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Measuring the Urban Road network pattern using connectivity analysis: A micro-level study in Egra Municipality, West Bengal

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Abstract

Egra Municipality is most important for providing administrative facilities to the Purba Medinipur District. Many other facilities, such as educational facilities (school, college), super specialty hospital facilities, transport and communication facilities, etc., are attracting many people from different places. So they have chosen Egra Municipality as their destination. The central areas of this municipality are already overcrowded, and population and building densities are relatively high. Now a days, gradually, the existing administrative boundary is being extended towards the periphery. So, the transport communication system and basic amenity facilities have to be improved. The aim of this paper is to analyse the road connectivity and network accessibility of the Egra municipality. The alpha index, beta index, gamma index, and cyclomatic number have also been used for understanding network accessibility in this area. The data sets were collected through a field survey that visited 14 wards of the Egra municipality area, and secondary data was collected from the Egra municipality office and an open street map. We used the connectivity analysis method to examine the accessibility of this area. According to calculations, mainly the 7, 11, and 13 wards are more efficient than other wards. Therefore, it would suggest that there is a need to improve the connectivity and accessibility of those periphery areas for the future growth and development of the Egra municipality.

Keywords: Road Networks; Connectivity; Structural Analysis; Accessibility

1. Introduction

Undoubtedly, Egra is an ancient town; the origin of this area dates back at least three and a half thousand years. Archaeological excavations at the village of Arenda by the Department of Archeology of the University of Calcutta have resulted in the discovery of archaeological sites by experts dating back at least three and a half thousand years. Earlier, the existence of this region was proven. If we consider the age of the Mahabharata to be five thousand years old, then the age of the theoretical civilization of this region is also quite ancient. Researchers believe that time is the age of black soil. In the seventh century, Gaur king Shashanka (606–625 AD) ruled Orissa till the end. During his reign, this part of the Midnapore district was included in Orissa. About 2-3 copperplates found during the reign of King Shashanka have been found in the present Medinipur district. One of them is a copperplate found in the village of Panchrol in the seventies of the last century (which is now preserved in the Ashutesh Museum of Calcutta University). According to the inscriptions on that copperplate, the area was known as BaratiVidhvabas, or the ruling area. Of these villages, at least four of the ones whose names are found in the records are Agrahar villages. This agrahar means 'those who divided the given land, along with the land donation, got some other rights related to the land from the king or the state. There is enough reason to guess that the name "EgraJanapada' is derived from Agrahar. Agrahar>Agraghar>Agghar = Egra.

The location of the city of Egra in the present-day East Midnapore district is quite important. The position of Egra today was not like this in the distant past. In the past, the Bay of Bengal was as wide as this. Just five kilometres to the south, at Kudi, the lighthouse still stands as proof. Angargeria is located in the south of Ward No. 2 of Egra City. It is said that

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Angraghat was at this place. Later, the place came to be known as Angargeria. The past name of Egra city was 'Agrapattan' which has been corrupted to Egra. The historic Hattanagar Shiva Temple is located in the heart of Egra city. It is said that this temple was built during the time of Odisha King Mukundadev. Inside this temple, there is a Shivalinga deep inside, at the same height as the temple. The area around this temple was forested in the past. Legend has it that a cow used to milk Shivalinga in the deep forest every day. When this incident came to the attention of King Mukunda Dev, he found this Shiv Linga and took a vow to build the temple. This temple was built in 1560. A fair is held here every year on the occasion of Shiva Chaturdashi. A large gathering of people takes place.

Sahitya Samrat Bankimchandra Chattopadhyay took charge as the Deputy Magistrate of the then Negua sub-division and lived in Egra as a sub-divisional town on February 9, 1860, and wrote his famous novel 'Kapalkundala'. This place is known as the 'Dakbungalow' of Kashba-Egra Mauza, which is now the administrative building of Egra Municipality. He has brought out the beauty of Daryapur, Chandpur, and undivided Kanthi subdivisions in his popular novel, 'Kapalkundala'.

