Method to assess the accessibility of essential amenities in Tripura, North East India

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Ease of access to a service or an amenity is measured by its accessibility level. In urban/rural areas, the key parameter used to measure accessibility is road connectivity. This is usually measured by the distance and/or time from the origin to the location of various amenities providing health, education, banking, shopping and other services. In addition to distance/time, for hilly regions like Tripura, North East India, road safety also plays a major role in accessibility to various amenities. This study first measures the level of amenities within a village and represents this with a score, viz. self-sufficient score (3S score). This score is further upgraded considering the amenities available outside that village but in nearby larger villages/cities. Unsignalized intersections being the most dangerous locations in hilly regions, the level of road safety has been measured based on road geometry information, i.e. the number of intersections, sharpness of the road curve coupled with altitude of the roads between the subject village and amenities in other villages/cities. This is known as the safety score of intersections. The value of the upgraded 3S score coupled with the safety score for intersections is considered in ranking the villages for their access to various amenities. The villages with minimum scores have been identified for further decision-making process.

Keywords: Accessibility level, essential amenities, hilly regions, road connectivity, self-sufficient score.

FOR any area/region, the level of access to various facilities (i.e. health, education, market, bank, post office, etc.) largely depends on the road network. Worldwide, the measurement of accessibility is primarily based on parameters related to 'road', i.e. network length, type of road, road width, surface quality, etc. A report by the World Health Organization in Geneva, Switzerland, has proposed a methodology focusing on access to all-weather roads[1]. It measures the share of the population that lives within 2 km of the nearest road in 'good condition' in rural areas. This method was applied to eight pilot counties: Ethiopia, Kenya, Mozambique, Tanzania, Uganda and Zambia in Africa, and Bangladesh and Nepal in South Asia. In total, it was estimated that about 34% of the rural population is connected, with roughly seven million people left disconnected.

India has an essentially rural-oriented economy, and the Government of India (GoI) has been systematically planning to provide all its villages and habitations with good road connectivity. However, presently, road connectivity in North East India is poor. Tripura, one of the states in NE India, has limited road network connectivity among its villages/towns. Road connectivity for any area/region is typically measured based on how other regions are connected to it and at what distance; assured road safety is also considered. Safety on the roads of Tripura is more challenging due to the hilly terrain. According to a report by GoI, there were 557 road accidents in Tripura in 2015 and 655 in 2019 (ref. 2). Also, during 2015, the accident severity (road accident deaths per 100 accidents) reported for Tripura was 32 and for the year 2019 it is reported to be 41.2. The increasing risk of commuting on Tripura roads is a major concern as, on the one hand, GoI is focusing on better road connectivity, while on the other, safety is a more important concern.

Studies focusing on road connectivity aspects are usually limited to accessibility measured in terms of distance and road construction cost. This study focuses on including road safety as a function of measuring road connectivity and, therefore, accessibility.

Literature review

According to Kanuganti *et al.*[3], the age-old tradition for measuring accessibility is the gravity model. It measures accessibility between people and amenities through the impedance factor of distance/time/cost. Another method used is 2SFCA (two-step floating catchment method). It is more advantageous than the gravity model as it considers the ratio of healthcare and population, which requires fewer data inputs and has a practical approach. The drawback of this method is that the access to any facility is measured in binary form that is yes or no. It does not consider the lower level of accessibility for the facility located just outside the defined buffer[3].

Zhang *et al.*[4] examined urban–rural differences in the association of access to healthcare with self-assessed health and quality of life (QOL). They measured access to

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healthcare based on self-assessed health and QOL at the 10th, 50th and 90th conditional quantiles. This was determined after controlling individual and household factors, showing that urban patients who received healthcare within two weeks gave higher ratings. The study recommended policy actions targeting identified vulnerable and rural populations to prioritize reducing barriers to seeking health services[4]. Senante *et al.*[5] adopted the synthetic index approach to quantify access to drinking water. Nearly 14 parameters were assessed to identify the most influential, complex and dissimilar parameters.

