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# Evaluation of Spatio-Temporal Settlement Pattern in an Airport Region

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**Abstract:** Envisioning the airport's expanding relevance as a hub for passenger movement and its immediate ancillaries and as a focal point for inducing growth that embraces enormous conurbations and associated services, this paper seeks to identify factors likely to impact the regions surrounding the airport, especially from a viewpoint of planning and development. The rationale for focusing on these areas is to determine the impact of change in landside connectivity in an airport region on the hierarchy and interaction of settlements. In order to explore the objective, the application of GIS, as well as statistical analysis, has been undertaken for the selected case study of Bagdogra Airport, West Bengal, India in the North-East region and with geographically challenging terrain. Methodologically, this paper tries to identify changes in the various types of socio-economic and urbanizing factors to find out the impact of change in connectivity on settlement patterns in the region. It is evident from the results that, while visualizing the spatial structure of the factors affected in the airport's region, the airport can be considered a pivot that induces urbanization and increases the number of amenities in its vicinity. As a result, it is apparent that large airports are transitioning from airport cities to new focus locations in the regions for the development of regional infrastructure that catalyze the phenomenon of urbanization.

**Keywords:** airport region; regional development; connectivity; settlement pattern



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## 1. Introduction

Airports are a transformative indicator of the enduring vitality of cities and have evolved with the increasing needs for air travel that have accompanied the urban population boom [1]. Transformations in the character and role of urban airports are taking place in the context of major shifts in factors influencing both cities and aviation. Urban populations have been constantly increasing and sprawling metropolitan regions have become the predominant urban form, with corresponding transportation infrastructure and connectivity demands [2].

The effect of an airport extends beyond the borders of the city in which the airport is located. There are three different ways that airports have an impact on the overall growth of a region. To begin, there are consequences that are directly related to the airport itself, which include any investments made, and the jobs that are created there. Second, indirect impacts are responsible for all of the money and employment that are produced as a result of enterprises outside of the airport delivering services to airport businesses [3]. Finally, there are the induced effects, which are utilized to describe the entire economic output of the airport industries' direct and indirect employment. Airline network effects as well as landside network effects, are notably associated with the features of air traffic and are generated by hub airports located on the top [4,5]. As a result, huge airports are evolving into more than just airport cities; rather, they are emerging as new epicenters of regional growth inside urban regions. Since the location of the major city center has become less significant than a strategic position within the regional context, airports have a critical position in terms of location. The influence of the airport extends well beyond the city

and the city region, affecting the surrounding area as a result of its catalytic effects. Due to the spatial evolution of networks, the induced effects of airports play a significant role in regional expansion by influencing the nearby population, employment, income, and amenity location growth. Numerous studies have demonstrated the association between regional economic growth and the physical availability of amenities [6]. Strategically located airports are linked to the expansion of a region's amenities, resulting in overall regional economic growth. Airports, in addition to the major cities, serve as growth engines and contribute to the establishment of new functional areas [7].

The fact that airports and the regions around airports are thriving does not necessarily indicate that the airport's potential as a growth engine is being utilized. As per the previous studies, it has been said that poor land use strategies and inadequate infrastructure both contribute to a lack of comprehension of the critical importance of airports and the regions around them [8]. Although the airport is frequently considered a doorway to the outside world, the city region is not commonly perceived as being accessible from the airport. According to the findings of the research, [9] this concept is supported since airport areas "are a new reality, frequently yet disregarded by planners and policymakers." Researchers suggest removing the airport from its secluded location and giving the airport a larger role in regional planning so that it can take on more significant responsibility for the immediate environment in which it resides [10]. This would involve making the planning process more comprehensive and involve the applicability of overall regional transport accessibility [10].

Despite this, airports continue to play a very significant role in megacity regions as a result of their involvement in connecting worldwide networks. The primary function of airports is to improve international and national accessibility and to make the economy in their immediate area, known as the airport region, compatible with that of the rest of the world [11]. Their significance is more all-encompassing and, even in terms of their effect, this significance is at par with that of a major metropolis. The economy is propelled in a significant way by the transportation sector. It is now common to elaborate that there is a connection between the business of civil aviation and the location of economic activities, and this connection has a catalytic effect on overall growth [12,13].

Many air services to distant or peripheral locations may not be financially feasible, which makes any operation unprofitable, as a result of the generally low traffic volume. As a result, the market would not provide these services in the absence of government subsidies and incentives. The outcome of this is that there will either be a restricted usage of services or none at all. If such air services could be backed by the relevant state, the continued provision of a sufficient standard of service would maximize the welfare (economic and social gains) for these regions [14].

Several mechanisms could influence regional characteristics of airport accessibility. First, a region's relative preference could increase, particularly when there is a significant difference in travel time to the nearest airport, as is the case in remote areas. Such impacts, if regarded as a regional amenity, could lead to population growth due to an increase in accessibility and preferential location. As an example, studies [15] demonstrate that cities have shown significant growth concerning the location of amenities. Second, airports can minimize travel time, thereby enhancing market access. Various resources require optimum accessibility, unlike economic activity that may be transferred, economic activity cannot relocate in response to changes in travel time. While examining airport accessibility and regional growth, simultaneity bias is the primary issue. Regional growth affects the accessibility of airports, while not taking this into account could result in inconsistent effect estimates. Therefore, it is important to identify the factors that affect airport access and induce regional growth at the regional as well as sub-regional scale [15].

