715	578	440	532	489	357	169	121	1048	793	871	1218	1197	823	0	1404	1090	1338
Kolkata	N21	792	692	656	449	794	923	1060	1021	929	915	1112	1235	1283	588	611	590	578	1010	1031	1404	0	314	562
Dhaka	N22	478	378	342	135	480	609	746	707	615	601	798	921	969	492	297	276	264	696	717	1090	314	0	248
Chittagong	N23	726	626	581	297	642	848	985	946	854	849	1046	1169	1217	740	545	524	168	858	956	1338	562	248	0

Source: Estimated by the author

Table 9: Neighbourhood Port Connection of NER under Scenario 4

Names	Guwahati	Shillong	Silchar	Agartala	Aizawl	Imphal	Kohima	Dimapur	Lumbding	Naogaon	Itanagar	Dibrugarh	Tinsukia
Nodes	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13
Existing Port	Kolkata												
Existing Distance	792	692	656	449	794	923	1060	1021	929	915	1112	1235	1283
Min Distance	726	626	581	297	642	848	985	946	854	849	1046	1169	1217
Difference	66	66	75	152	152	75	75	75	75	66	66	66	66
Nearest Port	Chittagong												

Source: Estimated by the author

Shortest Distance Analysis under Scenario 5

Under Scenario 5 (Table 10), with the inclusion of one more node i.e., Mandalay (N24) along with the nodes under Scenario 4, it is found that distance between any two nodes varies between 48 km to 1581 km. The maximal distance between any two nodes spread in between 849-km to1581 km.

The lower end of maximal spread is between Silchar (N3) to Mandalay (N24) whereas upper end of maximal distance is between Siliguri (N14) to Mandalay (N24). The lower end of minimal spread is between Dibrugarh (N12) to Tinsukia (N13) similar as that of previous four Scenarios. The Average path length in between any two nodes under Scenario 5 lies in between 437 km to 976 km. The lower end of average path length is for Silchar (N3) to Mandalay (N24), respectively. In comparison to Scenario 4, under Scenario 5 the lower and upper end values increases slightly under

Scenario 5. As mentioned above previously under Scenario 1, 2, and 3 Siliguri (N14) was the only available gateway for the NER whereas under Scenario 4 the geographical position of 6 LCS (N15-N20) along with their port connectivity to Kolkata (N21) and Chittagong (N23) via Dhaka (N22), Bangladesh paves the way for connectivity in the internal network of NER to its nearest port either through domestically or neighboring country Bangladesh, respectively. This is presented as Table 11below.

Table 10: Shortest Distance Matrix under Scenario 5

Names	Nodes	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	N24
Guwahati	N1	0	100	308	592	484	563	426	288	221	123	320	443	491	436	181	374	721	700	671	612	792	478	726	1145
Shillong	N2	100	0	208	492	384	475	505	367	275	223	420	543	591	536	81	274	621	600	583	712	692	378	626	1057
Silchar	N3	308	208	0	284	176	267	404	365	273	371	568	636	684	744	289	66	413	392	375	805	656	342	581	849
Agartala	N4	592	492	284	0	345	551	688	649	557	655	852	920	968	627	432	350	129	561	659	1089	449	135	297	1041
Aizawl	N5	484	384	176	345	0	414	551	541	449	547	744	812	860	920	465	242	474	216	522	981	794	480	642	696
Imphal	N6	563	475	267	551	414	0	137	275	367	440	637	546	594	999	556	333	680	630	108	715	923	609	848	582
Kohima	N7	426	505	404	688	551	137	0	138	230	303	500	409	457	862	586	470	817	767	245	578	1060	746	985	719
Dimapur	N8	288	367	365	649	541	275	138	0	92	165	362	271	319	724	448	431	778	757	383	440	1021	707	946	857
Lumbding	N9	221	275	273	557	449	367	230	92	0	98	295	363	411	657	356	339	686	665	475	532	929	615	854	949
Naogaon	N10	123	223	371	655	547	440	303	165	98	0	197	320	368	559	304	437	784	763	548	489	915	601	849	1022
Itanagar	N11	320	420	568	852	744	637	500	362	295	197	0	188	236	756	501	634	981	960	745	357	1112	798	1046	1138
Dibrugarh	N12	443	543	636	920	812	546	409	271	363	320	188	0	48	879	624	702	1049	1028	654	169	1235	921	1169	950
Tinsukia	N13	491	591	684	968	860	594	457	319	411	368	236	48	0	927	672	750	1097	1076	702	121	1283	969	1217	902
Silliguri	N14	436	536	744	627	920	999	862	724	657	559	756	879	927	0	617	768	756	1136	1107	1048	588	492	740	1581
Dawki	N15	181	81	289	432	465	556	586	448	356	304	501	624	672	617	0	355	561	681	664	793	611	297	545	1138
Sutarkandi	N16	374	274	66	350	242	333	470	431	339	437	634	702	750	768	355	0	479	458	441	871	590	276	524	915
Sabroom	N17	721	621	413	129	474	680	817	778	686	784	981	1049	1097	756	561	479	0	690	788	1218	578	264	168	1170

