Exploring the Network Accessibility in the Airport Regions of India: Case Study of Bagdogra Airport, West Bengal

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1 ABSTRACT

Transportation network development is considered to be one of the keys to modernization and development. Airports are emerging as new hubs of development. Airport corridors are the upcoming economic corridors being a connection between the airport and the host city through highways, expressways, and railways, where infrastructure is planned with more public involvement. At a regional scale, Aerotropolis is an extrapolation of the airport city, to the surroundings, where the reciprocation of the airport city can be seen in terms of amenities, services, industries, residences, and thematic and logistic spaces. For linking the airport for better access, an efficient road network is inevitable in the country. Connectivity measures are an indicator of the performance of airline networks, airports and regions which allow policymakers and industry professionals to benchmark and monitor the network performance against that of other airports, airline networks and regions and plan the regions accordingly. This paper seeks to derive the landside connectivity for the road network of different tiers of airports in their influence area and identify the regions that are most and least accessible in the Indian scenario. In order to explore connectivity and accessibility, the regions are ranked on the basis of some of the indices such as alpha, beta, Gama, Konig no. etc. Further, the study comprehends the case study of Bagdogra Airport, Siliguri, being the least accessible region as per the landside connectivity.

The study of landside connectivity includes a GIS-based analysis of links and nodes with the help of graph theory and centrality indices. Results derived indicates the impact of airport connectivity in the identified influence area of the region, the centrality indices increase with a decrease in distance from the airport. The results also indicate the emergence of important nodes and links, probing towards the need for comprehensive planning for new airport regions for better accessibility and induced development of the region.

Keywords: centrality, Regional Connectivity, Graph Theory, Accessibility, Airport Region

2 INTRODUCTION

As they are not silos, airports are essential to transport hubs working in multilayered local, state, national, and international transport networks. Therefore, facilitating airport accessibility is essential for the whole value chain. Whether travelling for business or recreation, a journey never concludes at the airport. (Plan, 2010)

Connectivity by air may play an essential part in boosting local economic development and supporting the long-term growth objectives of the economy at the national level. Air connectivity helps the incorporation of a nation into the global economy by improving the flow of products and services, as well as people, ideas, expertise, as well as financial investments. Because of this, air connectivity confers immediate benefits on those who make use of aviation services and broader benefits on the economy as a whole as a result of the favourable effects it has on productivity and economic performance. As a result of these beneficial effects, governments should make an effort to study the impact of their policies on air connectivity and the factors that contribute to better air connectivity results.(Jagoda Egeland International Transport Forum, 2018).As a result, as we respond to the difficulties of deteriorating road congestion and its influence on travel time and travel time reliability, the availability of mass transportation to connect airports throughout the world will become increasingly vital. (Hambarde, 2018)

For a very considerable time, the size of the air transport industry has doubled every fifteen years, growing faster than the bulk of other industries. Since 1960, the demand for passenger and freight services has grown along with technological development and corresponding investment. This increase in air travel compares favourably with the global GDP, the broadest measure of global output, which increased by more than five times in real terms over the same time period."Asia/Pacific continued to be the most active region, making

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up 35% of all revenue-based traffic followed by Europe and North America, each with 26% and 22%" (Industry High-level Group, 2019). The International Air Transport Association (IATA) predicts that by 2030, "India would surpass both China and the United States as the third-largest air passenger market in the world". The Indian government has been attempting to build more airports in order to handle the increased aviation traffic. India had 153 operating airports as of the year 2020. India plans to have between 190 and 200 operational airports by FY40. (IBEF, 2021). In order to maximise airport benefits, feeder connectivity to airports must be investigated associated with air transportation statistics and the requirement for airport connectivity.