Egra was the workplace of freedom fighters. Shaheed Khudiram Bose used to come to the present-day city of Egra to attract and train the youth in stick-playing and swimming. Uncrowned Emperor Birendra Nath Shasmal visited this Egra many times to attend the programme of the freedom movement. One of the centres of the freedom movement was Egra, whose centre of practise was the ancient, traditional Hotnagar Temple of Egra. Transportation, the movement and exchange of people, goods and services is an obligatory feature of modern life (Umoren et al, 2009)

Kanthi, Ramnagar, Digha, Mohanpur, Solpatta, Dantan, Sonakania, Belda, Patashpur, Bhagwanpur, Balichak, Debra, Kharagpur, Medinipur, Jhargram, Shalbani, Garbeta, Chandrakona, Ghatal, Ramjivanpur, and Tamluk are directly connected by road with the present Egra city (Sarkar, 2013). With important places like Haldia, Kolkata, Bishnupur, Arambagh, Purulia, Durgapur, Burdwan, Asansol, Siuri, Chittaranjan, etc. Besides, the city of Egra has now become one of the commercial centres due to its direct communication with the cities of Jaleshwar (Maity et al, 2021) Baleshwar, Chandbali, Chandipur, Dhamra, Cuttack, Bhubaneswar, Puri, Bihar, and Jharkhand in Orissa, especially Tatanagar, Jamshedpur, etc. As a result, the socio-economic character of the people living in Egra City has improved. At present, the area of Egra City is 16.95 square kilometers. Egra Municipality, as established on 9/6/1993, has 14 wards.

1.1. Study Area

Egra Municipality is in the southern part of West Bengal. Digha (bay of Bengal), the town, is connected by road with the major service centres like the S.D.O., police station, market, hospital, post office, etc. located between 21.9°N and 87.53°E (latitude and longitude). Egra towns situated from Digha (39 km), Junput (37.8 km), Contai (28.7 km), Kharagpur (80.9 km), Kolkata (186 km), and Haldia (102.7 km) are important to the connectivity and accessibility of the study area. In Egra, the wet season is hot, oppressive, and overcast, and the dry season is warm, muggy, and mostly clear sky. Over the course of the year, the temperature typically varies from 59°F to 92°F and is rarely below 54°F or above 97°F. Egra area consists of clay loamy soil character. As per the 2011 Census of India, Egra had a total population of 30,148, of which 15,291 (51%) were males and 14,857 (49%) were females. Population below 6 years was 3,241. The total number of literates in Egra was 23,447 (87.14% of the population over 6 years). Egra is a municipal city in the district of Purba Medinipur, West Bengal. The Egra city is divided into 14 wards.

Objectives

We know there are some specific and special aims and objectives behind any study or activity. The main objectives of the study are

- To provide an idea about the existing road network of the municipality.
- To study structural analysis and its application to the study area.
- To find out the special pattern of road network development in the study area.

