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Present status and prioritization of rural road accessibility: A case study of Sunamganj districts of Bangladesh

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Abstract This study was conducted to examine the Rural Transport Accessibility Index and improve the connectivity of the rural road network for agricultural development in the Sunamganj district, Bangladesh, and facilitate the distribution of agricultural products as well as its accessibility to people. The demographic, socioeconomic, and agricultural data of eleven Upazila's were obtained from the Bangladesh Bureau of Statistics (BBS) in order to fulfill the goals of this study. The administrative area boundary and transport network data were collected from the Local Government Engineering Department (LGED) and Roads and Highways Department (RHD), respectively. Rural Transport Accessibility was estimated using ArcGIS-Arc Map. Analyzes were performed using the Microsoft Excel Analysis Tool pack. To determine the priority ranking, Data Envelopment Analysis (DEA) and correlation analysis were used. The outcome of this method helped in ranking the Dharamapasha, Derai, Jagannathpur, Sullah, Tahirpur, Dakshin Sunamganj, Jamalganj, Chhatak, Dowarabazar, Bishwamvarpur, and Sunamganj Sadar Upazilas respectively inspect accessibility level. Improving rural road network considering agricultural productivity per kilometer and prioritizing the road ranking was prepared from the maximum habitations within the desired distance. These 121 links (Upazila Distance Matrix) were calculated. From Bishwamvarpur to Sunamganj Sadar, the maximum utility value was 12281.0. This link will be upgraded as the priority, and Jagannathpur to Sullah links will be upgraded as the least priority because of its minimum value of 149.9.

Keywords: rural transport accessibility, road network, Upazila distance matrix, Arc-GIS

1. Introduction

Road networks, as one of the oldest infrastructures of transport in the world is playing the main role in modernization, sustainable development, and daily human activities in both ancient and modern times (Al-dami and Haidar 2015). The integrated development of any region depends fundamentally on accessibility in general and the transport infrastructure in particular (Ribeiro and Silva 2011). A road network of high quality increases a nation's economic output by reducing journey times and costs, making a region more attractive economically (Rogers 2003). Bangladesh is a densely populated and laying country with around 165 million inhabitants living in 130,170 Km^2. A major portion of the population lives in rural areas. It is estimated that about 60.6% of its population lives in rural areas, most of whom fall below the poverty line.

Rural roads and transport are essential for sustainable agricultural development and are key components of rural development in Bangladesh. There is about 353,000 km of rural roads across the country. Rural road construction necessarily increases agricultural production and productivity by cultivating new land or using existing land to exploit the expanded market (URP BUET 2016). Rural roads play a task in the availability of physical access. In addition, physical accessibility is crucial for achieving the diversity of the Millennium Development Goals (Barret et al 2001).

The agricultural sector plays a vital role in the overall economic development of Bangladesh. The agricultural sector contributes 14.74% to the country's GDP and provides employment for about 41% of the labor force, according to the Labor force survey 2015-16 (Rahman et al 2020). Rural roads include secondary roads and other roads employed by communities in urban and rural areas and are operated by various municipalities. Local governments and communities generally manage these roads. However, improvements in the agricultural roads aren't managed and maintained. Management and financing arrangements for these roads are often scarce and sometimes aren't breathing (Buys et al 2010). Those roads serve dispersed households and populations, often with an agricultural or natural resources-based land use structure (Donnges et al 2007). Roads and bridges link to towns and villages, to motorable tracks, trails, and paths. Foot, animal, and bicycle paths also feed into rural roads; successively, rural roads link markets and peri-urban hubs (Fouracre et al 2006). A well-maintained road network will improve agricultural distribution and create new opportunities for agricultural trade (Inoni and Omotor 2009).

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The longer-term economic development of place's infrastructural development joined the highest priorities. Infrastructure plays a strategic role in producing large multiplier economic effects with agricultural growth. As agricultural incomes grow, consumption expenditures increase in rural areas, creating an increased demand for urban goods-the multiplier effect (Mellor and Johnston 1984). Poverty is a simple reality and an advanced concept at the same time, often responsive to seeing it, but once you define it, the justification becomes more elusive (Dercon et al 2009).

One of the most important problems in a road network is evaluating accessibility (Weiping and Chi 2011). Accessibility determines how easy or difficult it is to encourage in an area. The area is accessible when people can reach there at a suitable time, and the risk of not getting there on time would be heavy. Proposed measuring accessibility in terms of disutility index for spatial location-allocation of multiple center villages using rural roads. The location-allocation method optimizes some functions of access to the facilities, but it doesn't provide accurate information needed for improving or ranking the road linkages between settlements (Kim and Chung 2001). Due to the poor rural road connectivity of the proposed study area, people face a significant problem to the distribution of farm products. This work has been done to identify the issues to inspect the present status of the rural road network to determine road accessibility in the study area.

2. Materials and Methods

2.1. Study area

Sunamganj district lies between 24º 34' and 25º 12' north latitudes and between 90º 56' and 91º 49' East longitudes, respectively. The LGED road network is depicted in Figure 1, where the black, orange, and red colors stand in for Upazila, Union, and Village roads, respectively.