Existing studies measuring the level of access include that by Kanuganti *et al.*[6], who used the GIS platform, found that the need-based network connected more villages and provided better accessibility. Sarkar and Dash[7] used the accessibility index, priority index, and village priority index to arrive at decisions regarding the provision of infrastructure and facilities. Modinpuroju and Prasad[8] calculated weights for each link based on the population served, available facilities, and distance between two villagers to prioritise maintenance work. Mishra *et al.*[9] proposed a methodology that uses GIS and multi-criteria decision-making techniques for developing healthcare units (HCUs) to attain spatial efficiency in the distribution of facilities. The methodology assigns spatial weightage to the suitability index of the candidate locations in the objective function of maximizing coverage location-allocation problem embedded in ArcGIS. Habitations not served by the existing HCUs are considered candidate locations.

Kanuganti *et al.*[3] quantified accessibility using the two-step floating catchment area. This quantified the accessibility of different habitations to healthcare and the level of accessibility of villages having access to healthcare. Kanuganti *et al.*[6] compared networks prepared with need-based and demand-based connectivity approaches. As most of the literature has considered accessibility as the prime factor in assessing road connectivity, the present study focuses on updating the existing criteria of connectivity needs. Apart from checking the connecting habitations/villages by road, quantifying their level of access to various facilities is considered to strengthen the improvement strategies of GoI. To measure the level of access, apart from distance, the level of road safety is also considered.

As mentioned by Thomas *et al.*[10], to determine the living standards of rural regions, accessibility to basic amenities needs to be quantified. To measure accessibility broadly, there are two main methods, i.e. spatial and non-spatial. Both have their own pros and cons. In spatial analysis, geographic location and travel time are considered, while in non-spatial analysis, the socio-economic factors, demographic features, and friction factors that affect travel time and cost are considered.

The present study adopts a combination of both, i.e. spatial and non-spatial information, to measure accessibility. Study being focusing the measurement of accessibility, within road network parameters DISTANCE is the key parameter and considered. Apart from this, SAFETY is also considered in the method of quantification of accessibility.

Study objective and methodology

The objective of this study is to develop a methodology for measuring the level of accessibility of an area towards various facilities (i.e. education, health, etc.), considering road safety apart from distance between origin and destination.

For measuring the accessibility of an area, i.e. a village, the distance from the village centre to all facilities is calculated. If all the facilities (i.e. education, health, banking, post office, market) required for the society are available within the village itself, it is called a self-sufficient village in this study. If these facilities are not available within the village, distance to the facilities from the village centre is considered to calculate the weighted score, which is known as the self-sufficient score (3S score).

Usually, large villages/cities are observed to be self-sufficient, but those with less population usually do not have all the facilities within them. This situation is common in hilly areas like Tripura. In such cases, residents access facilities in other nearby habitats. Accordingly, village(s) close to a big village/city with more facilities have better access than village(s) far away. Sometimes, a cluster of habitations behaves as a city and serves each other, becoming self-sufficient even when these are small and far away from a major city/area. Considering all such situations, the 3S score has been upgraded for all the villages. Figure 1 presents this concept.

Initially, the 3S score for each habitation is calculated based on information related to various facilities within it. This is further aggregated for the village level. This village-level score is upgraded to include facilities in nearby villages. With the defined objective and methodology, this study is divided into interlinked tasks.

(1) The first task of this study is to prepare a geo-referenced database containing all the required information. This includes the road network covering all roads, locations of habitations, boundaries of villages covering multiple habitations, and locations of schools and healthcare centres. This is attributed to the demographic information collected from the Census of India. All secondary data are converted to a GIS platform and further strengthened with primary data collected during household surveys conducted in various parts of Tripura, and the road geometry is updated based on on-site visits. For all the collected data, various connectivity and safety-related indices are developed to sort all the villages based on their level of access to various facilities. This can be utilized further as a decision-making tool.