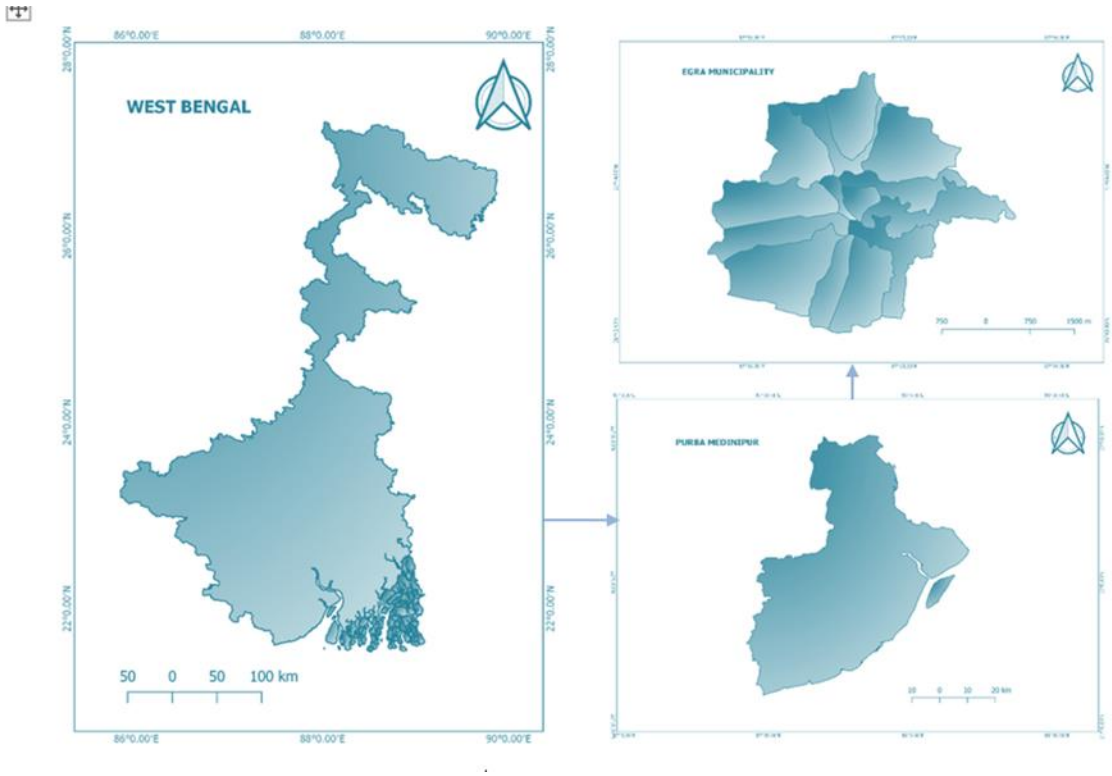


Figure 1 Location map of the study area

1.2. Data and methodology

The work is based on primary and secondary sources of data. Primary data is collected by visiting the 14 wards of the Egra Municipality Area. Secondary data is collected from the Egra Municipality and through Google Street Maps, websites, and other published materials, the internet, and maps of the Egra Ward Map. For the study, connectivity and accessibility were determined using various structural analysis methods. The degree of connectivity measures the completeness of the links between nodes. The accessibility is measured by the alpha index, beta index, gamma index, cyclomatic index, and road density. The important places are determined by the area in Egra Municipality randomly selected for the study, and accessibility is determined by counting the road linkages between them.

1.2.1. Road Density

The length of the road per square kilometre of area is known as road density**.** A higher value indicates more connectivity and efficiency.

$$\frac{\text{Road Length}}{\text{Area Sq. Km}}$$

1.2.2. Alpha Index ($\boldsymbol{\alpha}$)

One of the most useful measures of the connectivity of a network, particularly a fairly complex network. A higher value indicates more connectivity and efficiency.

$$\boldsymbol{\alpha} = \frac{\mu(\boldsymbol{e} - \boldsymbol{v} + \mathbf{1})}{\mathbf{2}\boldsymbol{v} - \mathbf{5}}$$

1.2.3. Beta Index ($\boldsymbol{\beta}$)

It is a very simple measure of connectivity, which can be found by dividing the total number of arcs in a network by the total number of nodes. A higher value indicates more connectivity and efficiency.

$$\beta = \frac{e}{v}$$

1.2.4. Gamma Index (γ)

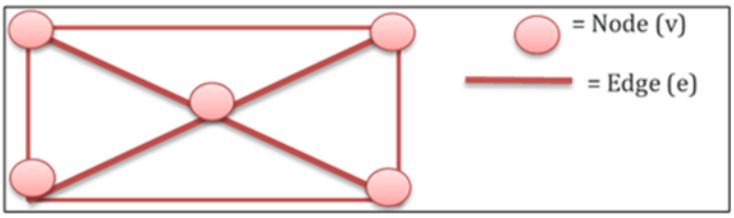
The gamma index (y) is a ratio between the observed number of edges and nodes of a network. A higher value indicates more connectivity and efficiency

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

1.2.5. Cyclomatic number (μ)

Cyclomatic number is a different way of measuring connectivity. A higher value indicates more connectivity and efficiency.

$$\mu = e - v + 1$$



The whole process is shown in the following chart (Fig. 2).