3 NEED FOR STUDY

The National Civil Aviation Policy 2016 was published by the Ministry of Civil Aviation (MoCA), Government of India, in order to improve regional connectivity through financial assistance and infrastructure development (NCAP 2016). The Regional Connectivity Scheme (RCS) for improving underserved air connections includes the Regional Airport Development Scheme for India (UDAN), which is a regional airport development programme. To encourage inclusive national economic development, employment creation, and the development of air transport infrastructure in all areas and states of India, the mission is to make air travel more accessible and more inexpensive. The possible RCS airports have been chosen based on the following characteristics, which are, first and foremost, a distance of at least 150 kilometres from the closest operating airport (with a few exceptions), The demographic profile, the industrial profile, the passenger demand, and the market potential all play a role. Potential for tourism at the airport and in the surrounding area, The quality of the airport's current runway and terminal, The requirement for new land purchases as well as financial expenditures, Access to other means of transport, such as highways and trains, as well as competition from these other modes(Anon., 2022). The rationale behind keeping the distance from operational airports at 150 kilometres is that there are very few airports in India that are closer together than 150 kilometres, and for a distance of 150 kilometres, travelling by road is much more advantageous in terms of time, cost, and convenience than flying, with the exception of areas that have topographical challenges such as hilly regions.. (Partner, 2004)

To better support the infrastructure of airports, it is necessary to improve other network connection infrastructures, which serve as the airports' primary support system. These shifts in the connectivity of the road network have led to the development of city areas surrounding airports. Authors such as Kasarda have placed an emphasis on airport-linked productivity, aviation-oriented agglomeration economies, and changes in connectivity indices. It is necessary to identify the changes in various factors related to connectivity and accessibility in the emerging airport-oriented regions in India, following the UDAN scheme that has been proposed and is currently being implemented in India. This is necessary in order to include such identified phenomena in policies that are linked to upcoming airport regions. Because air travel serves time-sensitive markets, ground access to airports must be efficient, and airport-related criteria must be updated on a regular basis. As a result, there is an urgent need to prioritise the integration of specialised transportation services in many additional Indian cities in order to establish a long-term solution(Gaonkar, 2013) (De Jong et al., 2008).

4 LITERATURE REVIEW

Such analysis is crucial to examine since it provides the insights required to develop measures to increase airport competitiveness. For example, these metrics can show how well an airport serves as a connecting hub in a certain origin-destination market in contrast to competitor hubs. Furthermore, connectivity parameters enable governments, terminals, and flights to track network performance over time and evaluate the impact of different policies to maintain or improve network performance. Because of this, connectivity measurements are frequently utilised as input for larger strategic airport and airline planning. Regional economic connectivity indicators can assist policymakers by analysing travel times to reach a specific proportion of global GDP or population from a predetermined location.(Matsumoto et. Al.2008).

In fact, academic studies have proposed a wide range of connectivity indicators that account for both direct and indirect connection in airline networks. Some are based on network topology and complex network theory, while others are based on the operational characteristics of airline hub-and-spoke networks or on findings from social science studies.(Burghouwt & Redondi, 2013)

4.1 Defining Airport regions

Dr. John Kasarda, an American urban economist and sociologist, emphasizes the significance of airports in transforming urban form in the twenty-first century, much as motorways, railways, and seaports did in the twentieth. He believes that the fourth revolutionary wave of transportation and communication will have the greatest impact on business location and the new proclamation of survival of the fastest with supply chain logistics and other time-sensitive economic activity, emphasising airport proximity as gateways and for movements of capital, materials, and information.Kasarda defines an Aerotropolis as a metropolitan sub-region centred on an airport. A typical metropolis has a core business district and commuter-linked suburbs, he argues. (Perera & Development, 2019)

Airport-related theories have been defined by several authors, including Airport Region, Airport Corridor, Aerotropolis, and Airea. An airport area is a developing aerotropolis in which the airport is linked to the host city and other industrial and logistical centres by road and rail networks. While other authors have proposed the development of an airport corridor between the airport and the host city. Airport corridors are characterised as a connection between the airport and the host city via motorways, expressways, and railways, with increased public engagement in infrastructure planning. Aerotropolis is a reproduction of airport city in terms of services, industry, homes, themed and logistic areas.(Correia & De Abreu E Silva, 2015)

4.2 Connectivity Measures

Sociological importance of connectivity measurements is obvious, as is the need for suitable connectivity metrics that account for both types of connectivity. Indicators of connectivity are applied to evaluate the performance of airline networks, airports, and regions. They enable policymakers and industry professionals to analyse and monitor network performance relative to other airports, airline networks, and regions, and to create regions accordingly.(Burghouwt & Redondi, 2013)