(2) The second task is to calculate the 3S score for all villages in Tripura. This indicates the level of education and health facilities available within a habitation, as well

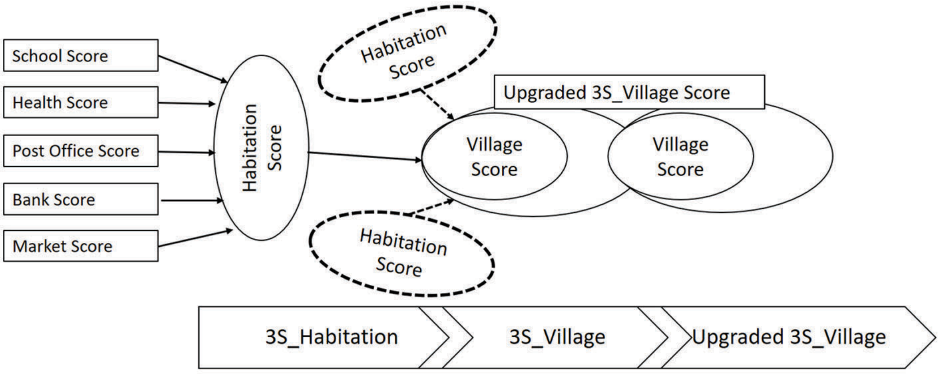

Figure 1. Concept of calculating the upgraded 3S score considering facilities in neighbouring villages in Tripura, North East India.

Table 1. Information on all eight districts of Tripura, North East India

	Demographic details			Education	Health
District	Number of habitations	Number of villages	Population	Number of schools	Number of healthcare centres
Dhalai	1088	148	405,972	884	24
Gomati	1152	134	433,782	613	17
Khowai	1159	79	363,547	494	12
North	705	84	393,436	529	22
Sepahijala	1280	116	491,565	644	22
South	1320	136	414,657	677	26
Unakoti	468	76	265,304	382	15
West	1515	90	534,833	705	40
Total	8687	863	3,303,096	4928	178

as considering the impact of other nearby larger villages with more facilities. This score is further updated considering facilities in nearby villages/cities.

(3) The third task is to develop a road safety index (RSI) for villages in Tripura. This assigns values based on their level of road safety, and is developed based on the sharpness of the curve and altitude of intersections on the roads.

(4) Lastly, the level of accessibility for every pair of villages is calculated to identify villages having minimum access to all facilities.

Self-sufficient score for villages

The prepared GIS-based database included road networks, 8715 habitations with all census information, 863 villages and 8 district boundaries. Table 1 provides district wise information with respect to population, number of schools and healthcare centres within each district of Tripura.

Based on availability within a village, the 3S score was calculated first. Tripura has 8687 habitations with a population of 3,303,096 and 4928 schools. Table 2 shows the number of schools in each district of Tripura. Schools of all categories (primary, secondary, higher secondary, etc.) are mentioned separately. Schools where younger students are enrolled are expected to be closer than those enrolling higher secondary level students. Table 2 provides aggregated information on various habitations within a village. For every habitation, the number of schools within a buffer distance of 500 m, 1, 2, 5 km and above 5 km has been determined using advanced tools of ArcGIS.

For each possible combination of school type and distance from the subject habitation, weights have been assigned (Table 3). The values of the matrix presented in Table 3 assure higher scores for schools near the habitation than those far away.

The obtained weights were rescaled between 0 and 100, and coded alphabetically between *A* and *E* (at the interval of two standard deviations) for easy handling by the decision-makers. For all 8687 habitations, the education score was calculated (Table 4).

As presented in Table 4, out of 8687 habitations in Tripura, 3695 had very poor (category *E*) education facilities, 4363 fell under the weak category (category *D*), 573 habitations had moderate education facilities (category *C*), and only 565 habitations were good or best (categories *B* and *A* respectively). This is an existing level of access and therefore demands attention for improvement in most of the habitations.