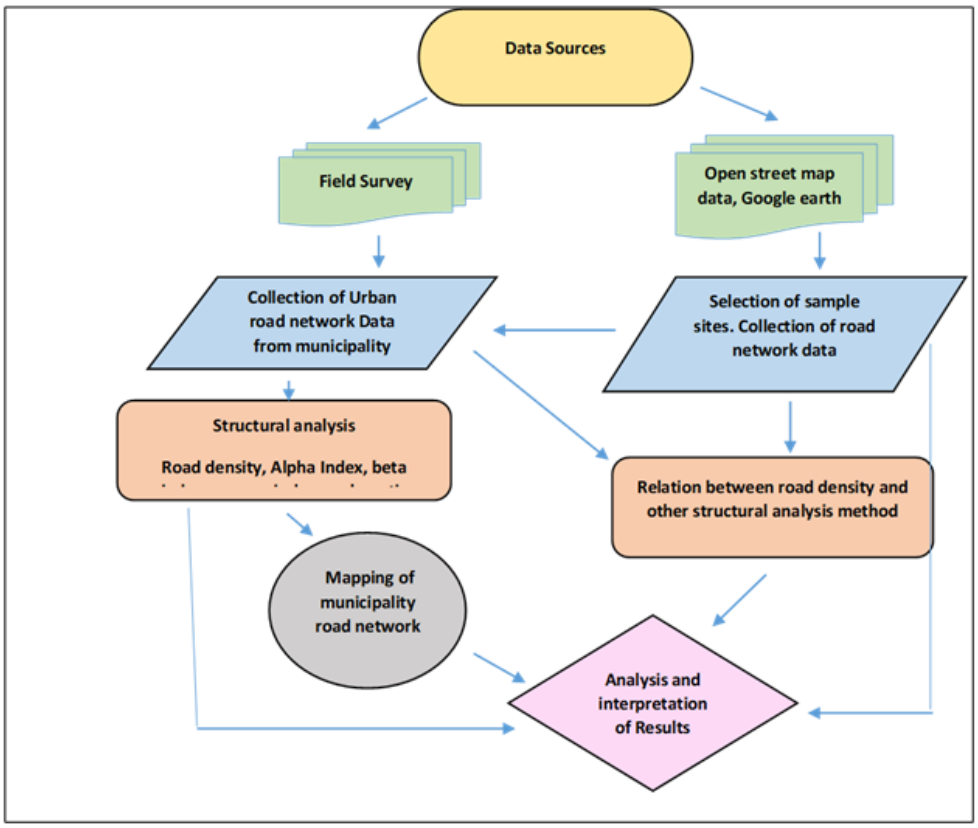


Figure 2 Flow chart of the study

2. Results and discussion

2.1. Existing road networks of the study area

Analysis of Network and Accessibility Facilities in the Egra Municipality Area A transport network is established with a view to facilitating economic and social activities both at the intra- and inter-regional levels. But once it is established, it plays an important role in shaping the space economy itself. The maximum possible limit to the amount of interaction between the nodes and the hinterland is determined by the availability of network facilities. When it comes to transportation networks, it is considered a neutral area. The transportation structure in Egra Municipality is composed mainly of roadways. The roadways are more important than other modes of intraregional transportation, especially on the micro level, because of the high flexibility and low expenditure involved in their construction. The degree to which a location is cut off by the transportation network on which it is built defines its accessibility.

The transportation system is important for urban and social development. The roles of urban transportation explained above are important because they affect the demand and supply of urban land. The transportation system influences virtually every aspect of community life. They are the means for moving people, goods, and services throughout communities, the region, and increasingly, to destinations around the Egra municipality, which is of equal importance. And the livability of our communities As a result, transportation planning is a particularly important component in the overall planning of what we want our communities to be.

Egra has rarely had good roads, especially in the central parts of the city. Internal city roads are in disrepair. The roads are narrow and winding and do not allow for fast traffic movement. People move to their work places and return both at peak hours. Congestion on roads is inevitable. Poorly maintained roads, heavy traffic, and waterlogging every year damage the road. The trend of trips and their frequency are increasing with the increase in income levels migration, participation of women, and a service oriented economy. Off street parking is another problem faced by urbanites. There is an acute shortage of parking spaces both on and off the streets in Egra . There is a lack of multi-level parking in most of the cities; hence, off street parking produces problems with the easy flow of traffic.

