The Jahangirnagar Review: Part II: Social Science, Vol. XLV, 2021
Printed in December 2021, ISSN 1682-7422 © Jahangirnagar University

Assessment of Road Network Accessibility in Savar Upazila: A Geospatial Approach

Bibi Hafsa*
Raju Ahmed**

Abstract: Transport network plays a vital role in sustainable development and provide access to people, places, goods and services. The transport network analysis provides a complete scenario of a region's transportation facility with geographical distribution pattern. The purpose of this research is to conduct a structural examination of the road network of Savar Upazila, the outskirts of Dhaka city, where traversed by a prominent national highway (Dhaka-Aricha, N5) that also passes the concentric industrial export processing zone surrounding Dhaka. The research has applied road network connectivity and accessibility analysis according to graph theory. The various indices of connectivity and accessibility were accomplished in Microsoft Excel. Google Earth Pro has been used for road database extraction. Nodes and Arcs have been assessed and identified by using ArcGIS tools. Although, database conversion, assessment and representation of maps were conducted with ArcGIS. This research reveals the most accessible zone is Savar Paurashava and the significantly less accessible zone is Amin Bazar, Yearpur, and Shimulia in Savar Upazila. The low road network connectivity indices of α, β, γ of Savar Upazila chronologically 0.026, 0.94, 31٪ which indicates the road network system is inferior and not well connected. However, the connectivity and accessibility indices have mostly remained consistent, showing that this study area's physiographic circumstances are nearly identical and that road connectivity is inadequate. In this circumstance, the road network structure needs to be enhancement of existing linkages reflected in variations in nodal accessibility in Savar Upazila.

Keywords: Transport network, Topology, Connectivity, Accessibility, Structural Analysis.

1. Introduction

Enhanced communication and transportation infrastructure encourages economic development (Rodrigue, 2016). Network analysis could be used to understand several types of development, in addition to endogenous and exogenous development (Tomasello et al., 2014). The network comprises nodes or vertices connected by edges, with vertices being specific locations in space and edges in transportation networks being genuine physical constructs like roads or train lines (Lin and Ban, 2013; Rodrigue and Ducruet, 2021). Road networks have a significant impact on social and economic development, and they are an essential component of public infrastructure. When new roads are built, or old roads are enlarged and repaired, the travel time is reduced, which enhances the accessibility of the zones. As a result of increased accessibility, changes in the population

---

* Assistant Professor, Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh. Email: hafsa@geography-juniv.edu.bd

** Postgraduate Researcher, Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh. Email: raju.45@geography-juniv.edu.bd.

and employment distribution occur (Gibbons et al., 2019). The transportation network is a crucial medium for human civilization since it allows people to operate in different areas. At both the national and international levels, enhanced transportation infrastructure directly positively impacts spatial accessibility. One of the essential features of assessing accessibility in a given location is that it determines the performance of the road network (Lv et al., 2021). The expansion of transportation networks is necessary for areas to achieve better mobility and economic growth opportunities. Although economic and social growth in a given region is typically concentrated in the large city and its agglomeration, a fair accessibility aim is to reach this center from the farthest settlement in a reasonable length of time (Gao and Sun, 2021). A modern World's economic, social, and political life is based on a well-functioning transport system. People need transportation to get to services, whether it's to our community centers or work. Many emerging states' economic backwardness is due to a lack of modern transportation systems. The transportation infrastructure plays a vital role in essential determinants of a country's achievement (Rodrigue and Notteboom, 2020). The reputation of transportation cannot be overstated, and it is sometimes referred to as the nation's "lifeline" despite Bangladesh's broad transportation industry. The importance of road transport in the growth and development of cities cannot be overstated. However, the proper growth of a region is dependent on the transport network. The transport network analysis provides a broad scenario of the geographical distribution pattern of transportation facilities in a given region. It is an essential part of transport geography since it entails describing the location of nodes, their interactions, and the distribution line or linkage. (Rodrigue and Ducruet, 2020). It is useful in advancing transport planning in the region in order to improve transportation productivity. More physical infrastructure investment, particularly in the road transport network, will bring the interior regions closer to the markets and minimize regional disparities (Amin, 2009). In this research, Savar Upazila has been considered to analyze the accessibility of transport networks. Savar Upazila is a prominent periphery region of Dhaka, which is works as connectivity and linkage to the Dhaka headquarters, where it is crossed by a major national highway (Dhaka-Aricha N5) that also travels through the concentric industrial export processing zone that surrounds Dhaka. As a result, this Upazila is connected to a complex transport network that supports a diverse range of economic activity (Mahmud et al., 2021). This region's transport is a vital human activity with a high spatial component that influences the geographic variance in other social and economic activities. The 'quantitative revolution' of the 1960s provided transport geographers with valuable new approaches and strategies for studying networks and effectively articulating their form and degree of complexity (Taaffe and Gauthier, 1973). However, no extensive study has been undertaken to determine the connectivity and accessibility of sites in the region, despite the fact that it is reasonable to conclude that the region has low connectivity and accessibility compared to international levels and indices. Generally, road network plays a vital role in bringing about sustainable growth (ESCAP, 2016). Structural analysis of transport systems is essential to evaluate the transport network. The study has applied road network connectivity and accessibility analysis according to graph theory which is explained with various indices and accomplished.

2. Aim and Objectives

The board aim of this research is to conduct a structural examination of the road network of Savar Upazila in the Dhaka District. The study accomplished two objectives that contributed to the achievement of the research goal.