To further elucidate this research, this study highlights various concepts of the airport and its surrounding areas to investigate the regional impacts of airports in India, where the government has formulated a scheme to provide subsidies for the establishment of airport infrastructure and airline routes to give an impetus to the aviation sector.

## 2. Literature Review

### 2.1. Advent of an Airport Region

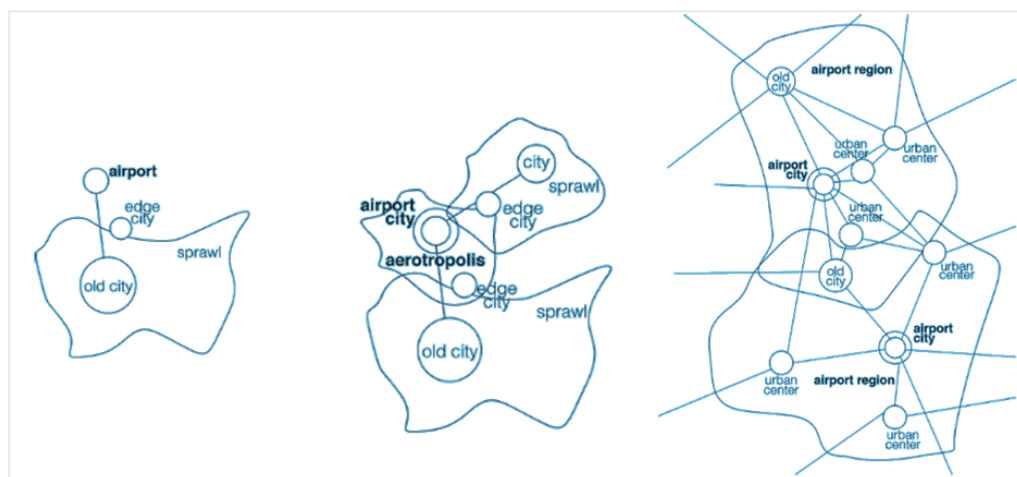
Transport innovations, in author Kasarda's view, are the primary factor in the growth of cities and economies. In terms of transportation, he argues that five overlapping waves of transport development have led to the preeminence of air travel. The first arose from the establishment of urban centers near waterways (seaports), the second from the development of river and canal transportation systems, the third from the introduction of railroads, and the fourth from the widespread adoption of automobiles (which expanded cities into outer suburbs with separate business districts). Airports are going to play a further pivotal role in driving the growth of modern cities in the fifth wave [16]. As stated by various researchers today, Kasarda's model is generally used in the planning and construction of new and remodeled major airports [17]. This is largely attributable to the abundance of nearby freight and business logistics centers, retail and entertainment venues, hotels, and service providers. Highways and railroads help support this urban core. Because of the airport's network of logistics, business, shopping, entertainment, accommodation, and service providers, roads and railroads support this infrastructure concentration [17]. All these attributes in the vicinity of an airport give rise to a whole new concept of the airport and surrounding areas, namely airport cities, airport corridors, aerotropolis and airea.

Airport corridors include public planned infrastructural developments along the road and rail buffer area between the airport and the host city as seen in the case study of Amsterdam Airport Schiphol. In Amsterdam Airport, so as to plan for economic development, a public private cooperative agreement has also been approved. In other airports, such as Copenhagen Airport, Denver International Airport, and Zurich Airport, there has been a substantial and comprehensive development along the major surface infrastructure between the city and the airport [18].

An airport city serves as the focal point and primary component of the aerotropolis, which was conceptualized in the 1990s. The aerotropolis also includes retail clusters, industrial areas, thematic parks, logistic parks, residential and commercial areas, and recreational facilities. All of these are spread in various zones surrounding the airport and are linked by a well-connected transportation network that comprises rail systems and motorways that are each linked to key regional nodes such as significant cities, well as to various logistic and freight facilities. Because it presupposes the presence of a second notion that is connected to it, namely the airport city, which is included into a regional framework that is more all-encompassing, this idea possesses hybrid qualities. While it has similar characteristics as the airport corridor, its layout is distinct from that of the latter and more expansive. This is due to the fact that it operates independently from the city that it is hosted in and serves as a kind of urban hub on its own. Aerotropolis also emerged as an unplanned structure of land use, while there were some planned contemporary instances (such as Incheon International Airport or Dubai World Central), there are no entirely publicly planned aerotropolises that have been finished as of today [19].

The area surrounding Denver and Berlin-Brandenburg airports is used by the author as an example of the airea, which is the most recent concept and has been defined by authors to explain some airport-related urban forms [1]. It can be argued that the airea is a hybrid of an airport corridor and an aerotropolis because it shares characteristics of both types of urban areas in terms of territorial development and relationship with the airport, but differs from them in that it lacks a homogenous, continuous form and is organized polycentrically [20]. Similar to the airport corridor, this idea takes into account the existence of public planning at the local, regional, and state levels. However, it is being developed by both public and private parties, with various scales of features, including economic and infrastructure activities. It can be said that the airport corridor and the airea concepts take into account both the engagement of public and private entities in their planning and building processes, having clearly originated distinct urban structures even though they are intended to be integrated with the host city and the metropolitan structure [21,22].

The conceptualization of airport region belongs to era of the 1970's [21] and it has been defined as an embryonic aerotropolis with the development of residential and industrial areas around the airport (Figure 1). It has the potential to give rise to the phenomenon of urbanization which is difficult to assess as the distinctions between the underlying and direct affecting factors are mostly unclear. In an airport region, the airport has direct connectivity to the host city and to various industrial, tourist, and logistic hubs through networks of road and rail systems [21].