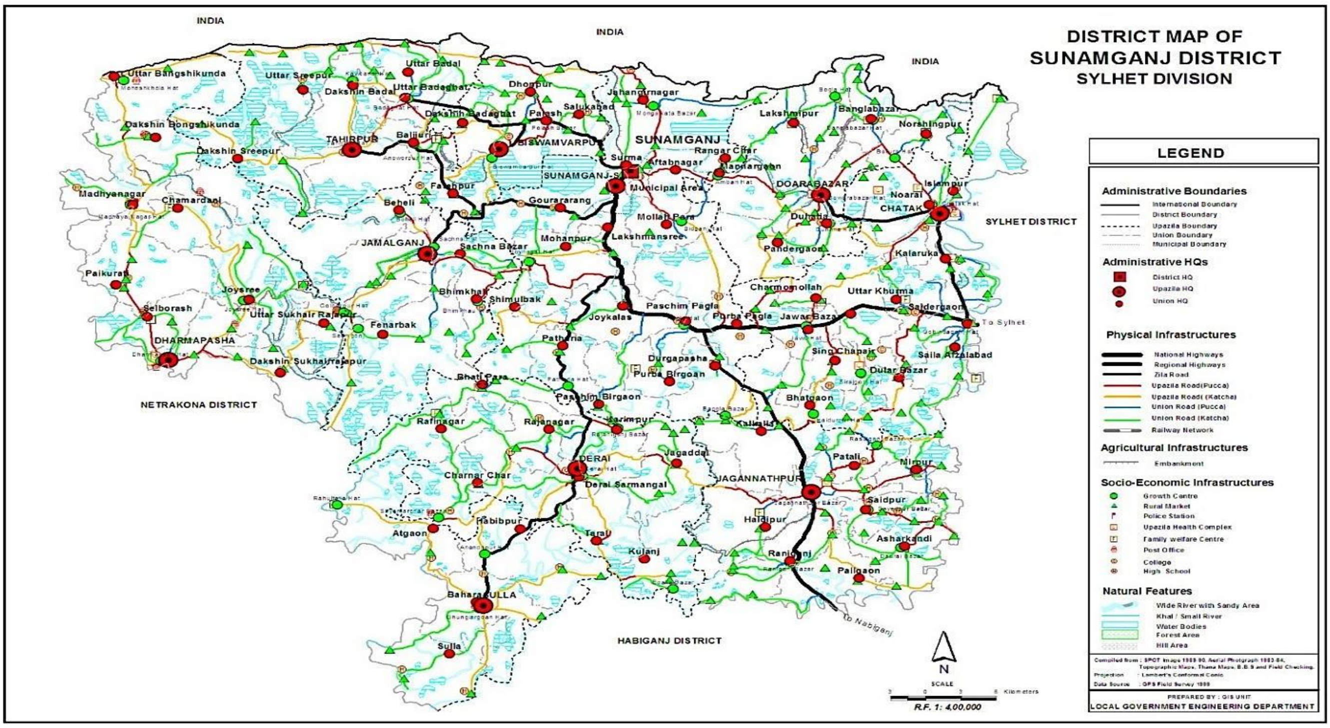

Figure 1 District map of Sunamganj.

2.2. Data Collection

Most of the secondary data were gathered from the Bangladesh Road Network under the supervision of the LGED and RHD. BBS provided the Head Count Index (HCI) data on poverty in the Sunamganj Districts of Bangladesh. The Department of Agriculture Extension (DAE) and BBS were used to compile agricultural statistics.

2.3. Data Processing

The ArcGIS-Arc Map 10.3 (64 bit desktop Esri Ireland) environment and the Microsoft Excel Analysis Toolset were used for data analysis. To establish the Pearson's correlation coefficient between accessibility index value and poverty statistics, population and poverty data were used.

2.4. Accessible Coverage Area

The number of rural residents who lived within two kilometers of an all-weather road was counted to calculate the rural transport accessibility index. Even short distances could be difficult for the populace to travel, especially in harsh weather. The indicator illustrates how crucial transportation is to enhancing rural access for rural residents. The fact needs to be expressly noted against the final RAI value. Every administrative Upazila in Sunamganj is measured for the RAI.

Step 1: The Upazila region polygon should be clipped by the RHD+LGED all-weather road.

Step 2: In GIS, locate the 2 km buffer zone surrounding an all-weather road on both sides.

Step 3: Using the buffer area to limit the demographic coverage for Upazila.

Step 4: Calculate the area under each Upazila using the clipping coverage.

Step 5: Determine how many populations are contained by the buffer zone.

Step 6: Apply the formula to calculate RAI, $\mathrm{RAI} = \frac{No\ of\ Rural\ People\ with\ Access}{\text{Total Population}} \times 100$ (1)

The complete estimation process has been (added in the supplementary section) described in Supplementary materials 1.

2.5. Calculation of the Rural Transport Access Index

GIS was used to determine the accessible area underneath each Upazila (Figure 2). The spreadsheet that was supplied had a detailed estimation. The estimated RAI values are then used to determine the order of the RAI values. Lower ranking values denote a higher level of accessibility, whereas higher ranking values denote a lower level of accessibility. The rural transportation accessibility index was determined using the formula mentioned in equation (1).