I. To illustrate the existing road topological network of Savar Upazila; and

II. To examine the connectivity and accessibility of road network systems in the Savar Upazila.

3. Study Area

Savar Upazila is located between 23°44'and 24°02' North latitudes and in between 90°11' and 90°22' East longitudes. The Upazila occupies an area of 280.12 sq. km, including 20 sq. km of river and 8 sq. km of the forested area (Banglapedia, 2015). The population of Savar Upazila was 1,385,910, where the population density was 4948 person/km (BBS, 2011). It has a fast-rising population and has seen a shift in its traditional agrarian land usage in recent decades as a result of rapid urbanization and industrialization. The study area has been under the administration of the RAJUK since 1995. The Dhaka-Aricha highway in Savar's principal transit route, covering around 30 km through the Upazila. The development has resulted in a significant change in the landscape in this study area due to the transport network accessibility (Amin, 2009). Shimulia, Dhamsona, Yearpur, Ashulia, Birulia, Bhakurta, Pathalia, Banagram, Kaundia, Tetuljhora, and Amin Bazar are among the 11 unions that make up Savar Upazila. The highway (Dhaka-Aricha, N5) crossed the Savar Paurashava, Pathalia, Banagram, Kaundia, Tetuljhora, and Amin Bazar (Figure-1). As a result, all of the unions' growth and development fluctuated due to the road network accessibility. In these unions, a lot of infrastructures have been built along this highway. The most important landmarks in the Pathalia union at Savar include Jahangirnagar University, National Memorial, Savar Cantonment, Savar dairy farm, Radio station, and Bank colony established along the highway. However, the roadway had little impact on urban development in the Banagram, Tetuljhora, and Amin Bazar unions, which are still characterized by agrarian culture and rural villages. The Dhaka-Aricha highway, one of Bangladesh's essential highways that connects numerous divisions, runs through Savar Upazila's urban center and acts as the main artery of vehicle transportation. The Upazila's terrain is made up of alluvium dirt from the Pleistocene epoch. From east to west, the elevation of the ground progressively rises. The alluvium soil of the Bangshi and Dhalashwari rivers makes up the Southern section of the Upazila (Sultana et al., 2017). Bangshi, Turag, Buriganga, and Karnatali are the major rivers. There are 62 kilometers of first-class pucca, 56 kilometers of semi-pucca, 562 kilometers of mud road, and 50 kilometers of highway (Banglapedia, 2015).

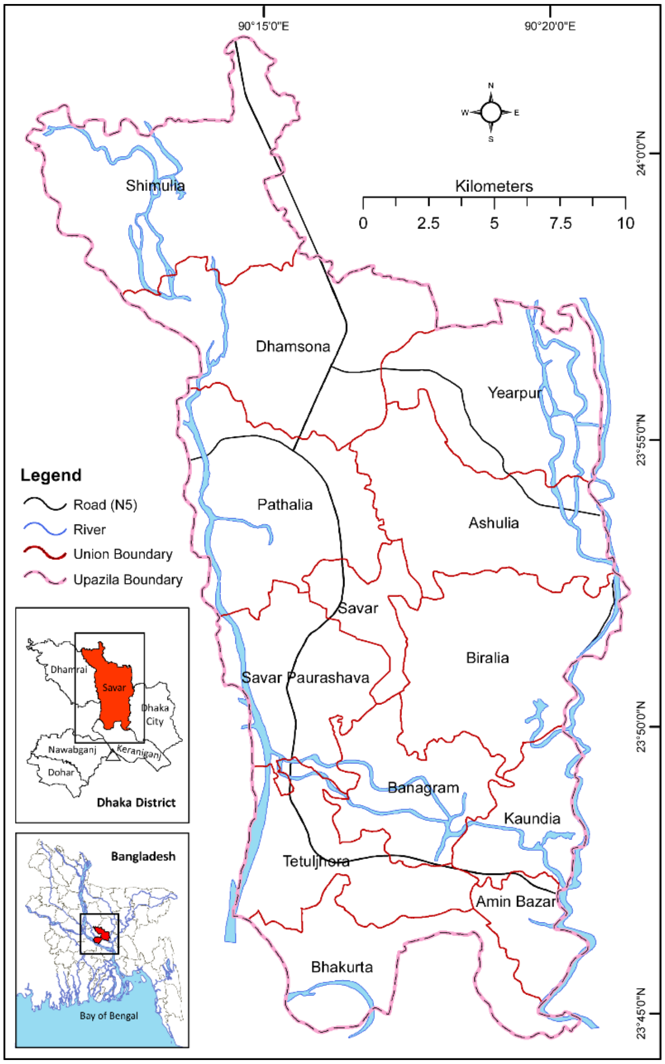

Figure 1: Study area in this research.