**Figure 1.** Advent of the airport region.

Further, most of the studies have conceptualized the growth pattern as an evolutionary process as it does not occur overnight. It becomes important to understand this phenomenon in regards to the upcoming airport regions for assessment of the scale of impacts, so as to synchronize the sub-regional growth with the aviation-oriented impacts. In the purview of this, the study tries to assess the spillover regional effects with respect to the above airport-oriented concepts and with respect to the urbanizing effects. The study encompasses the airport-oriented urbanizing effect through the assessment of change in the hierarchy of settlements. The study also attempts to formulate a framework to delineate the airport region based on the factors of connectivity and interactions of settlements in the region.

## 2.2. Indian Scenario

In India, many governmental schemes and reforms have amplified the thrust in the sector of aviation. They include, primarily the launch of the Ude Desh Ka Aam Nagrik (UDAN) policy to revitalize 31 underutilized airports around the country and enhance the country's rural aviation network, this change will open up 128 additional flight options for passengers, The fuel price drop that enabled the success of the low-fare airline business model has contributed to an enormous increase in air travel. The issues with rural connectivity, safety, and bilateral traffic rights were also addressed in the 2016 National Aviation Civil Policy, which also encouraged the development of Indian aerospace manufacturing [23]. With respect to the future of India, the International Air Transport Association forecasts that by 2030, India will see 300 million passengers depart through the movement of six million aircraft, based on economic projections made by Goldman Sachs. When total freight volume reaches 11.4 million tons in 2032, air cargo will have become an important part of the logistics sector [24]. As per the list of June 2020 published by AAI, in total there are 486 total airports, airstrips, flying schools and military bases available in the country, 123 airports with scheduled commercial flights including some with dual civilian and army use and 35 international airports.

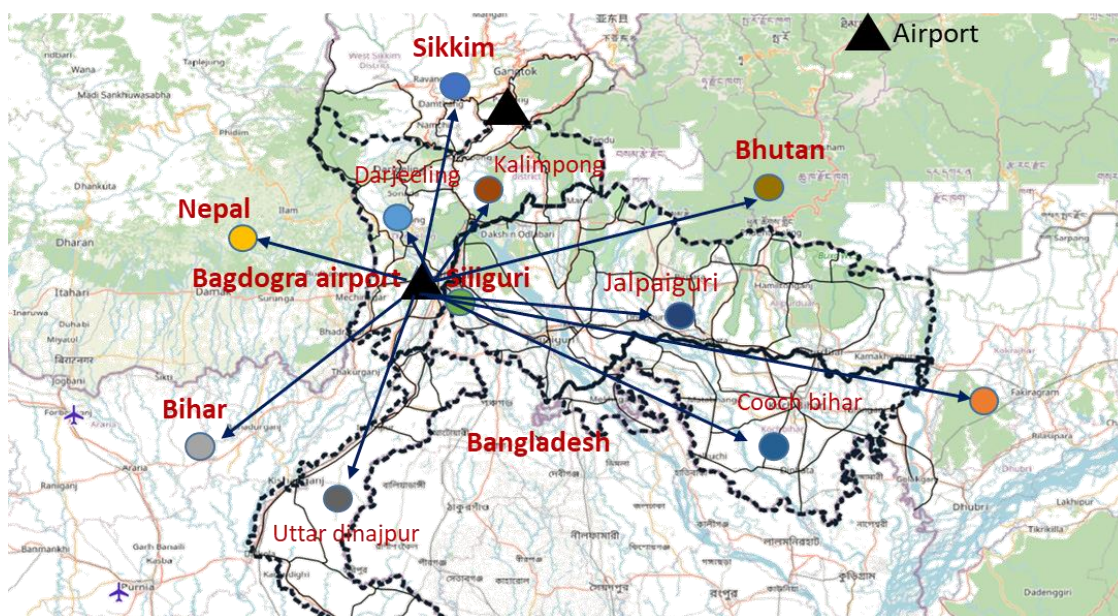
Northeast India is known for its inaccessible geography; therefore, it is essential that airports be built in such regions to improve its accessibility. Consequently, over thirty

airport development projects are currently underway in various Northeast Indian regions. In the next five years, AAI plans to develop over twenty airports in Tier-II and Tier-III cities. Guwahati will serve as an interregional hub, while Agartala, Imphal, and Dibrugarh will serve as intraregional hubs [25]. In order to evaluate the impact of an airport, especially in the regions of low landside connectivity, it is important to understand the role of airports in such inaccessible regions.

### 3. Methods and Material

#### 3.1. Study Area

The study deliberately explores the airports in geographically inaccessible regions such as the Northeast Region of India. In order to evaluate the change in development parameters with respect to landside connectivity in the region, Bagdogra Airport in Siliguri has been chosen. This airport is not only significant from a strategic point of view, but it is also a major international hub for the promotion of tourism and economic activity. The goal of this evaluation is to determine how the change in landside connectivity affects development parameters over a period of time. The airfield serves as a vital node in the transportation network that links Darjeeling and Siliguri to the rest of India as well as the rest of the world [26]. Further, the location is significant as it is surrounded by three major countries: Bhutan, Bangladesh, Nepal (Figure 2).