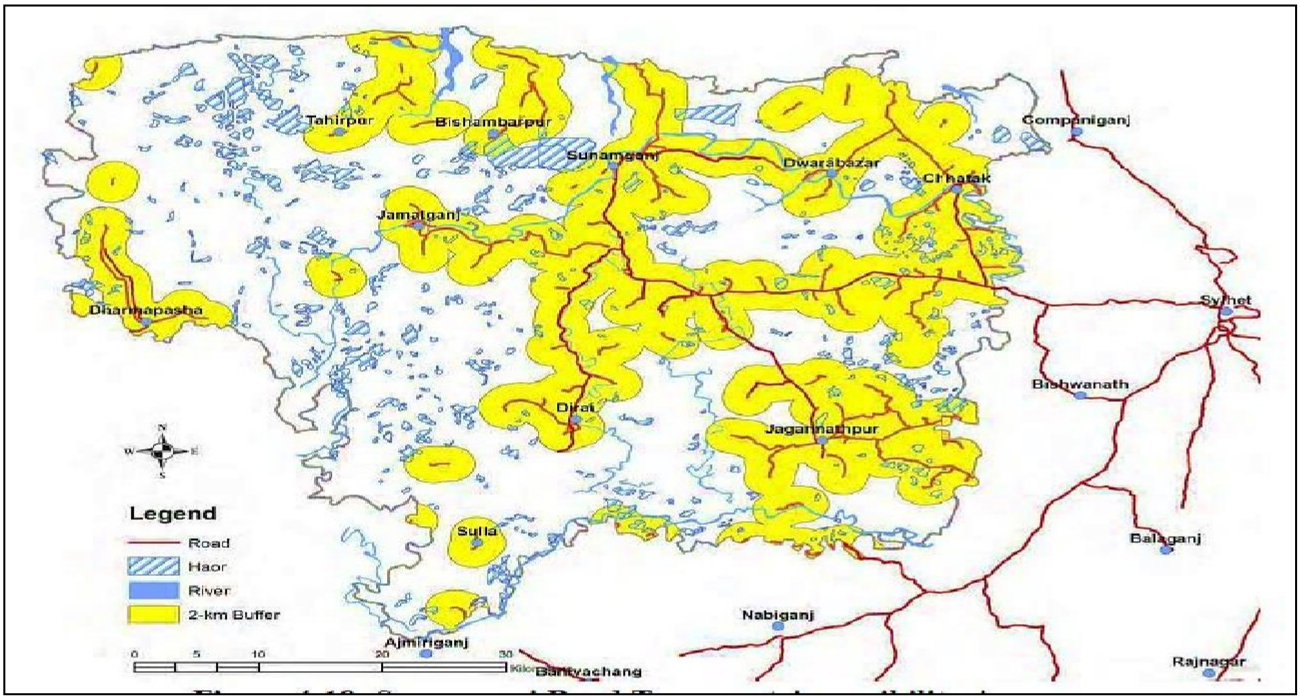

Figure 2 Land area and transport accessible area under each Upazila.

2.6. Data Envelopment Analysis (DEA)

DEA has been used to determine the most effective and equitable resource distribution for the rural transportation infrastructure. DEA uses the linear programming method to assess the comparative effectiveness of units with similar inputs and outputs. The only requirement is that the chosen inputs and outputs be measurable. Without scaling or translating them to a single standard measurement, the approach enables the examination of these various inputs and outputs in their original units. The DEA generates a single overall assessment of the relative efficiency of each comparable unit by accounting for these multiple inputs and outputs. In Supplementary materials 2, the full DEA history and procedure are presented.

The basic idea behind DEA analysis is that efficiency is measured as the proportion of weighted outputs to weighted inputs:

Efficiency, $\eta = \frac{Weighted\ sum\ of\ the\ outputs}{Weighted\ sum\ of\ the\ inputs}$ (2)

The weighted output function is $\sum w_1 \times P_n$ (3)

The weighted input function is $\sum w_2 \times RAI_n + w_3 \times L_n + w_4 \times E_n + w_5 \times H_n + w_6 \times EC_n$ (4)

Where,
w_1 = factoring in the objective function
P = Poverty
n = 1 to 11
w_2 = RAI's weighted input function
RAI = Rural Access Index
w_3 = weight of input in the Literacy Rate function
L = Literacy Rate
w_4 = Education Facilities' weighted input function
E = Education Facilities
w_5 = health facilities input function's weight.
H = Health Facilities
w_6 = weight of input in the economic facilities function
EC = Economic Facilities

2.7. Setting Target Value

Maximum Poverty value = 103 (within 11 Upazila)
Maximum Value Index Number = 17
Utilizing the Excel workbook function, determine which of the 11 Upazila zones has the lowest RAI value from the input function value range.
Minimum RAI value = 26
Least Value Index Number for the corresponding Upazila (having the minimum accessibility) in Dharmapasha is 11. The goal under the following constraints is to maximize input facility efficiency while minimizing the maximum Poverty Value by maximizing the minimum RAI value.

Setting Constraints:
1) Weightage factor, w1 less than or equal to 1 ($w_1 \leq 1.0$);
2) The Sum of weightage factors, $w_2+w_3+w_4+w_5+w_6$, should be less than or equal to 1
($w_2+w_3+w_4+w_5+w_6$ ≤; 1.0) and
Efficiency should be less than or equal to 1 ($\eta \leq 1.0$).

2.8. Rural Road network priority based on agricultural productivity

Priority lists were created using the average agricultural productivity across all linkages in all villages, calculated using the link-by-link provided formula.

Agriculture productivity value per km = $\frac{\text{Total crop produced along that road}}{Length\ of\ the\ road\ link}$ (5)

The population weight is multiplied by this agricultural productivity to obtain productivity value for that connection. The weighting of the population is determined per 1000 persons.

Weightage of Total population = $\frac{\text{Calculated habitation benefited by the for per 1000 person}}{1500}$ (6)

Finally, the utility value of each link was calculated for every link using the following formula Utility value per km = (Total weightage of road × agricultural productivity per km length of road) (7)

3. Results and discussion

3.1 Roads in Sunamganj

The district is crossed by regional roads R280 and R283; Sylhet-Sunamganj Road (66 km) and Sylhet-Sunamganj Bypass Road (7 km), respectively. They pass through this district and connect Sylhet with the North-Eastern part of Bangladesh.

3.2 Roads under Roads and Highways Department

Over 21,000 km of roads are currently maintained by RHD. This study is especially interested in paved roads that rural residents can access regardless of the weather to meet their daily requirements and activities. Table 1 shows the Distance Matrix (Upazila to Upazila) of Sunamganj road.