Accessibility has been a crucial criteria for measuring a network's spatial interconnectivity and evaluating travel prospects in transportation network development. Accessibility incorporates network metrics like connection and node accessibility. Several ways highlight a transportation network's connectedness and nodal accessibility. Hansen (1959) defined accessibility as "the potential for interaction and provided a potential-based approach to evaluate accessibility in cities". Garrison (1960) presented "graph theoretic principles to study the topological accessibility of a transportation network utilising accessibility indices (beta index, association number, alpha index, gamma index) and node accessibility indices (i.e., Shimbel index and nodal degree)". Transportation research uses graph theory-based network accessibility measurements. The objective of graph-based evaluations is to statistically evaluate the spatial distribution of travel opportunities based on travel times, distance, theoretical accessibility model, or structural-based approaches including spatial syntactic research. (Chen et al., 2014)

Some sites are more accessible than others, implying that there are disparities across the locales. Therefore, accessibility represents geographical inequality. Hence, the concept and idea of accessibility is based on two fundamentals: The first is the location, in which the relativity of areas/zones is assessed in relation with the transport infrastructures, which provide the means to facilitate movement. Each area/zone has a set of peculiar characteristics, such as its population or extent of economic activities. The second factor is distance, which is determined by the physical or geographical segregation among various areas/zones. Transportation must exist between two areas in order for there to be a distance between them. A network is a structure comprised of interconnected links. Several network-based indicators have been established to analyse the transport network, and these indicators may be categorised as measures of connectedness, cyclic property, and efficiency. Understanding the network structure has traditionally been of interest only to geographers, who consider the spatial form of the road network to be a crucial factor in regional development. In recent years, there has been a great deal of interest in comprehending the topology of transport networks that connect places in geographic space and contribute to the creation of new settlements as a result of enhanced connectivity (Sreelekha.M.G, 2016).

There are two linked geographical categories that are applicable to accessibility issues. The first category is topological accessibility, which deals with quantifying accessibility in a network of nodes and links (a transportation network). It is considered that accessibility is a quantitative property that only applies to specific components of a transportation system. The second form is contiguous accessibility, which includes assessing accessibility throughout a surface. Accessibility, also known as isochrone accessibility, is a measure of how well-connected various locations are across a given distance, given that geography is considered continuous. (Rodrigue, 2020).

Following these conditions, the indicators suggested for computing landside connectivity in the airport region are distance-based and topology-based on a system of nodes and linkages. According to various studies, the airport is related to changes in connectivity indices in the region served by that airport. Several research on discovering airside connectivity indices utilising the hub and spoke paradigm have been conducted(Jose & Ram, 2018).

5 OBJECTIVES OF THE PAPER

This research work attempts to determine the landside connectivity in the influence area of airport through nodal perspectives. The objectives of the paper therefore are –

(1) To formulate the methodology for computing landside regional connectivity of different tier of airports.

(2) To identify the regions on the basis of regional airside and landside connectivity in airport region.

(3) To delineate a region on the basis of change in connectivity for the selected airport region.

(4) To determine the change in degree of centrality of the selected nodes in the identified region.

6 FORMULATION OF METHODOLOGY

In order to identify the change in connectivity indices in regions of India, India has been divided geographically into four regions firstly based on airside connectivity indices using the hub and spoke concept. (Amal Jose, 2019) The author has already classified and ranked the 36 airports based on hub and spoke concept following the air connectivity indices such as Ranking based on Different tier of airports Participation Coefficient, Z-Score, $Hubbing\ Potential\ Index$ $(H.\ P.\ I.)$ and $Inter\ Community\ Coefficient$ $(I.\ C.\ C.\ )$. to evaluate airside connectivity at sub community as well as inter community level. (Amal Jose, 2019). Further to explore the landside connectivity, the categorized four regions have been chosen in order to rank airports on the basis of node and link-based connectivity parameters. In order to compute landside connectivity indices region wise, the extent of region has been buffered for radius of 150 km, 70km, 46 km for catchment area for different hierarchy of airports (Tier I, Tier II, Tier III). The indicators chosen for the analysis are, settlements including census towns and statutory towns acting as nodes in the airport region, and links are national highway, state highway and major district roads. Further in order to rank, the indices computed are Alpha Index,Beta Index, Gama Index, Konig Number using ArcGIS software.