**Figure 2.** Areas served by Bagdogra Airport.

#### 3.2. Methodology for Delineation of Study Area

The framework of analysis for the study has been divided into two stages: first, the delineation of a tentative airport region based on the geographical hinterlands created by all of the airports in the region using GIS tools; and second, the analysis of the defined airport region based on various indicators to evaluate the settlements in the airport region with respect to the geographical connectivity indicators to the airport. Combining the above two stages as shown in Figure 3, leads to the computation of the spatio-temporal patterns of settlements and connectivity in the region with respect to the airport.

Further, the study area has been delineated using QGIS tools to identify the area for analysing the indicators in the region. Firstly, all the existing airports have been mapped in order to demarcate the hinterlands of all the airports in the north east region. In QGIS, voronoid polygon and intersection tools have been applied to demarcate the areas of influence with respect to district boundaries. Using these tools, the delineated region of

influence of the airport consists of four districts: Darjeeling, Jalpaiguri, Koch Bihar, and Uttar Dinajpur, as shown in Figure 4.

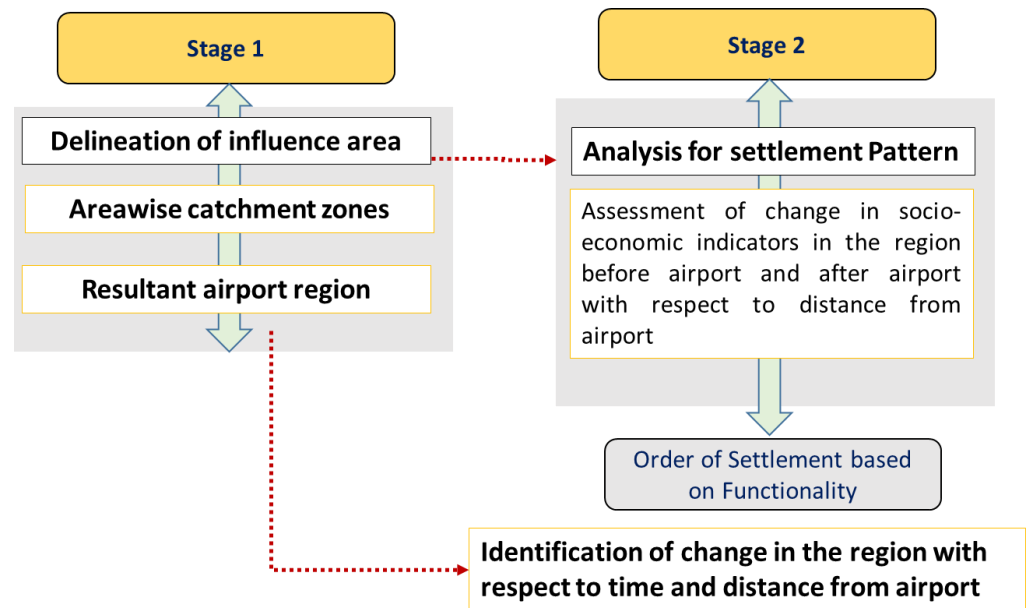


Figure 3. Study framework.

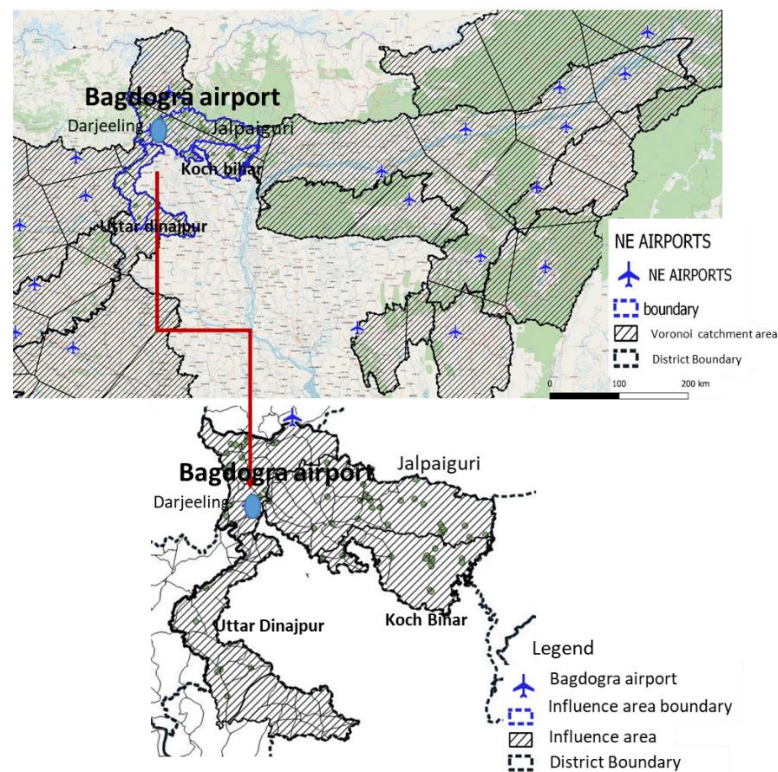


Figure 4. Delineation of the Study Area.