4. Materials and Methods

The transport system is heavily reliant on the flow of products and services and as a result, it promotes economic and social growth. Although, transport is essential in any part of the world. The improved road networks accessibility and mobility, resulting in considerable reductions in travel time and expenses. The strengthening of the road network is linked to socioeconomic changes such as access to education, health care, employment possibilities, household income, and poverty reduction. The essential components that demonstrate the degree of accessibility are nodes, vertices, and edges. This research has been conducted with secondary databases that were collected and extracted from various sources. The road database has been extracted from Google earth pro, which was conducted with digitization techniques. The extracted road file has been converted to Geodatabase using ArcGIS. Although, the quantifications of network topology line segments and points in the study area as a Geodatabase. The assessment of road network accessibility, road nodes and arc has been calculated and identified using the network dataset tools under the network analyst tools in ArcGIS. The road network spatial organization has been identified based on the graph theory. The Alpha Index, Beta Index, and Gamma Index have been used for assessing the connectivity of transport road networks in this study area. The level of road network accessibility was assessed with the shortest path matrix, associate number, and shimbel index. Microsoft Excel has been used for conducting the calculation of accessibility indices. The research of abstract arrangements made up of points and lines is known as graph theory. If a real-world system is idealized as a set of points (vertices) connected by a set of line segments, it can provide certain metrics of its structural features (edges). The study applied road network connectivity and accessibility analysis according to graph theory which explained various indices. The research methods of this study are illustrated extensively in Figure-2.

Figure-2: Pipeline of this research.

4.1 Application of network indices based on graph theory

Various network indices based on graph theory are used to evaluate the accessibility and performance of the network analysis. A graph is a collection of points known as nodes or vertices that are linked together by a network of lines known as edges. Vertices are dots that appear at the intersection of two or more edges, while edges are lines that link two vertices. Garrison and Marble (1962, 1964, 1965) made significant contributions to this discipline by developing the Alpha (α), Beta (β), and Gamma (γ) Indexes. This research revel is based on a few selected graph theory metrics that determine network indices.

4.2 Connectivity Indices

Connectivity refers to the density of connections in a pathway or road network and the directness of interconnections. Many short links, multiple intersections, and few dead ends characterize a well-connected road or path network. Connectivity of the roadway network is achieved by providing connections within individual developments, between developments, and by having a well-planned collector road network to supplement the arterial highway network (Qian et al., 2012). A connectivity index, generally defined as the ratio of links to nodes, can assess the study area's connectivity. As for connectivity increases, travel distances decrease, and route alternatives expand, allowing for more direct travel between destinations and a more efficient transportation system. To assess the connectivity of the present network system following indices have been used.

Alpha Index (α) is one of the essential network connection indicators. Alpha's value ranges from 0 to 1. The number 0 denotes the lowest level of connection, while 1 denotes the highest level. This metric is also given in percentiles.

$$\alpha = \boldsymbol{e} - \boldsymbol{v} + \mathbf{1}/\mathbf{2}\boldsymbol{v} - \mathbf{5} \ldots\ldots\ldots\ldots 1$$

Where, α indicates the Alpha Index, $\boldsymbol{e}$ means numbers of edges, and $\boldsymbol{v}$ means numbers of vertices.

Another basic network connection metric is the Beta Index (b). The number of links divided by the number of nodes is known as the link-to-node ratio. This index has a range of 0 to 1 as a value. Where 0 denotes the least amount of connectedness and 1 denotes the most. When the graph is complicated, the beta index surpasses one. The following formula is used to compute the Beta Index (β):

$$\beta = \boldsymbol{e}/\boldsymbol{v} \ldots\ldots\ldots\ldots 2$$

Where, β indicates Beta Index, $\boldsymbol{e}$ means the numbers of edges, and $\boldsymbol{v}$ means the numbers of vertices.

The connection between the number of observed and potential linkages in a graph is known as the Gamma Index (c). The gamma index ranges from 0 to 1 in value. The more the connectedness, the greater the value, and vice versa. The following is how you calculate the Gamma Index (c):

$$\gamma = \boldsymbol{e}/3(\boldsymbol{v} - \mathbf{2}) \ldots\ldots\ldots\ldots 3$$

Where, γ indicates the Gamma Index, $\boldsymbol{e}$ means numbers of edges and $\boldsymbol{v}$ means numbers of vertices.

4.3 Accessibility Indices

The structure of the transportation network determines accessibility. The most fundamental metric of accessibility is network connectivity. As a result, a connection matrix is generated to display the amount of accessibility. Because they are well linked, places with excellent connectivity are considered the finest location (Pearce et al., 2021). Weaker connection index values imply lower connectedness and vice versa. In this research, accessibility indices have been analyzed with the shortest path matrix, associated number, and shimbel index.

i. Shortest Path Matrix (SPM)

The Shortest Path Matrix (SPM) is a measure of the road network's efficiency. The computation of SPM takes a long time. It's the average number of steps taken along the shortest pathways for all feasible pairs of node networks. The higher the SPM value indicates, the lower the efficiency, and vice versa, which is calculated as:

$$SPM = \frac{\sum_{ij}^{n} d(vij)}{\sum_{ij}^{n} h(vij)} \quad \text{.......} 4$$

Where, SPM indicates the Shortest Path Matrix, $d(vij)$ represents all the pairs' shortest path lengths of the graph, $h(vij)$ represents the number of paths in the graph and n indicates the number of nodes.

ii. Associated number

Another metric for network accessibility is the associated number. Koning proposed it for the first time in 1936. It may be defined as the greatest distance between any two points. The associated number is the number of arcs required to link it to the furthest node. The highest number in each row is the related number. Lower accessibility is indicated by a higher value of the accompanying number and vice versa. The Centrality index is another name for a related number.

iii. Shimbel index

The Shimbel index is often used to assess the network's accessibility, and it is the total of all the shortest path lengths between all points (edges and nodes) in a circuit. A lower shimbel index number suggests more accessibility and vice versa. The Shimbel index is calculated as follows:

$$SI = \sum_{(i=1)}^{n} dij \quad \text{.......} 5$$

Where, SI is for the Shimbel index, dij stands for the shortest distance between nodes i and j, and n stands for the number of nodes.