6.1 Identification of regions on the basis of landside airport connectivity- Discussion

In order to identify the airport region on the basis of connectivity, the study area selection has been done on the basis of airside connectivity as well as landside connectivity. In order to compute landside connectivity, 36 airports of different tier of airports and 4 different regions have been identified using the ranking based on Different tier of airports, Participation Coefficient, Z-Score, Hubbing Potential, Potential Index, Inter community coefficient. In Region 1 that is the Northern Region, New Delhi, Jaipur and Lucknow having the highest ranking among all the eight airports. In Region2, that is the central India, Mumbai, Ahmedabad and Pune has the highest-ranking airports. In Region 3 that is the North east region, Kolkata, Guwahati and Bagdogra ranks the highest. In Region 4, Bangalore, Hyderabad and Chennai ranks the highest. (Amal Jose, 2019)

In order to further examine the connectivity indices in the 4 airport regions, some of the measures as defined in the Graph theory has been applied. Graph theory basically converts the transport networks into a matrix in which Edges are defined as Line segment (link) between locations, for example: roads, rail lines, etc. and Vertex are defined as impostant locales on the transportation network that is of interest (node), for example: cities, towns,public places, etc. The connectivity measures that are applied are Alpha Index, Beta Index, Gamma Index and Koenig No. These measures have been computed using QGIS, network analysis tool to convert the road network into Planar Graph. These indices have been defined as:

(a) “Beta Index. Measures the level of connectivity in a graph and is expressed by the relationship between the number of links (e) over the number of nodes (v). Trees and simple networks have Beta value of less than one”. (Arlinghaus, 2001)

(b) “Alpha Index. A measure of connectivity which evaluates the number of cycles in a graph in comparison with the maximum number of cycles. The higher the alpha index, the more a network is connected”. (Arlinghaus, 2001)

(c) “Gamma Index. 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. Gamma is an efficient value to measure the progression of a network in time”. (Arlinghaus, 2001)

(d) “Koenig number (or associated number, eccentricity). A measure of farness based on the number of links needed to reach the most distant node in the graph”. (Arlinghaus, 2001)

	Airports	Passengers FY 2019-20	Ranking based on passenger traffic	Tier of Airports	Beta Index	Alpha	Gamma Index	Konig No.(Shortest path length of farthest node)
Region-1	**New Delhi**	67,301,016	I	I	1.93	0.48	0.65	178
	Jaipur	5,031,561	III	II	1.58	0.30	0.54	96
	Lucknow	5,433,757	II	II	1.60	0.37	0.59	78
	Chandigarh	2,445,202	V	III	1.65	0.41	0.62	51
	Patna	4,525,765	IV	III	1.53	0.36	0.59	52
	Varanasi	3,010,702	VI	III	1.43	0.30	0.56	69
	Ranchi	2,485,293	VII	III	1.33	0.24	0.51	45
	Allahabad	414,064	VIII	III	1.31	0.24	0.52	52
Region-2	**Mumbai**	45,873,329	I	I	1.63	0.39	0.49	165
	Ahmedabad	11,432,996	II	II	1.42	0.27	0.53	83
	Pune	8,085,607	III	II	1.54	0.33	0.56	63
	Raipur	2,119,417	VI	III	1.33	0.31	0.57	48
	Goa	8,356,240	IV	II	1.48	0.41	0.62	93
	Indore	2,918,971	V	II	1.36	0.23	0.50	77
	Nagpur	3,061,548	VII	III	1.14	0.13	0.44	48
	Surat	1,515,557	VIII	III	1.33	0.23	0.50	72
Region-3	**Kolkata**	22,015,391	I	I	1.36	0.21	0.48	170
	Guwahati	5,457,449	II	II	1.20	0.13	0.43	120
	Bagdogra	3,197,168	III	III	0.94	0.00	0.36	78
	Imphal	1,506,435	V	III	0.88	-0.04	0.33	51
	Agartala	1,285,860	IV	III	0.67	-0.14	0.33	53
	Dimapur	192,899	VI	III	0.50	-0.29	0.25	60
	Shillong	30,502	VII	III	0.67	-0.14	0.33	75
Region-4	**Bangalore**	32,361,666	I	I	1.59	0.31	0.47	214
	Hyderabad	21,651,878	III	I	1.41	0.25	0.51	200
	Chennai	22,266,722	II	I	1.38	0.19	0.47	168
	Cochin	9,624,334	IV	II	1.23	0.13	0.46	89
	Vizag	2,681,283	VII	III	1.19	0.69	0.81	59
	Vijayawada	1,130,583	VIII	III	1.18	0.71	0.83	41
	Trivandrum	3,919,193	V	III	1.12	0.12	0.33	54
	Bhubaneswar	3,672,246	VI	II	1.28	0.39	0.60	56