#### Data Compilation for the Analysis

In the delineated region, for the four districts as described in Table 1 and for analyzing the hierarchy of settlements, data have been compiled for selected settlements with populations above 5000, all administrative headquarters (district headquarter, tehsil headquarter and block headquarter), all urban centers, and settlements having economic activity hubs including technical institutions and degree colleges. The data compilation includes

demographic data related to factors of urbanization, including population of settlements (administrative towns), number of census towns, class size of towns (“The Census of India has classified towns into six categories on the basis of their population: Class 1 towns with more than 1,00,000 population, Class II towns with 50,000 to 99,999 population, Class III towns with 20,000 to 49,999 population, Class IV towns with 10,000 to 19,999 population, Class V towns with 5000 to 9999 population, Class VI towns with less than 5000 population”). Further, to assess the interaction of settlements based on the presence of high order amenities and functionality dependence, the data have also been compiled for the infrastructure available in the towns: economic infrastructure; education facilities, including primary and secondary education; higher education facilities; health facilities; and public facilities. The data were retrieved for only the years 2001 and 2011 as the Bagdogra airport was given the status of an international airport in 2002 and the latest census data for 2021 had not been published at the time of writing (limitation of the study).

**Table 1.** Delineated region profile.

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	1,609,172	1,846,823	3149 km <sup>2</sup>	4	24	4	5
Jalpaiguri	3,401,173	3,872,846	6227 km <sup>2</sup>	13	35	3	4
Koch Bihar	2,479,155	2,819,086	3387 km <sup>2</sup>	4	12	6	6
Uttar dinajpur	2,441,794	3,007,134	3140 km <sup>2</sup>	3	5	3	4

Total no. of settlements in 2001 = 42. Total no. of settlements in 2011 = 96.

In the study area, as per the QGIS tools, the selected catchment zone with four districts is the tentative airport region for further evaluation of other indicators. According to previous research, it is essential to analyze an overall regional resource, socio-economic, and demographic profile in order to obtain an overview of the existing spatial structure describing the functional complexity of the settlement system, the change in settlement hierarchy, the hierarchy of central places, and the distribution patterns of association among functions within the region. This approach involves the mapping of data acquired from functional complexity, settlement hierarchy, and spatial interconnections investigations in order to determine “zones of influence” or service areas of different settlement types within the airport region [27].

Therefore, to analyze the settlement hierarchy, settlements of four districts have been mapped based on Indian census data, the population of 2001 and 2011 to capture the emergence of urban settlements or change in settlement size from 2001 to 2011 as in Figure 5. Further, isochrones have also been developed with respect to airports to define the geographical buffers of 50 km, 100 km and 120 km and to evaluate the impact of an airport with respect to its distance. Besides these isochrones, using buffer tools from the spatial data analysis plugin of QGIS, the map also consists of the buffers of 50, 100 and 150 km. It is clear that the area defined by isochrones, which defines the actual travel distance, is different from the buffer created as a result of the difficult geographical terrain in the region.

### 3.3. Hierarchy of Settlements in the Airport Region: Discussion

It can be observed in Figure 5, that there is an emergence of more urban settlements, concentrated more in the vicinity of the airport. Between 2001 and 2011, 28 out of 54 towns in the 50-km buffer zone around the airport became urbanized. There is also an increase in class size of 23 towns within a 50-km buffer. Within a 100-km buffer, 16 communities were urbanized, while eight settlements were improved in terms of class size. In the 150 km buffer, six communities were urbanized and three were upgraded in terms of class size, while in the 200 km buffer, four settlements were urbanized and two were improved.

According to Table 2, the shift in rural to urban settlements and the change in class size of towns is concentrated more near the airport, and this change diminishes as we travel away from the airport.

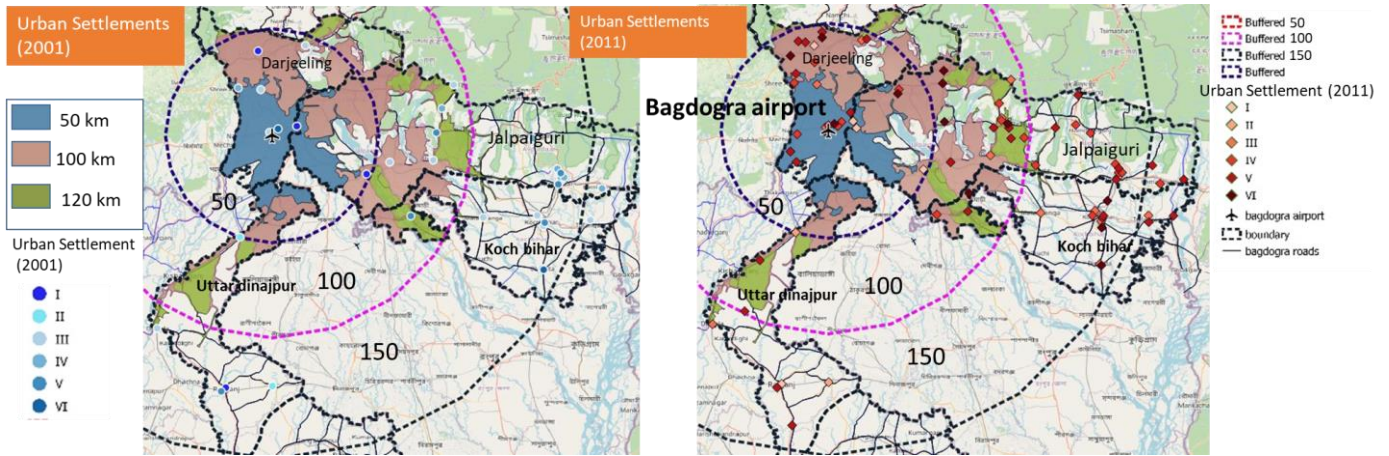


Figure 5. Hierarchy of settlements.

Table 2. Emergence of urban settlements.