Similarly, scores were calculated for other facilities, i.e. health, banks, post offices and markets. Table 5 presents the values for an average 3S score calculated considering all

Table 2. Number of schools in the eight districts of Tripura

District	Cat_1 Primary	Cat_2 Upper primary	Cat_3 Higher secondary	Cat_4 Secondary	Cat_5 Madrassa	Grand total
Dhalai	550	245	31	56	2	884
Gomati	293	188	45	73	14	613
Khowai	268	125	35	64	2	494
North Tripura	243	173	43	46	24	529
Sepahijala	274	156	59	89	66	644
South Tripura	360	152	94	67	4	677
Unakoti	187	87	32	43	33	382
West Tripura	320	154	117	88	26	705
Grand total	2495	1280	456	526	171	4928

*Primary school includes education up to class 5, upper primary up to class 7, secondary up to class 10, higher secondary is up to class 12 and Madrassa is a school with specific religious values.

Table 3. Weights assigned for the available school types at various distances

	Category				
Distance (m)	Cat_1	Cat_2	Cat_3	Cat_4	Cat_5
500	1	1.4	2	2.4	1
1000	0.9	1.1	1.4	1.6	0.9
2000	0.8	1	1.3	1.5	0.8
5000	0.7	0.9	1.2	1.4	0.7

Table 4. Education score and habitation

Score range	Category	Habitation frequency
>80	*A* (best)	6
61–80	*B* (good)	50
41–60	*C* (moderate)	573
21–40	*D* (weak)	4363
≤20	*E* (very poor)	3695

Table 5. 3S score for the eight districts of Tripura

District	Average of 3S
Dhalai	443
Gomati	532
Khowai	1048
North	503
Sepahijala	750
South	524
Unakoti	529
West	1482
Grand total	688

facilities (education, health, bank, market and post office) of all the villages within each district of Tripura.

Upgrading the 3S score based on road connectivity

Once 3S score is calculated, this score is updated by including the impact of facilities in nearby villages. This takes care of the distance between villages as well as the level of safety for the road connecting any pair of villages.

Considering the impact of facilities available in nearby villages through the upgraded score, the total score was calculated. This total score indicates the overall level of accessibility to all the major facilities (health, education, bank, market, post office). Based on the possible range of total scores, 5 categories were established with a range interval of 1000. For each category (*A*, *B*, *C*, *D* and *E*), the village frequency was categorized into five levels based on the 3S scores (Figure 2). A higher score indicates better overall facilities for a village. Table 6 presents the frequency distribution of all villages based on their 3S scores.

As presented in Table 6, only four villages fell under category *A*, indicating the best facilities. The second best, category *B*, is available for 13 villages. For categories *C*, *D* and *E*, the number of villages with existing level of facilities is 38, 134 and 674 respectively, indicating the need for improvement.

For villages under categories *D* and *E* (i.e. larger villages), road connectivity with villages under categories *A*, *B* and *C* (i.e. small villages) was analysed and based on a single parameter, i.e. distance. Figure 3 presents the frequency of villages having access to larger ones at a range of distances.

Considering the impact of villages with good 3S scores on the nearby villages, for all the villages of categories *D* and *E*, the 3S score was upgraded based on the nearest village of the higher category (*A*, *B* and *C*) and its distance from the candidate village. Accordingly, the upgraded 3S score for all villages under categories *D* and *E* (i.e. 808 villages) was recalculated using the equation

$$\text{Upgraded 3S village} = \frac{\text{3S village}}{\text{Distance}}. \quad (1)$$

Figure 4 presents the 3S score and upgraded 3S score for all the villages. The higher the score, the better the facilities. Only four villages were considered under category *A,* with a score of more than 4000. Majority of villages fell under categories *D* and *E*, indicating the major need to provide facilities in the state.

Considering the percentage improvement in the 3S score, the affected population was large. Table 7 details the affected/benefitting population due to upgraded 3S scores. As presented in the table, nearly 85% of the population fell under categories *D* and *E,* which need improved education and other facilities.

Approximately 70% of the population benefits from the facilities available in nearby villages.