Figure 2 Landside Connectivity Indices, (computed by author)

As per the connectivity indices for landside connectivity in various airport regions it is found that Region 1 As a metro hub, New Delhi ranks first in landside connectivity followed by Lucknow in Tier II and Chandigarh in tier III type of airports. In Region II as a metro hub, Mumbai ranks first in landside connectivity followed by Ahmedabad in Tier II and Surat, Raipur in tier III. In Region As a metro hub, Kolkata ranks first in landside connectivity followed by Guwahati in Tier II and Siliguri in tier III. In Region 4, as a metro hub, Bangalore ranks first in landside connectivity followed by Cochin in Tier II and Vijayawada in tier III type of Airport. For the identified four regions, Region 1 has the highest landside and airside connectivity values followed by region 2, region 4 and region 3.

Various researches have stated that airport influences the landside connectivity in a region over a period of time and in order to explore the same, measures of centrality has been computed. In order to investigate the most accessible and connected settlements as nodes in the airport region, the decadal change in accessibility parameters have been assessed with respect to road network. For the study, Bagdogra airport has been selected from the north east region, which is the region 3 as categorized in the Figure 2. In order to analyze the impact of airport on landside connectivity in the region, North-east has been considered in order to look at the change in connectivity parameters impacted by the provision of airport connectivity to the least accessible regions. Since road and rail facilities are inadequate in the region, therefore viable means of

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transportation in the North-Eastern states is by air. In UDAN scheme as well, impetus has been given to North-east Region for improving the regional air connectivity in the region.

7 CASE STUDY: BAGDOGRA AIRPORT, SILIGURI

The Bagdogra region of Siliguri in northern West Bengal, India, is site to Bagdogra Airport, a customs airport. Siliguri is the city that the airport serves. At the Indian Air Force's AFS Bagdogra, it is run as a civil enclave. Additionally, it serves as a gateway airport for other North Bengal area hill stations, including Darjeeling, Gangtok, Kurseong, Kalimpong, and Mirik. Each year, thousands of visitors use this airport. The airport serves as a significant transportation centre for the area, and in 2002, the Indian central government granted it restricted international airport status with limited international operations. The airport served 3.2 million passengers in 2019–20, a rise of 11.2% from the prior year, ranking it as India's 17th busiest airport. (Anon., n.d.)

Siliguri is strategically located with easy access to Nepal, Bangladesh and China. That is not all. The critical Siliguri Corridor marks the 60 km long and 22 km "Chicken Neck" connecting the rest of India with the north eastern states.

Conferring to the airport serving the North Bengal region, in order to compute the change in accessibility in the Bagdogra airport region, the study area identified consists of 4 districts which has been delineated by applying Voronoi polygon tool in QGIS, then applying intersection tool so as to demarcate the area with respect to district boundary. The demarcated area consists of districts namely Uttar Dinajpur, Jalpaiguri, Koch Bihar, Darjeeling.