5. Result and Discussion

When new roads are built or old roads are enlarged and repaired, the travel time is reduced, which enhances the accessibility of the zones. As a result of increased accessibility, changes in the population and employment distribution occur. The transportation network is a crucial medium for human civilization since it allows people to operate in different areas. At both the national and international levels, enhanced transportation infrastructure directly positively impacts spatial accessibility. One of the essential features of assessing accessibility in a given location is that it determines the performance of the road network. The Dhaka-Aricha Highway (N-5) runs through the Savar Upazila, connecting Dhaka with Bangladesh's northern region. Improving living standards and making the most use of existing transport networks are critical for the growth of this research area. Network analysis is widely used to comprehend a region's network infrastructure. The network analysis is a complicated process.

5.1 Structural Transport Network of Savar Upazila

Transport networks are extremely complicated spatial systems, and graph theory is used to analyze them. All types of flows are based on point-to-point movement, which is also responsible for spatial arrangements. A topological map or graph simplifies a transportation network to its most basic form, making it easier to comprehend the properties of transportation networks (Kansky, 1963). The topological transformation of actual routes of the study area is depicted in Figure-3. It is crucial to idealize the network into the form of a graph in order to apply graph theory to the analysis of a transportation network. It serves as the foundation for determining the structural features of a transportation system. These elements have been identified in topological networks, i.e., Nodes or vertices (v), Edges or links (e). The Nodes points that make up the fundamental constituents are known as vertices, referred to as nodes. Nodes or vertices are located at the junctions of two or more areas where a node at the end of an arc is known as an end node. On the other hand, the Edges or link lines connecting the vertices or nodes are called edges or links. Arcs are lines representing routes that link nodes. One arc only may link two nodes. The essential measures of transport networks are accessibility and connectivity of networks. Shows the structural network of the study area union wise (Figure-3):

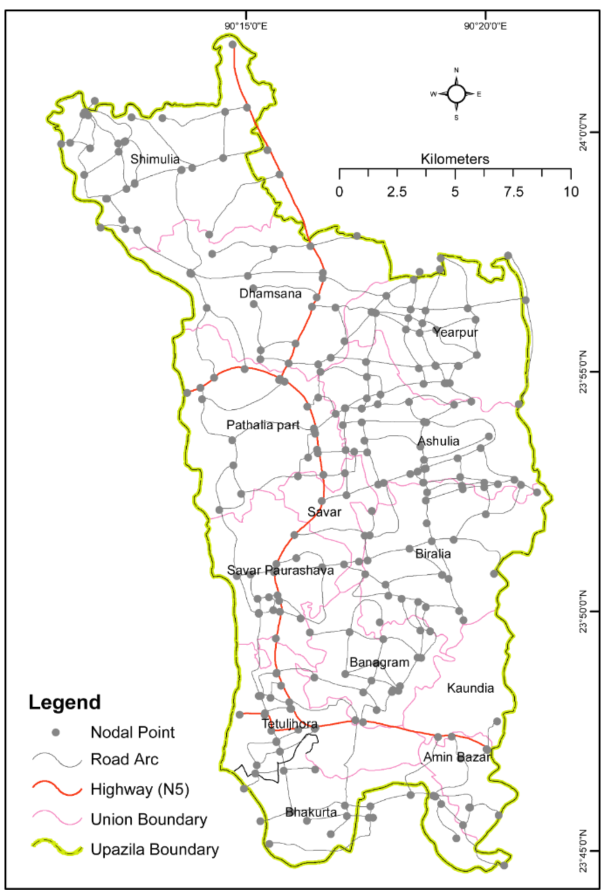

Figure-3: Structural network of the study area by union wise.

In this research, Ashulia occupied a significant number of nodal points and road arcs due to industrialization and structural development within the whole of Upazila. On the other hand, Kaundia engaged the lowest number of nodal points and road arc due to their low accessibility and development (Table-1).

Table-1: Structural network of the study area by union wise.

Union Name	No. of Nodal Point (v)	No. of Road Arc (e)
Amin Bazar	17	15
Ashulia	74	79
Banagram	41	33
Bhakurta	37	23
Biralia	60	46
Dhamsona	36	43
Kaundia	6	4
Pathalia	44	43
Savar	26	21
Savar Paurashava	36	36
Shimulia	37	44
Tatuljhora	42	38
Yearpur	44	48

5.2 Connectivity of Savar Upazila

According to Taaffe and Gauthier, 1973 “The degree of connection between all vertices is defined as the connectivity of the networks.” The higher the level of connectivity inside a transport network, the more efficient that system will be. Kansky (1963) researched the topology of transport networks and established several indices for assessing network connection. The *alpha*, *beta*, and *gamma* indices were used to quantify the connectivity of the transport network in this study.

5.2.1 Alpha index (α): One of the most features is available of network connectivity. The alpha index is the proportion of a network's actual number of circuits to its maximum feasible number of circuits. The Alpha index is a number that ranges from 0 to 100. The greater the degree of network connectivity, the higher the index. If the value approaches 100, it indicates that the network is increasingly connected (Saxena, 2010). In the Yearpur road network system, the value of Alpha index is 0.60 or 60% (0.60*100=60%). So, this network cycle is 60% of the maximum (Table-2). That means the connectivity of this network is good. This union road network system is better than any other union. It has a higher number of cycles than any other union road network.