Table 1 Existing road networks

Ward No	Mouza Name	Area (sq/km)	Pitch road (km)	Concreat + moram road (km)	Raw road (km)	Total length of road (km)
1	KasbaEgra,PurbachakAluya	1.3	2.5	1.157	0.15	3.807
2	Ulipur, Dalaluya,Bastiya	1.56	2.85	1.252	0.17	4.272
3	Dalaluya, Bastiya	1.25	1	0.948	0.52	2.468
4	Aluya, Bansidharpur	1.76	2.65	1.55	0.14	4.34
5	KasbaEgra	1.05	1.1	1.1	0.25	2.45
6	KasbaEgra	1.25	1.25	1.15	0.2	2.6
7	KasbaEgra	0.5	0.7	0.65	0	1.35
8	Purusottampur, Mahespur	1.5	3.5	1.65	0.15	5.3
9	Aklabad	1.08	1.5	1.2	0.1	2.8
10	Aklabad	1.15	2.25	1.05	0	3.3
11	Jagannathpur,Nurpur, Bajrapur,Badhjyakhol	1.62	2.8	2.6	0.12	5.52
12	KasbaEgra	1.06	1.25	1.175	0.18	2.605
13	KasbaEgra	0.75	1.75	1.05	0.25	3.05
14	Adlabad	1.12	1.5	1.118	0.118	2.728

Source: Egra Municipality office

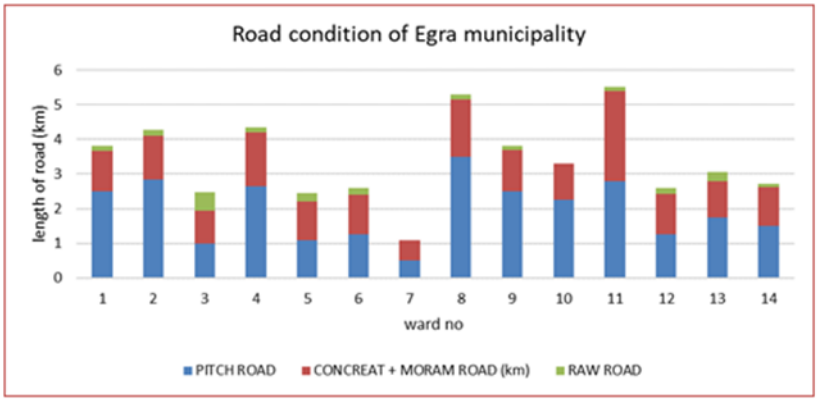


Figure 3 Road condition of Egra Municipality

2.2. Structural analysis of road network of Egra Municipality

Table 2 Ward wise composite score of road networks

Ward No	MouzaName	Node (v)	Edge (e)	Alpha Index (α)	Beta Index (β)	Gamma Index (γ)	Cyclomatic Index (μ)	Road Density
1	KasbaEgra,PurbachakAluya	81	92	0.08	1.14	0.39	12	2.93
2	Ulipur, Dalaluya,Bastiya	65	71	0.06	1.09	0.37	07	2.74
3	Dalaluya, Bastiya	31	33	0.05	1.16	0.41	03	1.97
4	Aluya, Bansidharpur	53	59	0.07	1.11	0.38	07	2.46
5	KasbaEgra	67	79	0.10	1.18	0.40	13	2.33
6	KasbaEgra	55	62	0.07	1.13	0.39	07	2.08
7	KasbaEgra	18	21	0.13	1.17	0.44	04	2.7
8	Purusottampur, Mahespur	84	96	0.08	1.14	0.39	13	3.53
9	Aklabad	57	58	0.02	1.10	0.38	02	2.59
10	Aklabad	41	41	0.01	1.19	0.42	01	2.87
11	Jagannathpur,Nurpur, Bajrapur,Badhjyakhol	43	55	0.16	1.28	0.45	13	3.41
12	KasbaEgra	26	28	0.06	1.08	0.39	03	2.46
13	KasbaEgra	28	34	0.14	1.21	0.43	07	4.07
14	Adlabad	44	52	0.11	1.18	0.41	09	2.43

Source: Computed by Author

2.3. Road density

The length of the road per square kilometer of area is known as road density. A higher value indicates more connectivity and efficiency. The average density of the road network system of the Egra municipality is 2.65 km / Sq. Km. The municipality has been classified into three regions on the basis of road density (Table 3, Fig 4). Seven wards, namely 3(1.97), 4(2.46), 5(2.33), 6(2.08), 9(2.59), 12(2.46), and 14(2.43), belong to the lower road density region. On the other hand, four wards, namely 1(2.93), 2(2.74), 7(2.7), 10(2.87), belong to themoderate road density region, while only three wards, namely 13(4.07), 8(3.53), 11(3.40) belong to a high-road density region.