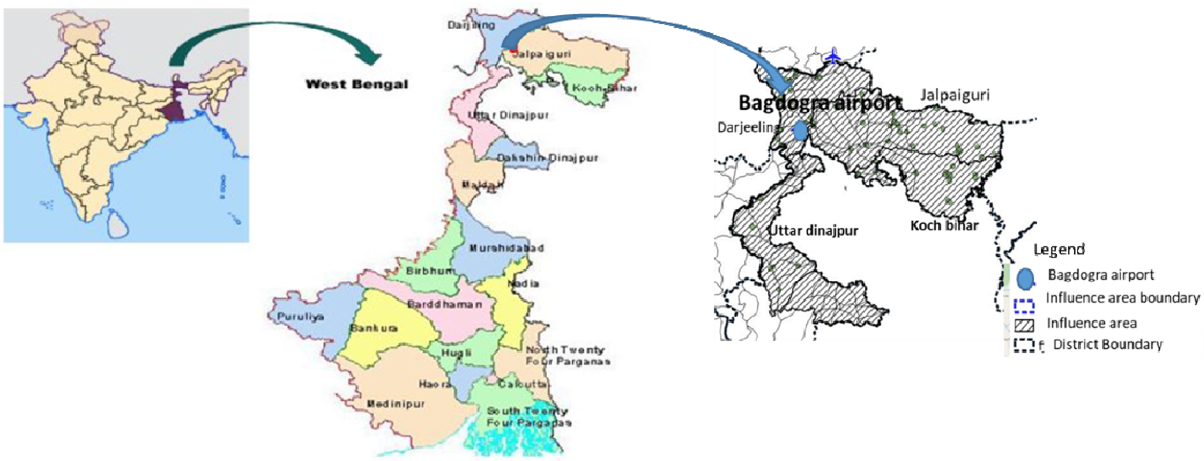

Figure 3 Study Area: Location of Bagdogra Airport and its region (Not to scale)

District	Population 2001	Population 2011	Area of the district	No. of census towns 2001	No. of census towns 2011	No. of statutory towns 2001	No. of statutory towns 2011
Darjeeling	1609172	1846823	3149sq.km	4	24	4	5
Jalpaiguri	3401173	3872846	6227sq.km	13	35	3	4
Koch bihar	2479155	2819086	3387sq.km	4	12	6	6
Uttar dinajpur	2441794	3,007,134	3140	3	5	3	4

Figure 4 Study area. Total no. of settlements in 2001=42, Total no. of settlements in 2011=96

7.1 Accessibility in the Region

The airport region tends to create various kinds of links with respect to the areas it serves. With time, these links change also tend to change in terms of capacities, gets upgraded and at times form new links to connect more and more places in the region. Similarly in the case area of Bagdogra airport region, through this study an attempt has been made to ty to figure out the trend of change in connectivity in terms of change in accessibility in the region. This change has been identified with respect to time as well as distance form the airport, and assessing the most accessible and connected urban settlements in the region. The question addressed here was, whether there is any change in the accessibility indices in the airport region and whether the airport has any role to play in the scenario. For the study, all the census and statutory towns have been taken as nodes, national highways, state highways and major district roads have been taken as the links in the region. The topological maps are extracted for the years 2001 and 2011 to see the change in these years, as in 2002 the airport was upgraded into an international airport and hence the impacts.

In order to see the change in accessibility during the year 2001 to 2011, centrality and shimbel index has been applied with respect to the distance from the airport. For computing the centrality measures in the region, the tools applied are spatial design network analyst tool in QGIS, further the network graph matrix has been generated for the network by planarizing the network into segments and finally the result has been shown in terms of heat maps.

7.2 Calculation of Centrality

7.2.1 Centrality Measures

Centrality measurements including degree, betweenness, and closeness could quantify how central or important each node or link is inside a network, so as to find out the emerging important nodes and links in the region. These indices are free from the effect of network size road capacities so that cross-network comparison is possible.

“Shimbel Index (or Shimbel distance, nodal accessibility, nodality). “A measure of accessibility representing the sum of the length of all shortest paths connecting all other nodes in the graph. The inverse measure is also called closeness centrality or distance centrality".

$$A_i = \sum_{j=1}^{N} d_{ij}$$

“Betweenness centrality measures the extent to which a particular node lies between other nodes in a network. A node tends to be more powerful if it is on the shortest paths connecting many node-pairs, as it may be in a position to broker or mediate connections between these pairs. The betweenness of a node i is defined as the ratio of all shortest paths passing through it and reflects its transitivity”. Thus,

$$C_B(i) = \sum_{k \neq i \neq j \in N} \sigma_{kj}(i)/\sigma_{kj}$$

where σkj is the sum of all shortest paths between nodes vk and vj, and σkj(i) is the number of shortest paths that pass through vi. Nodes that occur on many shortest paths between other nodes have higher betweenness than those that do not.