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

### 3.4. Functional Interaction of Settlements Based on Amenities: Methodology

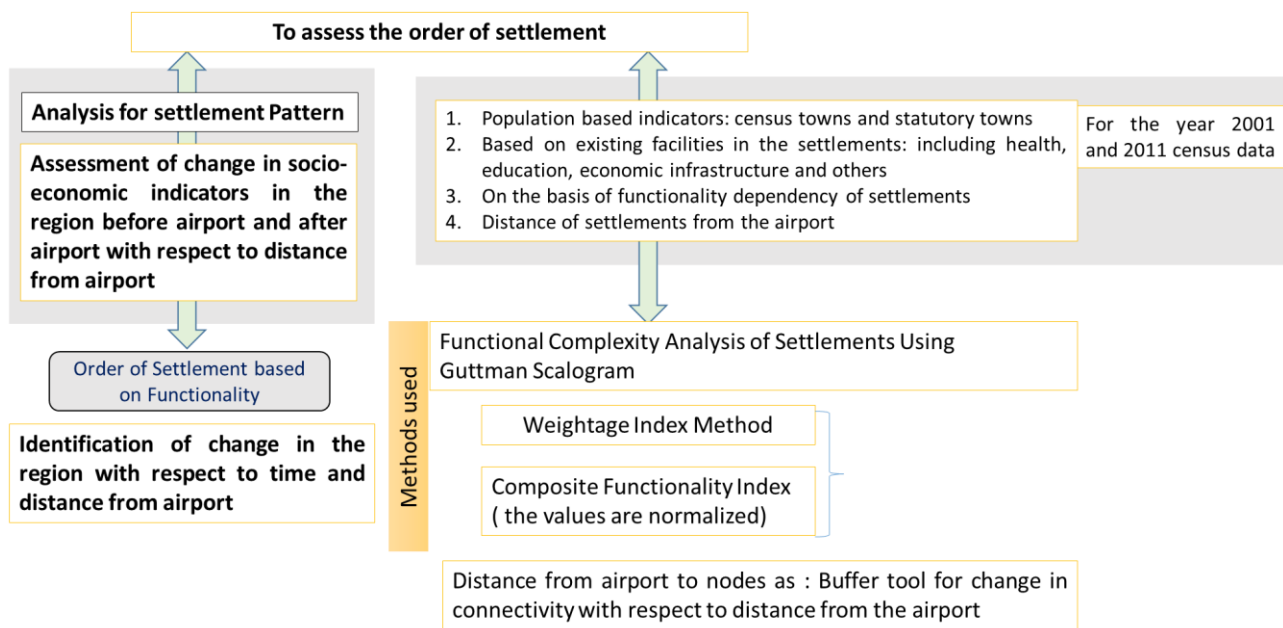
Further, in the selected airport region, it is important to evaluate settlement functional complexities, hence the technique of the cumulative functionality index. The objective of CFI is to find out the relative functional dependence of settlements in the region and therefore to know the high order as well as low order settlements there. Following an exhaustive literature research, the indicators chosen to cover all of the socio-economic functional profiles as well as the demographic profiles for the settlements are population-based indicators. Meanwhile, for all census towns and statutory towns [28,29] the measurements were based on existing settlement facilities such as health, education, economic infrastructure, and others, as well as on the functional reliance of settlements and settlements’ distance from the airport. In order to examine the change in connectivity with regard to distance from the airport, a functional complexity analysis of settlements was executed (Figure 6) using the weightage index method and the composite functionality index (the values are normalized).

Formulas applied: Following are the formulae applied to compute the functionality matrix

$$\text{Weightage of facility} = \frac{\text{Total no. of settlements}}{\text{No. of settlement having that facility}} \tag{1}$$

$$\text{Cumulative Functionality Index of a settlement} = \sum (\text{number of particular facilities in that settlement} \times \text{weightage of those facilities}) \tag{2}$$





**Figure 6.** Calculation of composite functionality index.

**Guttman Scalogram:** In regional analysis, the Guttman scalogram can be used to make a cumulative scale of functions (items) such as services, facilities, organizations, and establishments, and to rank settlements (cases) by the total number of functions they have. The matrix of functionality index, which evolved from Guttman's (1950) scalogram practice, was used to analyze and categorize existing settlements based on the availability or non-availability of key functions, as well as to identify clusters of settlements strategically interconnected within a given region [30,31]. The calculated composite functionality index accounts for high- and low-order settlements, where the hierarchy value is the indication of the extent of concentration of facilities in a settlement. CFI of a settlement is assessed based on the number and presence of the following types of facilities/amenities in the settlement. After calculating the weightage of each facility, the CFI for each settlement is calculated.