Table 3 Summery for Road Density

Category	Range	Ward No
High Density	3.37-4.07	13,8,11
Medium Density	2.67-3.37	1,2, 7,10
Low Density	1.97-2.67	3,4,5,6,9,12,14

Computed by Author

2.3.1. Alpha Index (α)

One of the most useful measures of the connectivity of a network, particularly a fairly complex network. A higher value indicates more connectivity and efficiency.Alpha index gives the range values from 0 to 1 that is from 0 to 100 per cent. The higher the index, the greater is the degree of connectivity in the network. The municipality has been classified into three regions on the basis of Alpha values (Table 4, Fig 4). Five wards, namely 2(0.06), 3(0.05), 9(0.02), 10(0.01), 12(0.06) belong to the lower road connectivity region. On the other hand, five wards, namely 1(0.08), 4(0.07), 5(0.10), 6(0.07), 8(0.08) belong to the moderate road connectivity region, while four wards, namely 7(0.13), 13(0.14), 14(0.11), 11(0.16) belong to a high-road connectivity region.

Table 4 Summery for Alpha Index (α)

Category	Range	Ward No
Higher value	0.11-0.16	7,13,14,11
Medium value	0.06-0.11	1,4,5,6,8
Lower value	0.01-0.06	2,3,9,10,12

Computed by Author

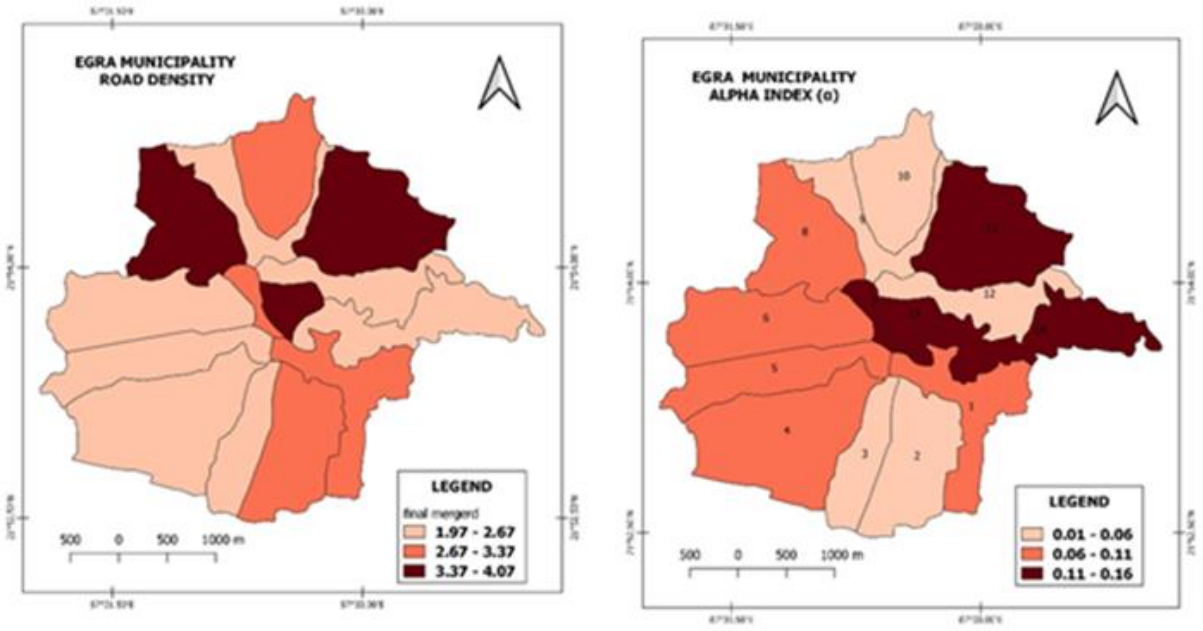


Figure 4 Road density Alpha index

2.3.2. Beta Index (β)

It is a very simple measure of connectivity, which can be found by dividing the total number of arcs in a network by the total number of nodes. A higher value indicates more connectivity and efficiency. The beta index ranges from 0.0 for

networks, which consist just of nodes with no arcs, through 1.0 and greater where networks are well connected. The municipality has been classified into three regions on the basis of beta values (Table 5, Fig 5). Seven wards, namely 1(1.14), 2(1.09), 4(1.11), 6(1.13), 8(1.14), 9(1.10), 12(1.08) belong to the lower road connectivity region. On the other hand, six wards, namely 3(1.16), 5(1.18), 7(1.17), 10(1.19), 13(1.21), 14(1.18) belong to the moderate road connectivity region, while only one ward, namely 11(1.28) belongs to the high road connectivity region.