Table 1 Distance Matrix (Upazila to Upazila) of Sunamganj road.

Distance Matrix (Upazila to Upazila) km	Bishwamvarpur	Chhatak	Dakshin Sunamganj	Derai	Dharamapasha	Dowarabazar	Jagannathpur	Jamalganj	Sullah	Sunamganj Sadar	Tahirpur
Bishwamvarpur	0	71	47	51	349	85	56	33	71	16	43
Chhatak	71	0	77	70	331	13	55	75	91	56	85
Dakshin Sunamganj	47	77	0	19	313	33	41	38	83	19	97
Derai	51	70	19	0	292	84	56	54	20	35	64
Dharamapasha	349	331	313	292	0	345	292	352	271	333	362
Dowarabazar	85	13	33	84	345	0	69	88	105	69	98
Jagannathpur	56	55	41	56	292	69	0	60	76	41	70
Jamalganj	33	75	38	54	352	88	60	0	75	20	23
Sullah	71	91	83	20	271	105	76	75	0	56	85
Sunamganj Sadar	16	56	19	35	333	69	41	20	56	0	30
Tahirpur	43	85	97	64	362	98	70	23	85	30	0

3.3 Roads under the Local Government Engineering Department

There are currently 4767.33 km of roads under LGED across Sunamganj. However, the length of the entire coverage has not yet been extended to all roads. The road density of the district is slightly below the national average (2.99 km / km^2). However, there are wide variations in road density by Upazila. The highest road density is in Chhatak (2.6 km / km^2) and the lowest in Sunamganj Sadar (1.33 km / sq. km). In Table 2, the current LGED network in Sunamganj is displayed. In Supplementary Materials 3, the full data processing procedure has been detailed, and Figures 3 and 4 depict the share of paved and unpaved road length in km.

Table 2 Status of the road in Sunamganj under LGED.

LGED – All Season Road Network	Surface Type		Total length (km)	Percentage	
	Paved (km)	Unpaved (km)		Paved(km)	Unpaved (km)
Upazila Road	586.79	264.38	931.32	63.01%	28.38%
Union Road	370.48	379.74	750.22	49.38%	50.61%
Village Road (Type-A&B)	490.04	2595.52	3085.79	15.88%	84.11%
Total LGED	1447.31	3239.64	4767.33	42.75% (avg.)	54.36% (avg.)

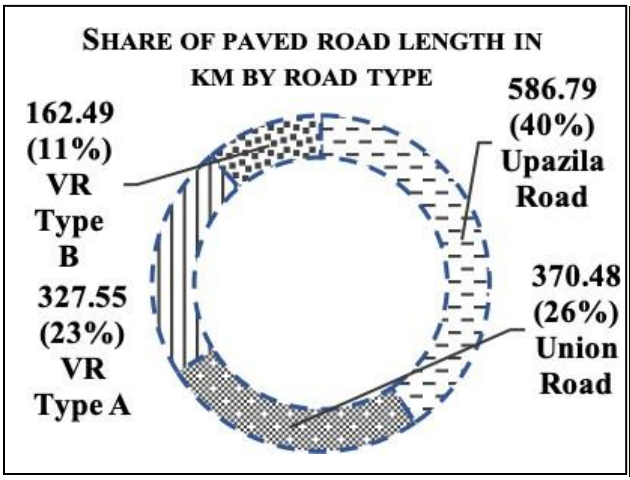

Figure 3 Share of paved road length in Km.

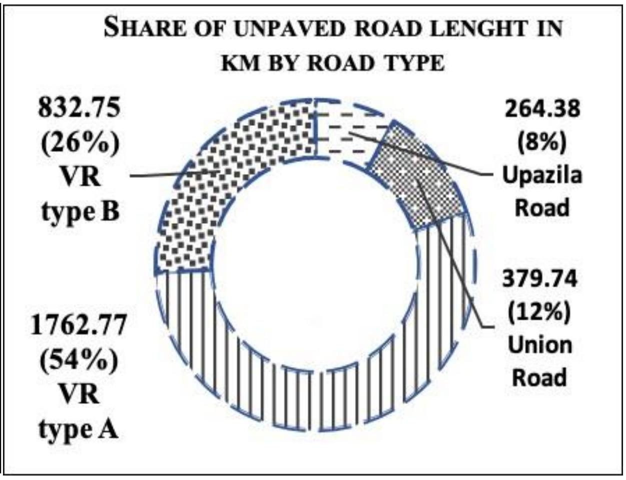

Figure 4 Share of unpaved road length in Km.

3.4 Comparative Relation between RAI and Poverty

Here, the Lower Poverty Line (LPL) and the Upper Poverty Line are contrasted in terms of the level of transport accessibility (UPL). Table 3 shows the Poverty Head-Count Rates (%). The Upper and lower poverty level in Bangladesh is shown in figure 5 and figure 6, respectively.

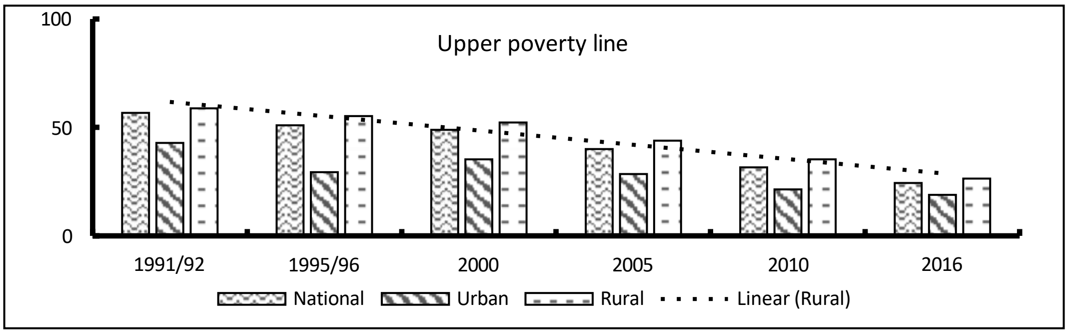

Figure 5 Upper Poverty Level in Bangladesh.