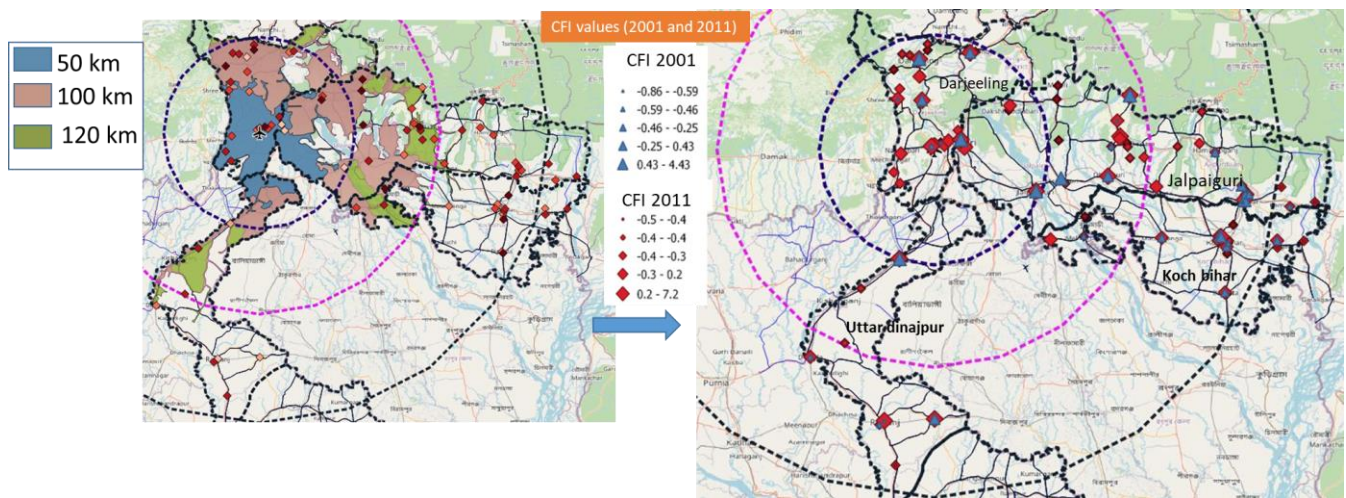
The weightage was computed for all the settlements for the various type of infrastructure, such as health, education, economic, public facilities etc., as shown in Figure 7. This weightage was then further used to calculate the functionality index for each settlement and then mapped using QGIS. The CFI value for each settlement for the years 2001 and 2011, after being calculated, were overlapped on the isochrones of 50 km, 100 km and 120 km and buffers of 50 km, 100 km and 150 km to see the impact of an airport on the functionality order of settlements (Figure 8).

### 3.5. Cumulative Functionality index from 2001 to 2011: Discussion

As per the objective of the study, i.e., to determine the functionality of the settlements and the impact of airport on the changing order of settlements, while spatially mapping the indices it can be observed from Figure 8 that a change in CFI values with respect to the distance from the airport from 2001 to 2011 can be noticed more in the vicinity of the airport. With the increasing distance from the airport, the CFI values tend to reduce and the settlements lying near to the airport tend to have higher CFI values, which shows an impact on the change in the order of settlements. The functionality of a settlement denotes the higher and lower order of settlements as well as the dependency of lower order settlements on the more functional settlements.

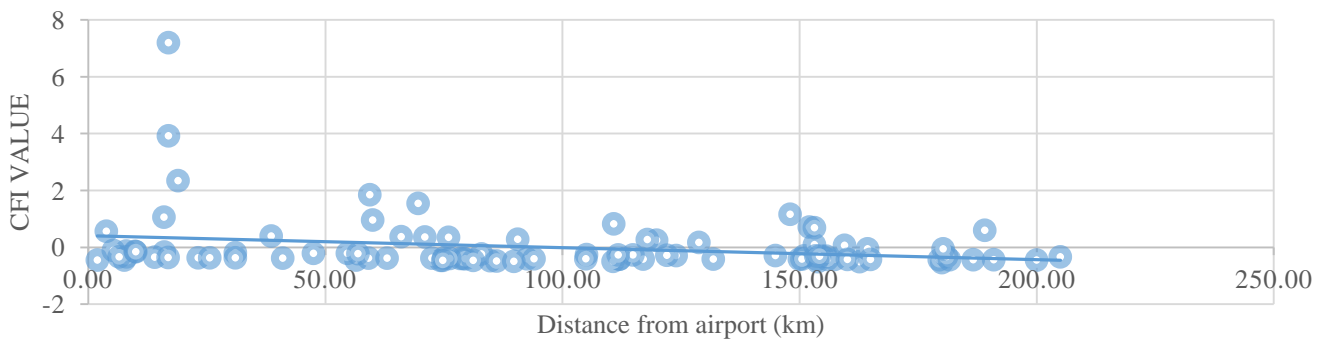
Type of Infrastructure	Type of Facility	Weightage	Type of Infrastructure	Type of Facility	Weightage
Economic Infrastructure	Nationalised Bank (Numbers)	0.56	Health Facilities	Hospital Allopathic (Numbers)	0.36
	Private Commercial Bank (Numbers)	0.20		Hospital Alternative Medicine (Numbers)	0.07
	Co-operative Bank (Numbers)	0.35		Dispensary/Health Centre (Numbers)	0.55
	Agricultural Credit Society (Numbers)	0.15		Family Welfare Centre (Numbers)	0.20
	Non-Agricultural Credit Society (Numbers)	0.29		Maternity and Child Welfare Centre (Numbers)	0.24
Education Facilities: Primary and secondary	Private Primary School	0.66	Maternity Home (Numbers)	0.08	
	Govt. Middle School	0.84	T.B. Hospital/ Clinic (Numbers)	0.17	
	Private Middle School	0.25	Govt. Primary School	0.98	
	Govt. Secondary School	0.80	Govt.-Working Women's Hostel	0.07	
	Private Secondary School	0.23	Private-Working Women's Hostel	0.04	
	Govt. Senior Secondary School	0.59	Govt.-Stadium	0.08	
	Private Senior Secondary School	0.17	Private-Stadium	0.05	
	Govt. Degree College-Art Only	0.06	Govt.-Cinema Theatre	0.07	
	Govt. Degree College-Commerce Only	0.01	Private-Cinema Theatre	0.25	
	Govt. Degree College-Art and Science Only	0.05	Govt.-Auditorium/Community Hall	0.32	
Higher Education Facilities	Govt. Degree College-Art, Science and Commerce	0.14	Private-Auditorium/Community Hall	0.11	
	Private Degree College-Art, Science and Commerce	0.01	Hall		
	Govt. Degree College-Law	0.01	Private-Hall		
	Private Degree College-Law	0.00	Govt.-Public Library	0.52	
	Govt. Degree College-University	0.01	Private-Public Library	0.06	
	Govt.-Management Institute	0.02	Govt.-Public Reading Room	0.33	
	Private-Management Institute	0.03	Private-Public Reading Room	0.05	
	Govt.-Polytechnic	0.06	Fire Fighting Service	5.33	

Figure 7. Weightage for each facility in the region.