Zokhawthar	N18	700	600	392	561	216	630	767	757	665	763	960	1028	1076	1136	681	458	690	0	738	1197	1010	696	858	480
Moreh	N19	671	583	375	659	522	108	245	383	475	548	745	654	702	1107	664	441	788	738	0	823	1031	717	956	474
Pangsu Pass	N20	612	712	805	1089	981	715	578	440	532	489	357	169	121	1048	793	871	1218	1197	823	0	1404	1090	1338	781
Kolkata	N21	792	692	656	449	794	923	1060	1021	929	915	1112	1235	1283	588	611	590	578	1010	1031	1404	0	314	562	1490
Dhaka	N22	478	378	342	135	480	609	746	707	615	601	798	921	969	492	297	276	264	696	717	1090	314	0	248	1176
Chittagong	N23	726	626	581	297	642	848	985	946	854	849	1046	1169	1217	740	545	524	168	858	956	1338	562	248	0	1338
Mandalay	N24	1145	1057	849	1041	696	582	719	857	949	1022	1138	950	902	1581	1138	915	1170	480	474	781	1490	1176	1338	0

Source: Estimated by the author

Table 11: Neighbourhood External Connection of NER under Scenario 5

Names	Guwahati	Shillong	Silchar	Agartala	Aizawl	Imphal	Kohima	Dimapur	Lumbding	Naogaon	Itanagar	Dibrugarh	Tinsukia
Nodes	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	Nodes
Existing Route	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata	Kolkata
Existing Distance	792	692	656	449	794	923	1060	1021	929	915	1112	1235	1283
Min Distance	726	626	581	297	642	582	719	857	854	849	1046	950	902
Difference	66	66	75	152	152	341	341	164	75	66	66	285	381
Optimal Route	Chittagong	Chittagong	Chittagong	Chittagong	Chittagong	Mandalay	Mandalay	Mandalay	Chittagong	Chittagong	Chittagong	Mandalay	Mandalay

Source: Estimated by the author

Conclusion

Up to Scenario 3 Kolkata (N21) was the only available port connectivity for NER which every node under internal transportation network of NER was bound to bore heavy transaction cost as the feasible distance from Kolkata (N21) to any of the nodes described on the Scenario 1. There may be several regions behind under development of NER, the partition in 1947 disrupted it is traditional connection which were economically more viable. Based on the shortest distance matrix under Scenario 5 the difference between distance travel through existing route of Kolkata (N21) port via Siliguri (N14) and the optimal route to the nearest port i.e. Chittagong (N23) either through Dhaka (N22), Bangladesh or through Sabroom (N17) or through Mandalay (N24) through Moreh (N19) open are the possibility of connecting the geographically sequester regions NER an opportunity to connect the internal network of NER with rest of the world economy. If the road transport network of NER is given the opportunity to connect with the rest of the world as mentioned here under Scenario 5, the policy Act East policy proposed by the Government of India to connect the South Asian Countries through NER will get new dimensions. To reap the benefit of Act East policy in full swing, the economically feasible external transportation network which will connect the internal road network of NER is the most important infrastructure need of the time. This study finds that external transportation network as proposed under Scenario 5 is the best possible solution out of available alternatives which can reconnect this region with the transport network which were available before partition in one hand as well as opening of another connection through Mandalay (N24) as a part of Act East Policy proposed by the Government of India, on the other hand will create a new vista for the NER.

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