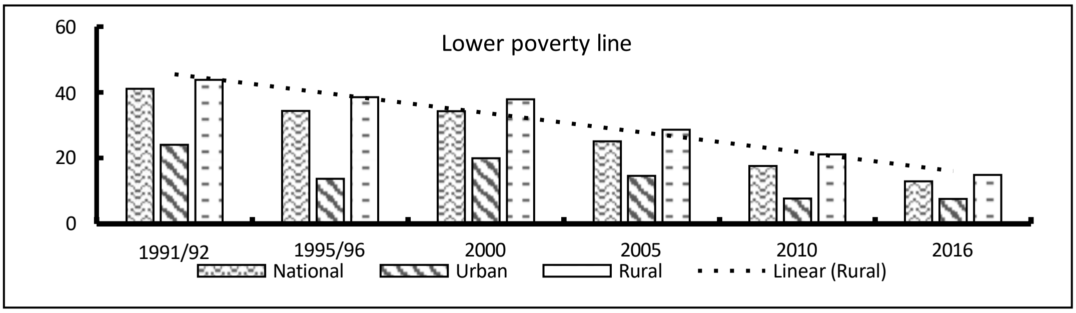

Figure 6 Lower Poverty Level in Bangladesh.

Table 3 Poverty Head-Count Rates (%).

	Upper poverty line						Lower poverty line					
	1991/92	1995/96	2000	2005	2010	2016	1991/92	1995/96	2000	2005	2010	2016
National	56.7	51	48.9	40	31.5	24.3	41.1	34.4	34.3	25.1	17.6	12.9
Urban	42.8	29.4	35.2	28.4	21.3	18.9	24	13.7	19.9	14.6	7.7	7.6
Rural	58.8	55.2	52.3	43.8	35.2	26.4	43.8	38.5	37.9	28.6	21.1	14.9

3.5 Comparative Relation of RAI with the Socio-Economic Parameters

3.5.1 RAI with Poverty and Literacy Rate

All types of population density, poverty rate, and literacy rate are included in Supplementary materials 4 from district statistics, and a line diagram has been built using these data to understand the relationship with the predicted RAI value.

Supplementary materials 4 include data from the district's statistics on population density, poverty rate, and literacy rate. Using this information, a line diagram has been created to visualize the relationship between these variables and the estimated RAI value. The relationship between each Upazilla's RAI and the poverty rate has shown in figure 7.

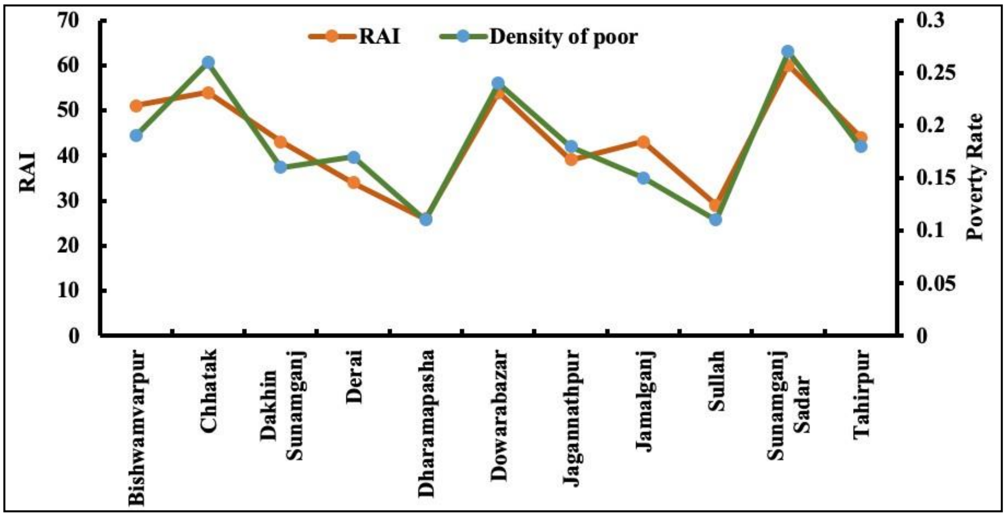

Figure 7 RAI with Poverty Rate.

The relationship between each Upazila's RAI and literacy rate is shown in Figure 8, where the overall trend is that, except Sulla, residents of areas with higher accessibility levels tend to have higher literacy rates than those with lower levels. As a result, this region has a higher literacy rate.