Table 5 Summery for Beta Index (β)

Category	Range	Ward No
Higher Value	1.213-1.28	11
Medium Value	1.147-1.213	3,5,7,10,13,14
Lower Value	1.08-1.147	1,2,4,6,8,9,12

Computed by Author

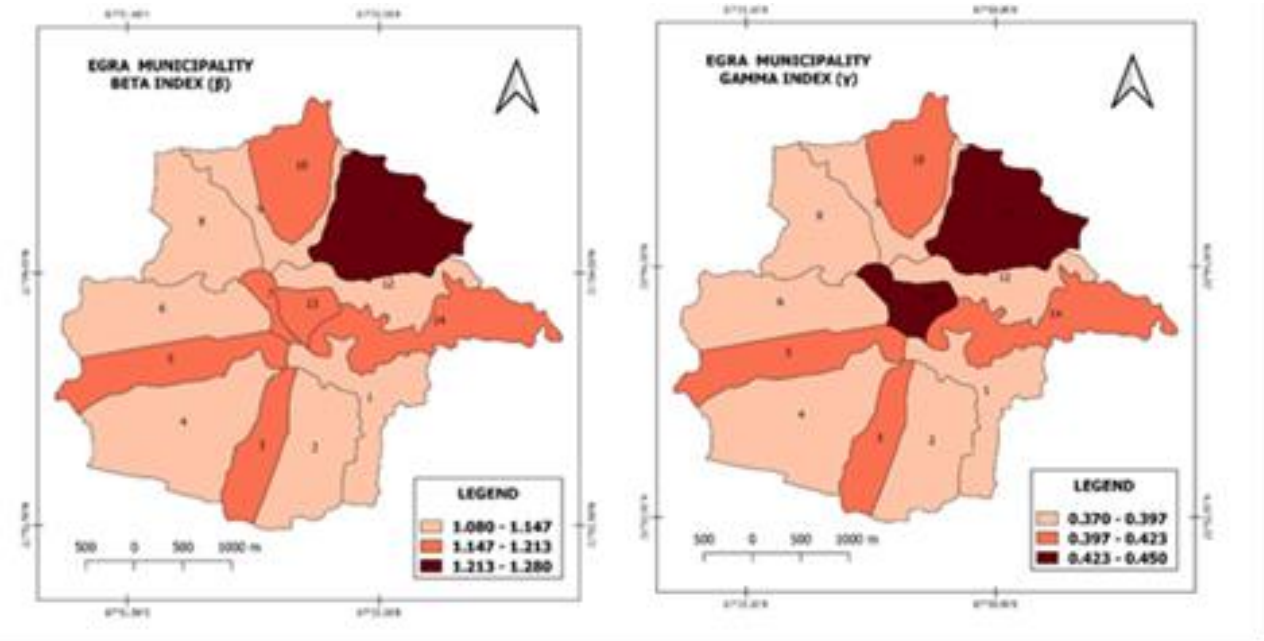


Figure 5 Beta Index, Gamma Index

2.3.3. Gamma Index (γ)

The connectivity of the network is evaluated in terms of the degree to which the network deviates from an unconnected graph and approximates a maximally connected one. The numerical range for the gamma index is between 0 and 1. The gamma index (γ) is a ratio between the observed number of edges and nodes of a network. A higher value indicates more connectivity and efficiency. The municipality has been classified into three regions on the basis of gamma values.(Table 6, Fig 5) Seven wards, namely 1(0.39), 2(0.37), 4(0.38), 6(0.39), 8(0.39), 9(0.38), 12(0.39) belong to the lower road connectivity region. On the other hand, four wards, namely 3(0.41), 5(0.40), 10(0.42), 14(0.41) belong to the moderate road connectivity region, while only three wards, namely 11(0.45), 7(0.44), 13(0.43) belong to the high road connectivity region.