**Figure 8.** Functionality index of settlements for the years 2001 and 2011.

It is important to distinguish the difference in order of settlements with respect to distance from the airport in order to explore the impact on functionality indices of settlements. Hence, to intricately analyze the change and note the upgrading of settlements with respect to travel distance from the airport, Figure 9 can be used to understand the phenomenon of change in the Bagdogra airport region. It can clearly be seen that the cluster of settlements that had a major upgrade from 2001 to 2011 in the functionality indices at lower distances from the airport.



**Figure 9.** Change in CFI with respect to distance from airport.

### 3.6. Results and Discussion

In this study, an attempt has been made to formulate a framework for evaluating settlement patterns in the airport region, while addressing the impact of an airport on the peripheral areas of a less accessible region. The focus of the study is concentrated on the regional effects of airports that are visible after a period of time as the connectivity evolves and the inaccessible areas get the opportunity to grow indirectly due to the airport. In the first stage, we used GIS techniques of creating hinterlands of all the airports in the region and, as a result, delineated a tentative region. To further strengthen the delineation process, a combination of travelled distance, change in settlement class size and functionality index was applied, followed by stage two. The combination was further incorporated with the analysis of the interdependence of settlements in the region based on the CFI values. As per the results, the class size of the towns as well as the functionality index were found to be higher in the vicinity of the airport and hence the dependence of the region on these towns. As per the two stages of analysis, that is the delineation and the settlement pattern in the delineated region, the results show that the extent of the impact lies in the radius of 150 km and that beyond that radius the changes tend to reduce.

An attempt has also been made to translate the spatial analysis into the impact of airports in terms of emerging growth centers. As can be seen from the results of the case study of Bagdogra Airport, the areas geographically closer to the airport have been stimulated and the concentration of high-order facilities can be seen in these areas. This case suggests that the functional dependence and urbanizing phenomenon are somewhat limited in the vicinity of the airport. Visualizing the two different aspects it can be inferred that the airport is a growth-inducing agent in geographically inaccessible areas. The realization of a region's economic potential can be aided by its well-developed transportation infrastructure, which acts as a facilitator in this process.

#### 4. Conclusions

The focus of the study is concentrated on the regional effects of airports that are visible after a period of time. The current study utilized spatiotemporal datasets for the years 2001 and 2011 in conjunction with GIS-based approaches to elucidate the case of the airport region and the system of settlements in the delineated region. Numerous studies have been undertaken to determine the association between airports and development parameters, this research investigates the relationship between airport landside connectivity and the regional spatial structure of settlements, as well as their interdependence.

The study has dealt with the delineation technique and conjectured regional growth in terms of spatial structure. This approach may help in identifying those areas whose links are weak or inaccessible, as well as peripheral regions that have inadequate access to high-quality services and amenities, and may be critical for consideration in airport-oriented planning and development. Further, while planning for airport cities and regions, this study proposes one of the methodological approaches for developing underdeveloped peripheries and planning for the cities and towns that are in the vicinity of the airport and potentially lie under the influence of airport-driven development.

In India, the government has launched a regional connectivity scheme focused on providing airports at the regional scale, to provide viable connectivity as well as induce socio-economic development in less accessible regions. Therefore, it becomes important to articulate the spatial structure at the regional as well as sub-regional level while planning to ensure the utilization of the airport as a growth inducing node. Evidently, the study shows that there is a paradigm shift in the concentration of locations of high-order amenities and infrastructural facilities in the delineated airport region, although the scope was limited to the analysis of spatial structure, more factors need to be assessed to further identify the predominant impacts. Analysis approaches such as regional resources systems, a settlement hierarchy system, and functional interdependence are critical for determining and facilitating equitable growth at the regional and subregional levels and identifying major gaps in structures of spatial systems and linkages between suburban areas of the region. This shall aid in catalyzing the growth and development processes even at the settlement level in an integrated manner.

In addition to this, in order to empirically evaluate the direct and indirect causality of the airport, it is necessary to assess other socio-economic and physical factors in order to determine the epicenters of growth and the dynamic nature of socio-economic development processes in the region, given that the context and potential of different regions vary according to their peculiarities. Further, more research that conducts a similar methodology but which applies it to other factors may help in planning regions based on the outcomes.

#### 5. Limitation of the Study

The analysis has been based on the secondary data retrieved from the Indian census. Data were available only for 2001 and 2011, as the latest data for 2021 have not been published yet.

**Author Contributions:** Conceptualization of the research objective was done by S.R. and was further developed by S.S. under the supervision of S.R. Following the concepts, the methodology has been comprehended by S.S. followed by analysis using QGIS software and investigation of the research objectives. The manuscript was developed by S.S. under the supervision of S.R. All authors have read and agreed to the published version of the manuscript.

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