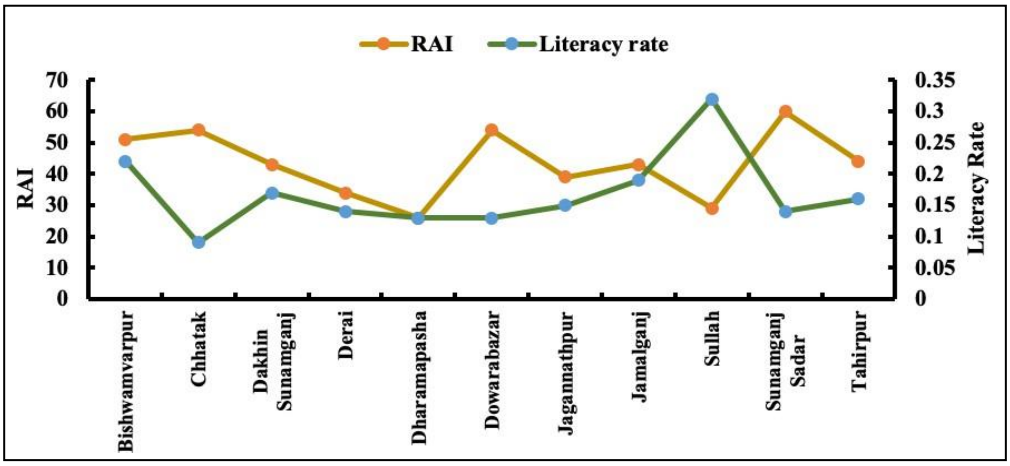

Figure 8 RAI with Literacy Rate.

3.5.2 RAI with Education and Health Facilities

In Supplementary Materials 5, district statistics are used to track all kinds of educational and medical facilities. Using these statistics, a line diagram has been created to illustrate the relationship between these facilities and the expected RAI value.

With certain exceptions, such as in Sulla, Tahirpur, and Dharmapasha, it can be shown in Figures 9 and 10 that the normal pattern is that education and healthcare facilities are more numerous where RAI values are higher and are less numerous where RAI values are lower. The accessibility of road transportation is limited due to its geospatial array. However, in actuality, due to the region's rugged terrain and some Union/Villages' isolation from the mainland, locals enjoy accessibility via waterways and unofficial roads (local walkways year-round).

On the other hand, a distinct situation exists in Bishwamvarpur, Chhatak, and Sunamganj Sadar, where there are fewer educational and medical services but a higher accessibility value. Because Sunamganj Sadar is an urban region and Bishwamvarpur and Chhatak are industrial hubs, a sizable population resides there. As a result, the formula takes the educational and medical facilities into account less (facilities per thousand of the population).

3.5.3 RAI with Facilities for Rural Economy and Industry

All types of economic and economic facilities are recorded from district statistics in Supplementary materials 6, and a line diagram has been created using these data to understand the relationship with the predicted RAI value.

With few exceptions, such as Dakshin Sunamganj, Derai, and Tahirpur, Figure 11 illustrates the overall trend that economic and economic facilities are higher when RAI value is higher, and are lower where RAI value is lower.

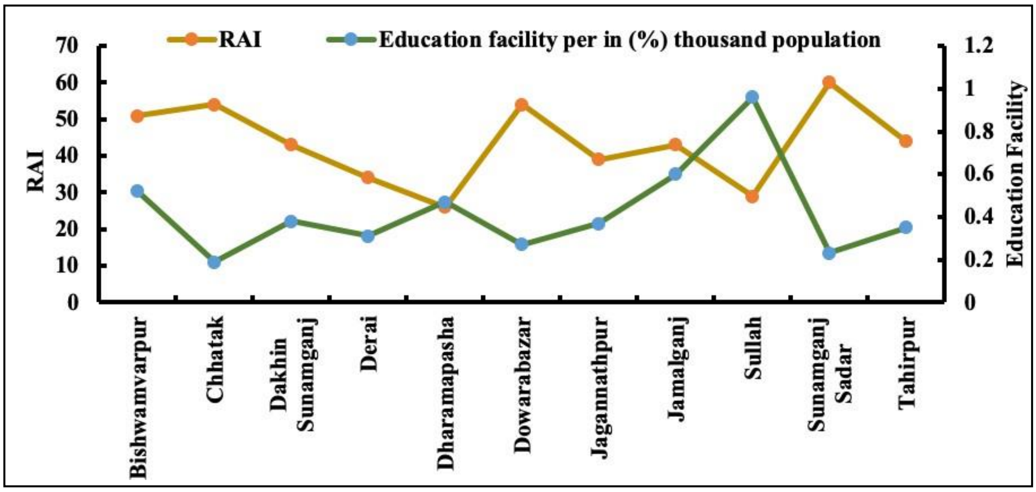

Figure 9 RAI with Education Facility.

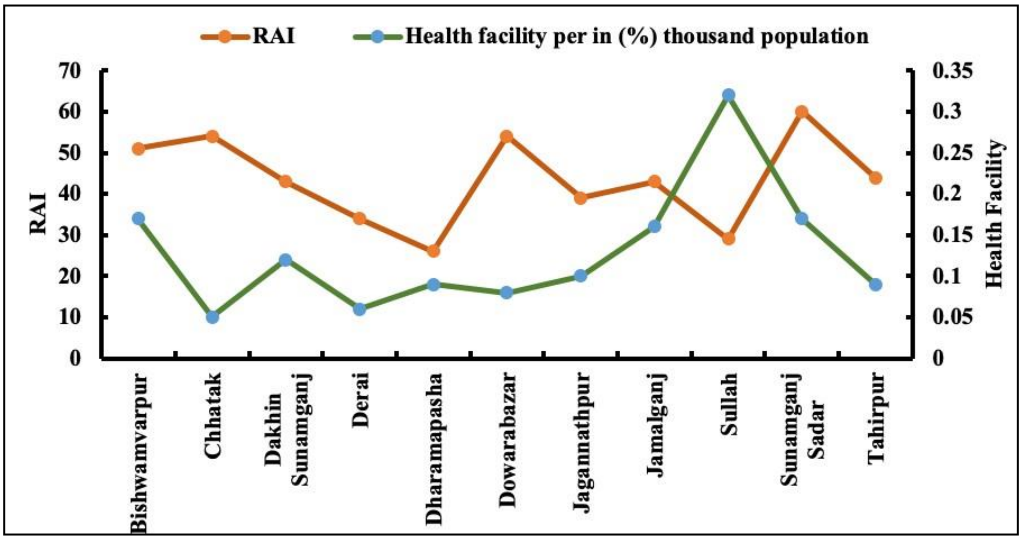

Figure 10 RAI with Health Facility.