5.2.2 Beta index (β): The Beta index is a simple computation that quantifies the connectivity of a network by dividing the total number of arcs by the total number of nodes. The Beta index varies from 0 for networks consisting solely of nodes with no arcs to 1 and larger for well-connected networks. The following are some of the properties of the index:

- β value for three types of structures and disconnected networks, the value is always smaller than 1. When the network has no edges, this will provide zero values. This study area has 8 unions which a β index of less than 1 (0.062-0.97), such as; Bhakurta, Kaundia, Biralia, Banagram, Savar, Amin Bazar, Tatuljhora, Pathalia.
- β value for any network configuration with only one circuit is always 1. This study Savar Paurashava where β index is 1.
- For a complex network configuration with several circuits, the β value exceeds 1 circuit (Saxena, 2010). This study has four unions which a β index of more than 1 (table: 4). This value represents that this network is more connected compared to the others 9 union network systems.

5.2.3 Gamma index (γ): The gamma index is the ratio between a transport network's observed number of edges and vertices. The gamma index has a range of 0 to 1 as a numerical value. As defined by the index, the degree of connectivity ranges from no interconnectivity to every node in the graph having an edge connected to every other node (Saxena, 2010). This metric can be expressed as a percentage and so has a range of 0 to 100. In this network system, the most significant gamma index is 0.42 of the Dhamsona union. The network is 42 percent connected in terms of maximum connectivity, indicating that the road network is moderately connected, with nearly 50 percent of the system connected. The Gama index is less than the Dhamsona union of the study area in this case. This number denotes a lack of connectivity in this route network. α, β, γ index of Savar Upazila chronologically 0.026, 0.94, 31٪ which indicates the road network system is inferior and not well connected.

Table-2: Union-wise connectivity indices of the study area.

Union	α	β	γ
Amin Bazar	0.034	0.88	0.333
Ashulia	0.041	1.06	0.365
Banagram	0.09	0.80	0.282
Bhakurta	0.188	0.62	0.219
Biralia	0.113	0.76	0.264
Dhamsona	0.119	1.19	0.421
Kaundia	0.14	0.66	0.333
Pathalia	0	0.97	0.341
Savar	0.085	0.80	0.291
Savar Paurashava	0.014	1.00	0.352
Shimulia	0.115	1.18	0.419
Tatuljhora	0.037	0.90	0.316
Yearpur	0.602	1.09	0.380

5.3 Accessibility: According to Robinson and Bamford (1978), Accessibility is one of the most significant characteristics of a transport network, and the geographer is particularly concerned with accessibility as a locational trait. A geographer is interested in node connectivity associations in terms of accessibility when looking at a transport network. The structure of a network changes when new linkages are added, or current linkages are improved. Developments in nodal accessibility reflect these changes. The graph theory is used to calculate nodal accessibility. Any network can be described as a matrix, with rows corresponding to origins and columns corresponding to destinations. The number of rows and columns corresponds to the number of network nodes. According to the convention, the horizontal rows of a matrix are defined as origin nodes, and the vertical columns are defined as destination nodes. The research area's 13 unions have been assigned a level of nodal accessibility. Topologically, Accessibility can be evaluated in three ways, such as;

- **By shortest path matrix:** the number of arcs utilized in the shortest path between all feasible pairs is determined by the shortest path matrix.
- **By the associated number:** the number of arcs required to connect a node to the farthest away node and
- **By the Shimbel index:** obtained from the shortest path matrix, which shows how many arcs are required to connect any node to all other nodes in the network using the shortest path.

5.3.1 Road Accessibility in Study area

The current research is focused on nodal accessibility. To determine the nodal accessibility, the unions and Paurashava are used as the main nodal sites (Figure-4). The relative location of a vertex in the transport network determines the degree of accessibility to that vertex. When compared to vertices on the periphery, centrally situated vertices are frequently more accessible. The Shimbel Index was used to identify such differences in the degree of accessibility across the Study area.

5.3.2 The Network as a Matrix

Any network can be described as a matrix, with the sources and destinations represented by the rows and columns, respectively. The number of rows and columns corresponds to the number of network nodes. According to the convention, the horizontal rows of a matrix are defined as origin nodes, and the vertical columns are defined as destination nodes. Each cell entry in the matrix can be used to record information about a pair of nodes' relationships. Any node in a network that is well connected to other nodes is said to be accessible. The topological graph in Figure-4 shows that the shortest path matrix has been prepared in the appropriate squares and the number of arcs in taking the shortest path between all the paired nodes (Figure-5). The top row of figures in the matrix gives the number of arcs in the shortest path from Amin Bazar to all the other nodal centers.

5.3.3 Topological Graph

The study of transport networks has become a crucial component of geographical research. Transport networks are extremely complicated spatial systems, and graph theory is used to analyze them. A regional transport system consists of a series of point-to-point movements connecting origins and destinations. “When different points, whether in one, two, or three-dimensional space, are linked together into a structure, they are said to form a network. Such networks by carrying flows of goods, people, information or anything else that is moved from place to place, give rise to regional transport system” (Robinson and Bamford, 1978).