Quantifying the level of road safety

While calculating upgraded 3S scores, distance was considered as described earlier. Apart from distance, in the case of safety on hilly roads, sharp curves in the road network, including at the intersections, play a critical role. Therefore, apart from distance, the number of unsafe intersections on the roads connecting a pair of villages needs to be considered along with their level of risk (level of safety). The level of safety between any pair of villages is calculated based on the number of intersections, the sharpness of the curve at such intersections, and the altitude of intersections. A scoring system has been developed considering the risk level changing with these parameters. For assigning scores, intersections with a higher number of intersecting roads have been considered more unsafe than those with fewer intersecting roads. The summation of the radius (sharpness of curve) of intersecting roads varies from zero (right-angled intersections) to more than 2000 m. Non-zero and lower radii indicate a sharper curve and, therefore, higher risk. Further, an intersection with a higher altitude clubbed

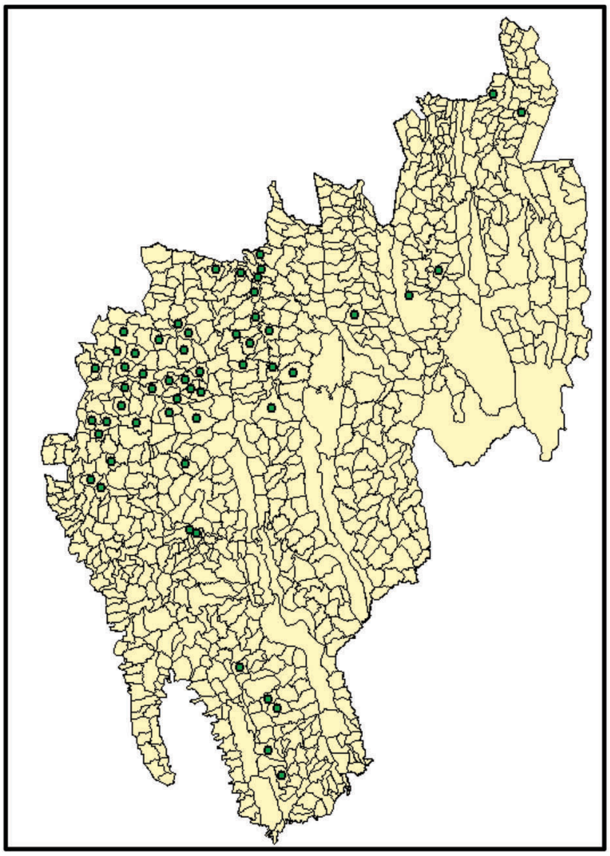

Figure 2. Villages under categories *A–C*.

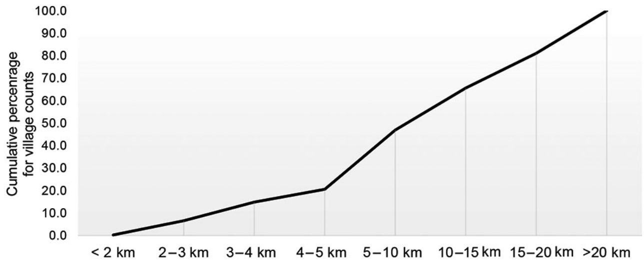

Figure 3. Distance from a small village to the nearest large village versus village counts.

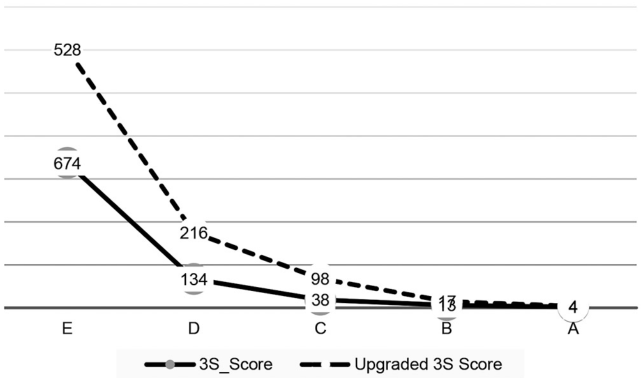

Figure 4. Frequency distribution for villages of five categories with 3S and upgraded 3S scores.