“Closeness centrality:

Closeness centrality measures the extent to which a node is close to all other nodes along the shortest path and reflects its accessibility in a given network.” The closeness of node i is written as:

$$C_C(i) = \frac{n-1}{\sum_{v_j \in V, i \neq j} d_{ij}}$$

“In other words, a node’s closeness is the inverse of the average shortest distance from that node i to all other nodes in a given network. The larger the i value, the more convenient it is to reach other nodes”.(Wang et al., 2011)

7.3 Discussion

The measure of betweenness centrality in Figure 5 illustrates a node's importance by the percentage of pathways that connect it to other nodes. The concept is that a node that plays a larger role in connecting more other nodes is more significant.Hence it can be seen in the Figure 5 that during the year 2001 to 2011, the betweenness centrality has been outrightly emerging near the airport and along another city of Jalpaiguri which is directly linked to Siliguri through highway 27.

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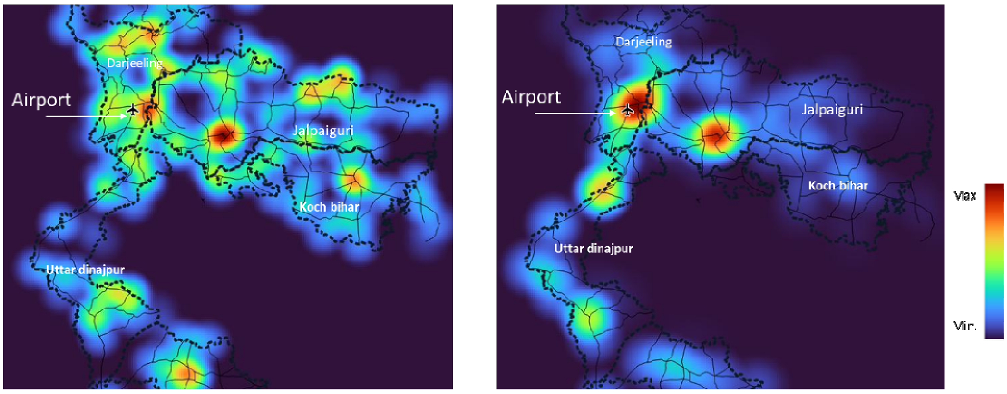

Figure 5 Betweenness centrality 2001 and 2011 (calculated by author)

Further in order to see the emerging nodes with more edges have greater importance, measure of degree centrality in the region has been computed. Degree centrality measures the importance of a node by the number of edges (degree) the node has. The region had a lot no. of important nodes spread out in the region but as it can be seen in 2011, comparatively the emerged nodes are lying in the vicinity of the airport as in the Figure 6.

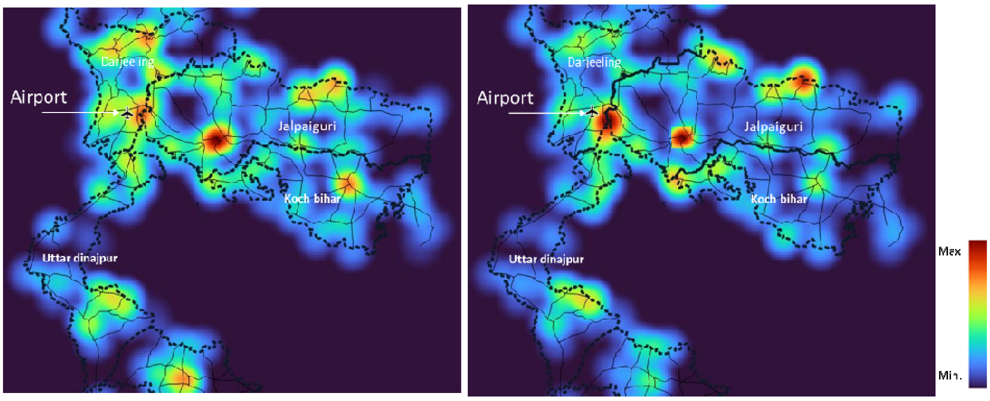

Figure 6 Degree Centrality 2001 and 2011 (calculated by author)

Further, in order to measure accessibility on the basis of shortest paths, another measure of shimbel index has been computed that is shimbel index. Shimbel index is the measure of accessibility representing the sum of the length of all shortest paths connecting all other nodes in the graph. The inverse measure of Shimbel index is also called closeness centrality or distance centrality. It is calculated as the reciprocal of the sum of geodesic distances to all other nodes. The idea of calculating this measure is that the closer a node is to other nodes, the important the node is. The measure is based on the topological distance between the nodes, for which if the value is high then it has lesser accessibility. As it can be seen in the figure 7 the light green patches show the reduction in values in the region specially in the nearby areas to the airport showing increase in accessibility in the region.