A topological map or graph simplifies a transport network, making it easier to comprehend its characteristics. The topological properties of line patterns or networks are described in such a map based on contiguity, relative locations, and systematization of lines and junctions rather than distances and directions.

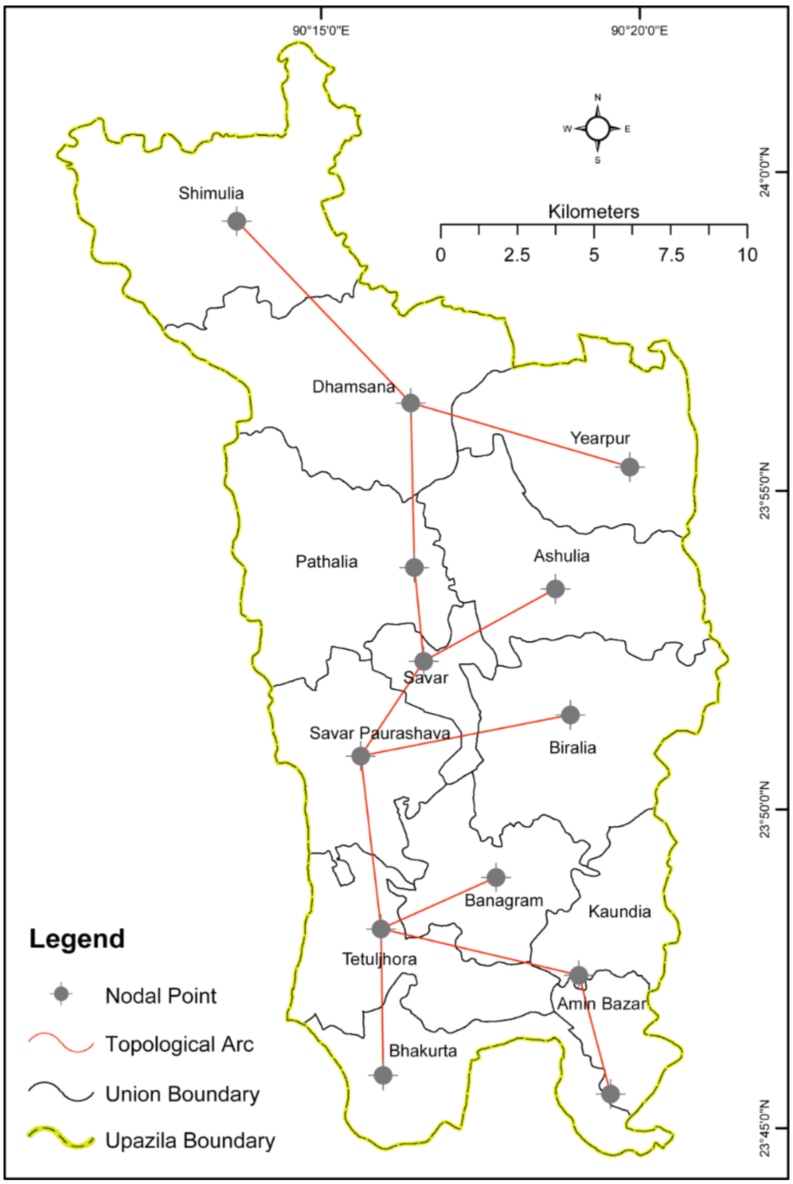

Figure-4: Topological map of the study area.

5.3.4 Shortest Path Matrix: Any node in a network that is well connected to other nodes is said to be accessible. Figure-5 depicts 13 nodes connected by a series of arcs, with the most accessible node, Savar Paurasava, readily apparent. As shown in Figure-5, accessibility can be determined by creating a matrix known as the shortest path matrix. Each row's totals can be summed up, and the node with the lowest total is the most accessible. Savar Paurasava has the lowest total (27), making it the most accessible, while Shimulia has the most incredible total (51), making it the least accessible.

5.3.5 Associated number: The number of arcs required to connect a node to the farthest node is the related number, the associated number is the highest number in each row, e.g., in row Amin Bazar, Yearpur, Shimulia7 and in row Savar Paurasava, Savar with an associated number 4 (low) is the most accessible of all nodes. Smallest associated number is the most accessible node which this study got the most accessible node is Savar Paurasava, Savar.

5.3.6 Shimbel Index: The Shimbel index, on the other hand, is generated from the shortest path matrix, which represents the number of arcs required to connect every node in the network to all other nodes through the shortest path. The Shimbel Index is calculated by adding the sum of each row. This is accomplished using the shortest path matrix (Figure-5), which shows the number of arcs required to connect every node to all other nodes in the network using the shortest path. The shortest path matrix between 13 nodal points in Savar Upazila is shown in Figure 2, illustrating their accessibility. The node with the lowest Shimbel index is the most accessible, while the node with the highest Shimbel index is the least accessible. Table-6 reveals that the 27 Shimbel value of Savar Paurasava has the greatest accessibility from all other nodal points. Because Yearpur, Shimulia, and Amin Bazar are located in the Study area's foremost union, the shortest path analysis shows that they are less accessible. Lower numbers suggest greater connectedness and accessibility, according to the Shimbel index analysis.