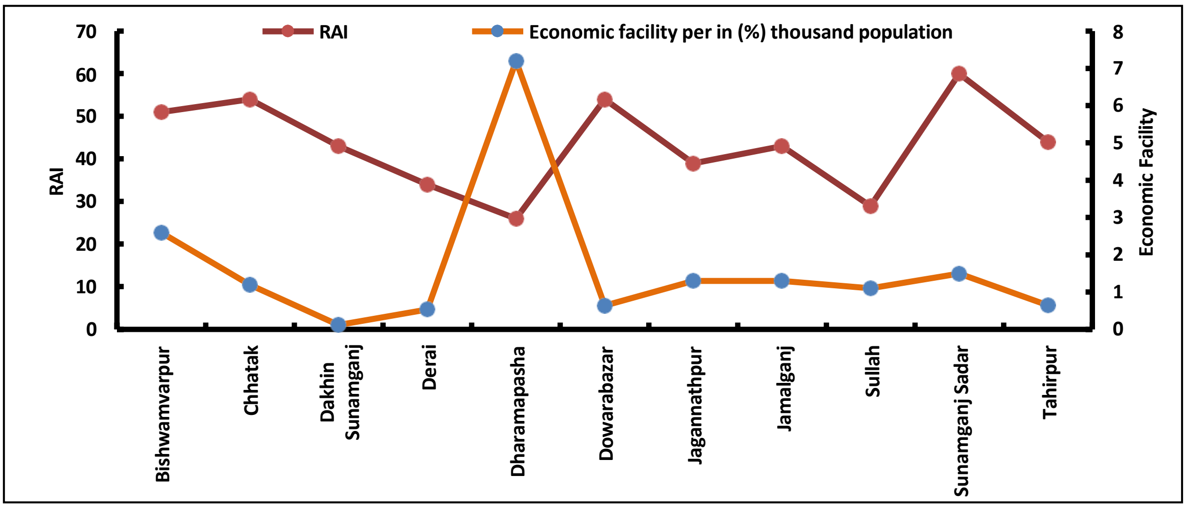

Figure 11 RAI with Economic Facility.

3.6 Interpretation of the Results of the Correlation Coefficient

3.6.1 Accessibility (RAI) Vs. Poverty

The correlation coefficient between the dependent variable (y = poverty) and the independent variable (x = accessibility) is -0.57982. First, it is negative, demonstrating an inverse relationship between accessibility and poverty. This demonstrates that improving accessibility will probably reduce poverty and vice versa. Second, the result of 0.57982 indicates a moderate connection.

3.6.2 Accessibility (RAI) Vs. Literacy rate

The correlation coefficient between the dependable variable (y = literacy rate) and the independent variable (x = accessibility) is +0.57235, which is positive in the beginning, demonstrating a connection between accessibility and literacy rate. In light of this, it can be seen that increasing accessibility will likely increase literacy rates and vice versa. Also, a moderate association exists, as shown by the value of 0.57235.

3.6.3 Accessibility (RAI) Vs. Educational facilities

The correlation coefficient between the dependent variable (y = educational amenities) and independent variable (x = accessibility) is +0.41657, which indicates that there is a positive relationship between accessibility and educational amenities. In light of this, it can be seen that increasing accessibility will likely increase literacy rates and vice versa. Also, the correlation is rather moderate, as indicated by the value of 0.41657.

3.6.4 Accessibility (RAI) Vs. Health facilities

The dependent variable (y = health facilities) and independent variable (x = accessibility) have a correlation coefficient of +0.59022, which means, First of all, it is favorable, showing a direct correlation between accessibility and medical facilities. In light of this, it can be seen that increasing accessibility will likely increase literacy rates and vice versa. Besides, the correlation is rather moderate, as indicated by the value of 0.59022.

3.6.5 Accessibility (RAI) Vs. Economic Facilities

The correlation coefficient between the independent variable (x: accessibility) and the dependent variable (y: economic amenities) is +0.35742. This indicates that accessibility and economic amenities are directly correlated. In light of this, it can be seen that increasing accessibility will likely increase literacy rates and vice versa. Furthermore, as shown by the correlation's value of 0.35742, it is fairly moderate.

3.6.6 Accessibility (RAI) Vs. Total Socio-Economic Facilities

The correlation coefficient between the dependent variable (y = Total Socio-Economic Facilities) and the independent variable (x = accessibility) is +0.57159, which indicates that there is a positive relationship between the two variables. This demonstrates that improving accessibility will probably raise literacy rates and vice versa.

3.7 Testing the Significance of the Correlation Coefficient (t-Test)

The null hypothesis and the alternative hypothesis are suggested, and they are as follows: Ha: > 0 or Ha: > 0 or H0: = 0 (the correlation is zero) (the correlation is different from zero), considering n = 11 with a degree of freedom for uneven variance and a 95% confidence level or 5% significance level. Thus, the significance level is (100-95) = 5% and the confidence level is C = 95%. The following outcomes (Table 4) were obtained using the t-Test Excel data analysis tool:

Table 4 Significance Test Results.

t-Test: Two-Sample Assuming Unequal Variances		
(RAI and Poverty)	**Variable 1**	**Variable 2**
Mean	42.6	3.1
Variance	123.6	0.988888888888889
Observations	11	11
Hypothesized Mean Difference	0	
DF	11	
T stat	11.19070479	
P(T<=t) one-tail	6.96E-07	
t Critical one-tail	1.83311293265624	
P(T<=t) two-tail	1.39248E-06	
t Critical two-tail	2.262157163	

3.8 Interpretation of Results of Significance Test Results

(a) In this case, it is determined that t Stat = 11.190704 and t Critical two-tail = 2.262157. As a result, t Stat = 11.190704 > t Critical = 2.262157.