Table 6. Frequency distribution of villages

Range of total score	Frequency (no. of villages)	Category
0–1000	674	*E*
1000–2000	134	*D*
2000–3000	38	*C*
3000–4000	13	*B*
4000–5000	4	*A*
Grand total	863	

Table 7. Percentage improvement in 3S score versus affected population

Percentage improvement in 3S score	Affected population	Percentage population
0–100	2,633,240	70.27
100–200	552,845	14.75
200–300	186,827	4.99
300–400	59,519	1.59
400–500	74,572	1.99
>500	240,392	6.41

with a sharp curve is considered highly unsafe compared to an intersection of the same curve at a lower altitude.

With these criteria, an equation was developed to calculate the safety score at intersections.

$$\mathrm{SSI} = \frac{\sum_{n=1}^{N}(RR)}{N * R}, \tag{2}$$

where SSI is the safety score at intersections, N the number of intersecting roads, RR the radius of the road (m) for RR $\neq 0$ and A is the altitude of intersections (m).

The total number of intersections with 3, 4 or 5 roads was 18,291, 1896 and 25 respectively. Figure 6 provides information regarding the number of intersections falling within a particular range of altitude values. As presented in Figure 5, the majority of intersections have altitudes less than 100 m. Figure 6 presents these 19,221 intersections with further details by adding more range categories for altitude.

Figure 7 indicates the range of altitudes for all intersections in Tripura. This highlights the high-altitude areas clearly, where safety becomes an additional concern. Since altitude is considered an important parameter with respect to safety, locations of high altitude are highlighted. This information is required for better decision making with respect to corrective safety measures.

The calculated SSI is based on eq. (2) was further normalized for the range 0–100. Figure 8 presents the frequency distribution of intersections based on the range of SSI values.

Table 8 presents a list of the top five villages with a maximum number of intersections within them. Table 9 presents a list of the five most unsafe villages with respect to safety at intersections. These have been identified based on the average SSI values. (SSI values are calculated based on the number of intersecting roads, the radius of all intersecting roads and the altitude of the intersections.)

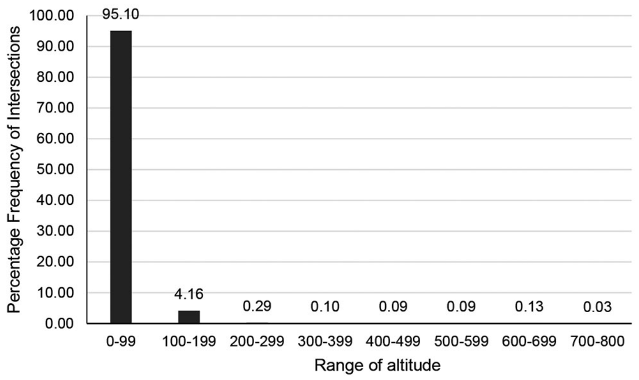

Figure 5. Percentage frequency distribution of intersections based on altitude.

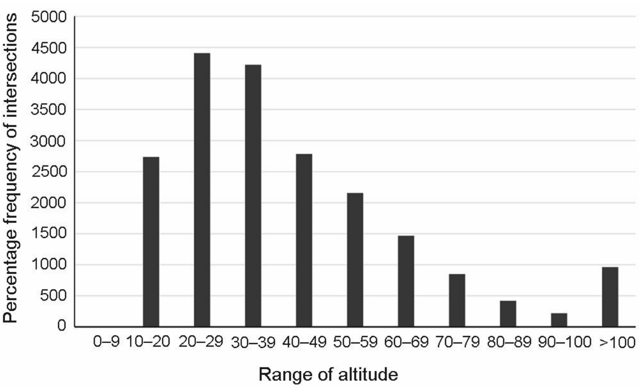

Figure 6. Percentage frequency distribution of intersections based on altitude.