Nodal Point	Amin Bazar	Kaundia	Banagram	Bhakurta	Tetuljhora	Savar P.	Biralia	Savar	Ashulia	Pathalia	Dhamsona	Yearpur	Shimulia
Amin Bazar	0	1	3	3	2	3	4	4	5	5	6	7	7
Kaundia	1	0	2	2	1	2	3	3	4	4	5	6	6
Banagram	3	2	0	2	1	2	3	3	4	4	5	6	6
Bhakurta	3	2	2	0	1	2	3	3	4	4	5	6	6
Tetuljhora	2	1	1	1	0	1	2	2	3	3	4	5	5
Savar P.	3	2	2	2	1	0	1	1	2	2	3	4	4
Biralia	4	3	3	3	2	1	0	2	3	3	4	5	5
Savar	4	3	3	3	2	1	2	0	1	1	2	3	3
Ashulia	5	4	3	4	3	2	3	1	0	2	3	4	4
Pathalia	5	4	4	4	3	2	3	1	2	0	1	2	2
Dhamsona	6	5	5	5	4	3	4	2	3	1	0	1	1
Yearpur	7	6	5	6	5	4	5	3	4	2	1	0	2
Shimulia	7	6	6	6	5	4	5	3	4	2	1	2	0

Figure-5: Shortest Path Matrix for road accessibility

Table-3: Accessibility Index of Study Area

Name	Associated Number	Shimbel Index
Amin Bazar	7	50
Kaundia	6	39
Banagram	6	41
Bhakurta	6	41
Tetuljhora	5	30
Savar P.	4	27
Biralia	5	38
Savar	4	28
Ashulia	5	38
Pathalia	5	31
Dhamsona	6	40
Yearpur	7	50
Shimulia	7	51

Three accessibility measurement of the study area shows the most accessible zone is Savar Paurasava which is connected with the Dhaka-Aricha national highway and situated in the middle of the study area. Based on Shimbel Index, all the 13 nodal centers have been divided into five categories shown in Figure-6.

- **Very high Accessible Centers (Below 28):** One nodal center, namely Savar Paurasava, is included in this category which connected with other nodes
- **High Accessible Centers (28-33):** Three nodal centers, namely Savar (28), Tetuljhora (30), and Pathalia (31), lie in this category. All these centers are connected with the national highway.
- **Moderate Accessible Centers (34-39):** Three nodal centers, namely Ashulia (38), Biralia (38), and Kaundia (39), lie in this moderate category.
- **Less Accessible Centers (40-46):** Only Dhamsona lies in this category connected with Shimulia and Yearpur. This center is located near the periphery of the Upazila, and that's why it gets the high value of the Shimbel Index and is less accessible from other centers.
- **Very Less Accessible Centers (Above 46):** Three nodal centers, namely Amin Bazar (50), Yearpur (50), and Shimulia (51), are enlisted in this last category. Due to their farthest location, these centers are very less accessible. Shimulia is situated on the northern side of this study area, a very less accessible nodal center.

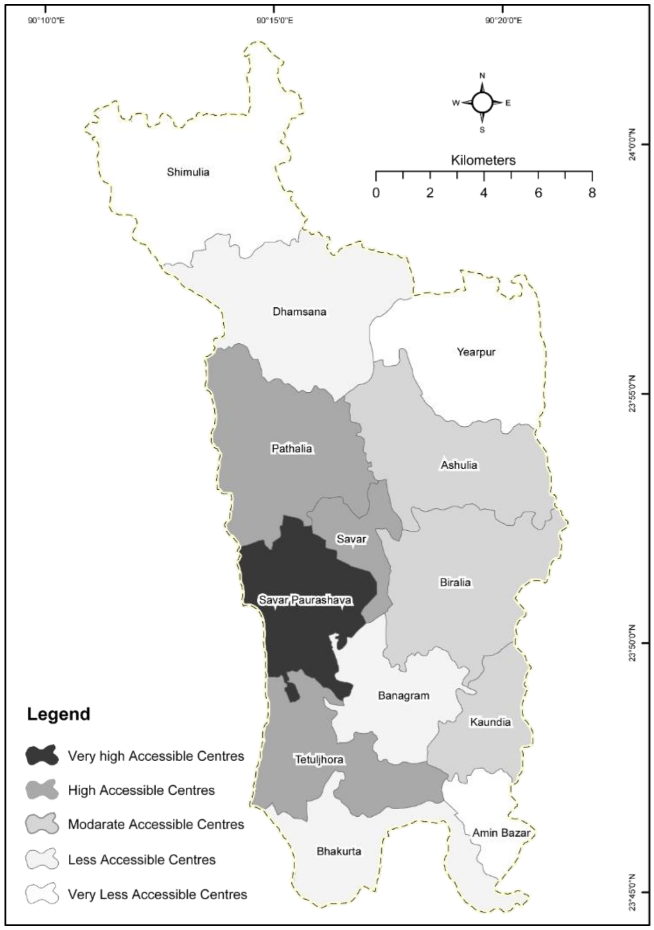

Figure-6: Accessibility map of Savar Upazila.