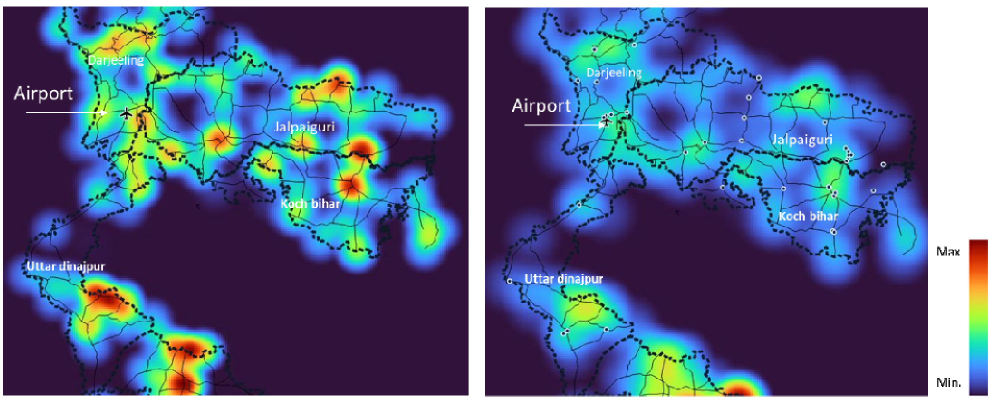

Figure 7 Shimbel Index 2001 and 2011 (calculated by author)

The centrality measures computed for the airport region shows the change in the accessibility in the region during 2001 to 2011, it is important to look into the change in settlement pattern in the region to see the emerging nodes based on the demographic changes. In the delineated area, using the QGIS software, all the census and statutory towns have been mapped to identify the change, along the radius of 50km,100km and 150km. The buffer zones have been mapped, using the buffer tool in QGIS. Further, for the same distances, isochrones have also been mapped, using the network analyst tools for getting the exact geographical distance that can be covered via roads. As in the figure 8 given below, it can be inferred that Emergence of urban settlements in the airport region can also be seen being concentrated more in the vicinity of the airport within a distance of 50 to 100km. Also in the region, there has been a prominent change in class size of the towns. It can be seen that settlements have been upgraded which are concentrated in the proximity of the airport.

Figure 8 Settlement Pattern- 2001 and 2011, computed by author

Based on Change in Class size of the Settlement (2001 to 2011)		
Distance Buffer(km)	Rural to Urban	Change in Class size
50	Out of 54 settlements, 28	23
100	16	8
150	6	3
200	4	2

Figure 9 Settlement class size

Visualizing the two different aspects, it can be inferred that, as per the change in hierarchy of settlements in terms of urbanization with respect to the links spread in the region, the impact is concentrated more in the radius of 50 to 120km of radius from airport.

8 CONCLUSION

Airport Connectivity and Accessibility not only enhance connectivity to other regions but also helps in improvising the intraregional linkages. Airports in a region are envisioned for providing better connectedness at domestic as well as international levels, besides this they are also associated with an emergence of new nodes, edges and links around the airport.

This study has applied the Graph Theory to examine the overall landside structure of road network around the airport in the region and the centrality of the network. This paper has examined the landside network of 36 airport regions, which consequently shows that the tier-I airports dominate the ranking in terms of better connectivity in the region. Further to specifically explore the impact of airport on connectivity in the region, North East region having the lowest ranking has been considered. Major findings in the study are, it could be inferred that in a period of time, the accessibility has increased more in the vicinity of the airport, as compared to other parts of the delineated region. The airport is playing a major role in developing the network and giving rise to emergence of various nodes in the region. The findings confirm previous links between the airport landside network and underlying geographical settlement patterns.Therefore, with upcoming airports, it is a necessity to consider the regional linkages of the airport as they are directly linked to emerging cities and towns and thereby links among them. Airports cannot be planned as isolated silos; they also require a comprehensive planning to avail the profound potentials of airport as a transport infrastructure. Further the study should also be done to analyze the impact on development of the region, as it has been inferred from this study that, in the airport region there lies an emergence of various urban settlements as well as many towns and cities tend to upgrade due to better connectivity and accessibility as an implication of airports.

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