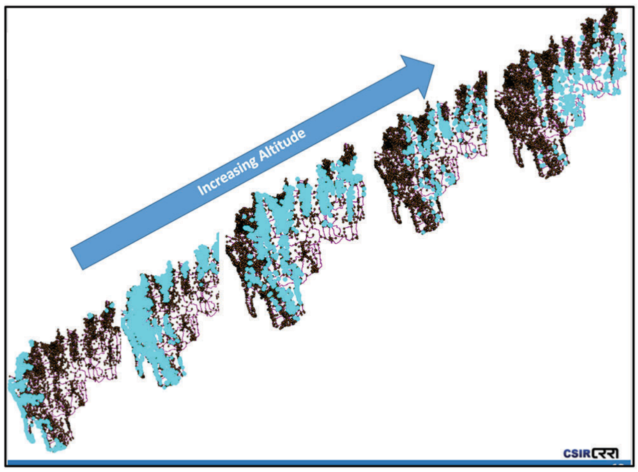

Figure 7. Direction of increasing altitude in Tripura.

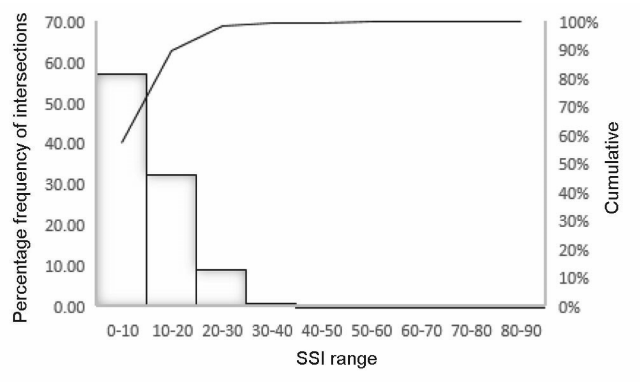

Figure 8. Frequency distribution of intersections based on safety score of intersection ranges.

Table 8. Top five villages with respect to the number of intersections within

Village	District	Number of intersections within
Agartala municipality	West	2628
Badharghat	West	734
Pratapgarh	West	315
Kailashahar	Unakoti	295
Jogendranagar	West	291

Table 9. Five most unsafe villages with the lowest values for average safety score of intersection (SSI)

Village	District	Number of intersections	Average SSI
Sabual	North	6	0.25
Tlakchi	North	12	0.28
Jamraipara RF	North	15	0.30
Joyrampur part	Dhalai	3	0.40
Vangmun	North	23	0.44

Conclusion and recommendations

Every village in India must be connected by roads as part of the Pradhan Mantri Gramin Sadak Yojna (PMGSY). The parameters that affect the commute to access various facilities are road safety and road connectivity. Accordingly, the need to assess various facilities must be expanded to cover road safety parameters apart from the distance covered to access these facilities. Furthermore, relevance to hilly road networks and occurrence of sharp intersections found to have a wide range within the study area of Tripura.

The present study has quantified the accessibility to various facilities in Tripura. This includes facilities within a habitation/village as well as those in neighbouring villages. The quantified level of facilities within a village is the self-sufficient score, which is further upgraded to include the impact of nearby large-sized villages/cities having more facilities. Further, safety while moving from one village to another has been quantified and is known as the safety score at intersections. Considering both scores, the level of accessibility is calculated for each of the 863 villages in Tripura. Through various developed indices, the levels of accessibility, connectivity, and safety have been quantified for each pair of villages, which can support better decision-making.

However, with every additional facility and/or improvement in road connectivity/safety, the calculated scores will have to be upgraded. The developed GIS-based database is useful to strengthen the data-based decision-making process. It is strongly recommended that this database be maintained, with regular updates by all the stakeholder departments. For this, we will share all the updated databases with the respective agencies.

Policy implications

For the existing road network conditions and facilities, all accessibility scores were calculated. However, being a dynamic factor due to changes in road safety levels and facilities, it should be calculated at regular intervals (maybe once a year).

The database preparation, updating and calculation of various scores and indices require a skilled workforce and, therefore, work should be assigned suitably. Further, it is recommended to have a central, secure portal for all local authorities to access and share their latest database. Since all analyses include a multilevel collation, with the help of IT professionals, this database and supporting calculation can be converted into a user-friendly software package for easy handling at the level of decision-makers.

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