6. Conclusion

The transport network has played a crucial role in spatial interaction in the study area. The purpose of the study is to the structural analysis of the transport network of Savar Upazila, which this study illustrated union-wise. One of the most significant parts of network analysis is accessibility and connection. The topological and geometric components of the road network's spatial organization are examined (graph-theoretic measures). The research area comprises 12 unions and 1 Paurashava, with 473 arcs and 500 nodes. The graph theory is used to calculate nodal accessibility. The analysis of each point's connectedness and accessibility is neither practicable nor viable. Out of these nodal sites, the places that have been the most interactive for various functional and service objectives have been chosen to research connectivity and accessibility indices. The alpha, beta, and gamma indices were used for connectivity analysis, while for accessibility analysis, the *shortest path matrix*, *associated number*, and *Shimbel index* were used. These three accessibility analysis methodologies identify Savar's extremely high accessible zone, which is located in the research area's center and connects all nodal points. Areas with excellent accessibility attract more people and goods, resulting in the formation of towns and cities. So, the Savar zone is most prominent from all other nodal centers. The study area connectivity and accessibility indices union-wise have not varied mostly, indicating physiographic conditions of this area are almost the same and poor road connectivity. Changes in nodal accessibility reflect the structure of a network and changes in reaction to the addition of new linkages or the enhancement of existing linkages.

References

Amin, S.R. (2009), A Study on The Land Value of Savar municipality, Master of Urban and Regional Planning, (Thesis). Department of Urban and Regional Planning Bangladesh University of Engineering and Technology Dhaka,

Banglapedia. (2015). Savar Upazila. In National Encyclopedia of Bangladesh. Retrieved from https://en.banglapedia.org/index.php/Savar_Upazila

BBS. (2011). Bangladesh Population and Housing Census, Statistics and informatics division, Ministry of planning, Bangladesh. http://www.bbs.gov.bd/site/page/47856ad0-7e1c-4aab-bd78-892733bc06eb/Population-and-Housing-Census

ESCAP. (2016), Making the Road Sector A Key Vehicle for Sustainable Development, Bangkok. Available at: https://www.unescap.org/sites/default/files/Study%20report%20on%20making%20the%20road%20sector%20a%20key%20vehicle%20for%20sustainable%20development.pdf

Gao, X., & Sun, D. (2021). Transport accessibility and social demand: A case study of the Tibetan Plateau. Plos one, 16(9), e0257028. DOI: 10.1371/journal.pone.0257028

Gibbons, S., Lyytikäinen, T., Overman, H. G., & Sanchis-Guarner, R. (2019). New road infrastructure: the effects on firms. Journal of Urban Economics, 110, 35-50. DOI: 10.1016/j.jue.2019.01.002

Kansky, K. J. (1963). Structure of Transport Networks: Relationships between geometry and regional characteristics' University of Chicago. Department of Geography, Research Papers, (84).

Lin, J., and Ban, Y. (2013). Complex network topology of transportation systems. Transport reviews, 33(6), 658-685. DOI: 10.1080/01441647.2013.848955

Lv, T., Zeng, C., Stringer, L. C., Yang, J., & Wang, P. (2021). The spatial spillover effect of transportation networks on ecological footprint. Ecological Indicators, 132, 108309. DOI: 10.1016/j.ecolind.2021.108309

Mahmud, K. H., Hafsa, B., & Ahmed, R. (2021). Role of transport network accessibility in the spread of COVID-19-a case study in Savar Upazila, Bangladesh. Geospatial Health, 16(1). DOI: 10.4081/gh.2021.954

Pearce, D. M., Matsunaka, R., & Oba, T. (2021). Comparing accessibility and connectivity metrics derived from dedicated pedestrian networks and street networks in the context of Asian cities. Asian Transport Studies, 7, 100036. DOI: 10.1016/j.eastsj.2021.100036

Qian, Y. S., Wang, M., Kang, H. X., Zeng, J. W., & Liu, Y. F. (2012). Study on the road network connectivity reliability of valley city based on complex network. Mathematical Problems in Engineering, 2012. DOI: 10.1155/2012/430785

Robinson, H., & Bamford, C. G. (1978). *Geography of transport*. Macdonald & Evans. ISBN 10: 0712107304 / ISBN 13: 9780712107303

Rodrigue, J. P. (2016). The Role of Transport and Communication Infrastructure in Realising Development Outcomes. In The Palgrave Handbook of International Development (pp. 595-614). Palgrave Macmillan, London. DOI: 10.1057/978-1-137-42724-3_33

Rodrigue, J. P., and Ducruet, C. (2021). Graph Theory: Definition and Properties. Methods in Transport Geography. Available From: https://transportgeography.org/contents/methods/graph-theory-definition-properties/

Rodrigue, J. P., and Ducruet, D.C. (2020). Chapter 2, Transport systems (fifth ed.). Routledge Taylor and Francies group. ISBN 978-0-367-36463-2.

Rodrigue, J. P., and Notteboom, D.T. (2020). Chapter 3, Transport systems (fifth ed.). Routledge Taylor and Francies group. ISBN 978-0-367-36463-2.

Saxena H.M. (2010), Transport Geography, Rawat Publication, Jaipur and New Delhi, pp. 54-70, ISBN 81-7033-945-6

Sultana, N., Alam, A. K. M. R., & Hoque, S. (2017). Some physical and chemical characteristics of soil in selected wetlands at Savar, Bangladesh. Jahangirnagar University Environmental Bulletin, 6, 13-26.

Taaffe, E. J., and Gauthier, H. L. (1973). Geography of transportation. Prentice-hall. Englewood Cliffs, N.J., pp 100-148. ISBN 0-13-351395-5

Tomasello, M. V., Perra, N., Tessone, C. J., Karsai, M., & Schweitzer, F. (2014). The role of endogenous and exogenous mechanisms in the formation of R&D networks. Scientific reports, 4(1), 1-12. DOI: 10.1038/srep05679