Table 6 Summery for Gamma Index (γ)

Category	Range	Ward No
Higher Value	0.423-0.450	11,7,13
Medium Value	0.397-0.423	3,5,10,14
Lower Value	0.37-0.397	1,2,4,6,8,9,12

Computed by Author

2.3.4. Cyclomatic Index (μ)

This is based upon the condition that as soon as a connected network has enough arcs or links to form a tree, then any additional arcs will result in the formation of circuits. The municipality has been classified into three regions on the basis of gamma values (Table 7, Fig 6). Four wards, namely 3(3), 7(4), 9(2), 10(1) belong to the lower road connectivity region. On the other hand, six wards, namely 2(7), 4(7), 6(7), 14(9), 12(3), 13(7) belong to the moderate road connectivity region, while only four wards, namely 1(12), 5(13), 8(13), 11(13) belong to the high road connectivity region.

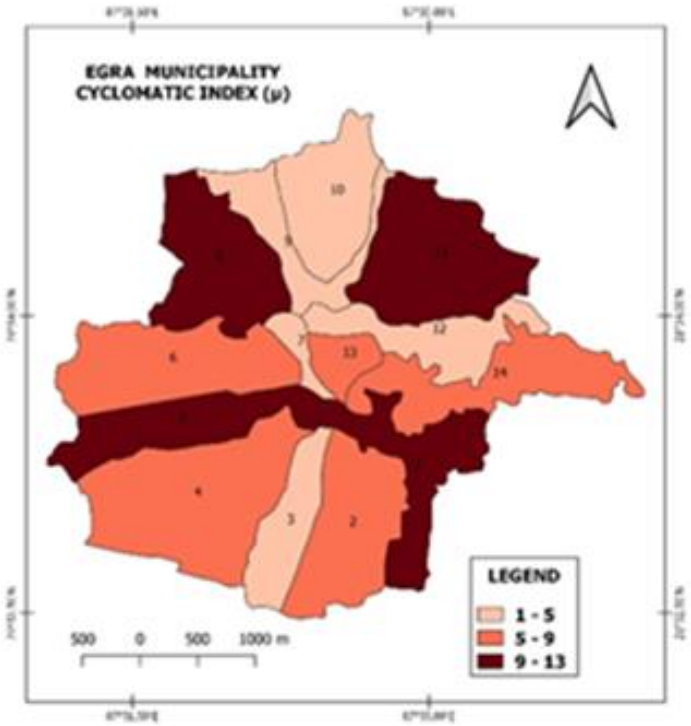


Figure 6 Cyclomatic Index

Table 7 Summery for Cyclomatic Number (μ)

Category	Range	Ward No
Higher Value	9-13	1,5,8,11
Medium Value	5-9	2,4,6,12,13,14
Lower Value	1-5	3,7 ,9,10

Computed by Author

2.4. Suggestions

Egra Municipality is most important for its surroundings growth and development. But the Egra Town area has so many problems due to overpopulation. Therefore, to solve all the civic problems of this town and its adjoining peripheral area, the planning authorities at the state and central levels should prepare a master plan for all of its urban regions. To develop the outskirts of Egra town, proper planning is required. Migration leads to the sprawling of the urban area. So consequently, Road density increases. This urban area is extended in a haphazard manner. There is no proper planning for the development of the urban area.

- There should be proper planning to develop this urban area and take proper management measures.
- Transport and communication systems have to be developed more.

3. Conclusion

The study focused on a connectivity analysis of Egra Municipality during the year 2020. A structural method is applied to determine the accessibility of various wards. We calculate 693 nodes and 781 links (based on field observation and information collected). The road density in the municipality was greater than the average of 2 km per square km. That indicates the degree of connectivity of this municipality as well. As a result, 11, 13 no wards recorded the maximum degree of connectivity, and 14, 5 no wards recorded a fairly good degree of connectivity. On the other hand, the remaining wards are situated in areas with low degrees of connectivity. Now a days, gradually, the existing administrative boundary is being extended towards the periphery. So, the transport communication system and basic amenity facilities have to be improved. Therefore, it would suggest that there is a need to improve the connectivity and accessibility of those periphery areas for the future growth and development of the Egra Municipality. So, the transport communication system, basic amenities (e.g., garbage, sewerage, drainage, sanitation, and drinking water facilities) have to be improved. Municipality authorities should be concerned about the development of this urban area, and if the area can be developed in a proper manner, this area may be developed as an ideal urban area.

Compliance with ethical standards

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Disclosure of conflict of interest:

There are no conflicts of interest regarding the publication of this paper.

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