In this case, the null hypothesis may be rejected.

(b) Here P value is = 1.3 X 10-06; P << α – indicates the relationship is statistically significant.

(c) The null hypothesis might be disproved because the P value in this instance is so low.

3.9 Results of DEA

A graph with Poverty and RAI on the vertical axis and Upazila on the horizontal axis was displayed (Figure 12) in the order of priority of resource allocation. The horizontal axis's left side denotes resource allocation with a higher priority, whereas the right side denotes resource allocation with a lower priority. Building physical infrastructure to promote accessibility and hence reduce poverty should receive higher financial priority, according to the Upazila on the left side of the graph's horizontal axis, which shows locations with higher poverty and lower accessibility levels. The left side of the graph represents high priority, and the right shows low priority, sending a message to policymakers about investment priorities.

3.10 Rural Road network priority based on agricultural productivity

The utility values were found for each link, and the maximum utility value was 33967.59, meaning these links will be upgraded as first priority. Likewise, utility values were found for each link, and on the basis of utility, value priority will be decided. For this research 11 Upazila has been shown, and these 121 links were calculated. The maximum utility value is

12281.01, which Bishwamvarpur to Sunamganj Sadar means this link will be upgraded as the first priority. Further, all the links can be compared and priority decided.

Secondary data was gathered from various sources, primarily from various government entities, to conduct the studies because no original data was gathered. It is encouraging to compare the methodology with (Anjaneyulu et al 2007), who developed a scheme for planning rural roads based on secondary data sources. Road network, demographic, socioeconomic, poverty data, and agricultural production of Sunamganj districts are the key topics covered by secondary data. In this study, the accessibility of road transportation was discovered and examined, as well as the relationship between accessibility and socioeconomic and poverty-related factors. This findings is consistent with that of (Singh 2010) found a link between infrastructure and agricultural development. Agricultural development was strongly correlated with the agricultural infrastructure index, followed by the transport and communication index. Prioritizing physical infrastructure and facility-based assessments of agricultural production improvement by the occupancy of rural areas was done using data envelopment analysis. Many roads in the district may be considered for improvement, further upgrading, and maintenance. The primary goal of rural road development, such as accessibility improvement, which is better reflected in utility value per km, lower utility values than the cut-off rate but has higher utility standards, can be prioritized for development. In conclusion, the decision may be based on the context of core network development and based on the overall context.

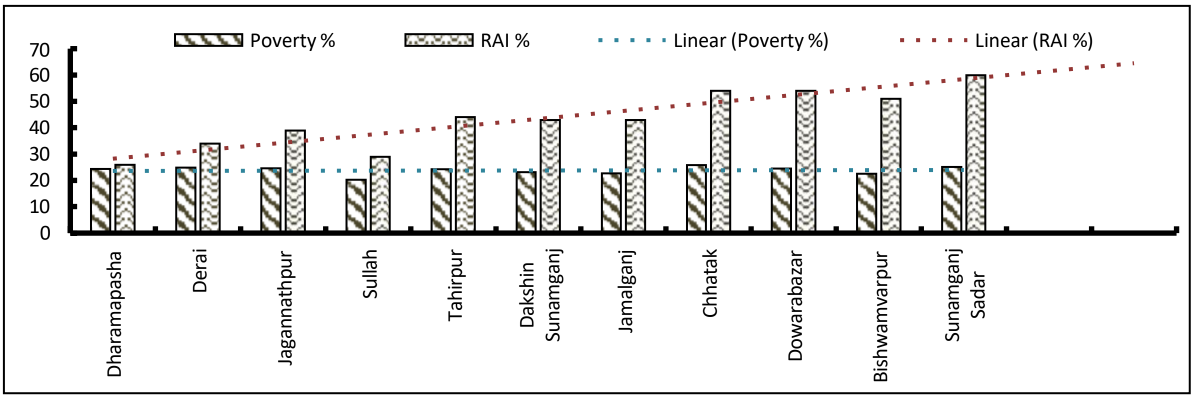

Figure 12 DEA-Based Priority Ranking of Upazila.

4. Conclusion and recommendations

This study developed methodologies to quantify accessibility at different levels. Also, an agricultural-based approach has been developed for rural road connectivity to improve access to basic facilities. Through this study, the distribution of funding for physical infrastructure fairly, and the Upazila priority listing for transportation accessibility and poverty incidence was created. Accessibility to transportation and socioeconomic factors are correlated. The social state of an area is better, whereas transportation accessibility is higher. The agricultural-based rural road network planning approach proposed in this study ensures accessibility to the needs of the rural population. The number of habitations with no accessibility increases significantly with the decrease in the population density of the region. Also, the percentage increase in accessibility per kilometer of road construction is higher in densely populated areas. Increasing household income will enable them to spend more on their family members' education, health, and social ties, all of which raise the standard of living for everyone. Despite this, the transport industry directly contributes 11.53% of GDP and serves as the foundation for all other sectors. In the long run, its indirect GDP contribution is tremendous.

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Conflict of Interest

The authors declare no conflict of interest.

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