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A Robust Approach for the Infrastructural Classification of Railway Stations in Tripura, India

Uma Análise Robusta Das Infraestruturas Das Estações Ferroviárias Oferecidas Aos Passageiros Em Tripura, Índia

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Abstract

An infrastructural classification is a Decision-Making Unit (DMU) for the service providers to deliver better infrastructure. This paper intends to classify the infrastructural facilities of the railway stations offered to the passengers in Tripura through an alternative synthetic indicator. The study is based on both primary and secondary data. The existing synthetic indicator is also applied to it and generalisation of the indicator called generalised synthetic indicator is framed according to the nature of the observed data sets. A robust synthetic indicator, linear order of existing and proposed alternative synthetic indicator, has been developed to classify the railway stations of Tripura based on existing infrastructural facilities. The study reveals that stations are categorised into four different (very good, good, poor and very poor) infrastructural classifications due to the frequency of passenger mobility, the proximity of urban centres, location of industrial units, land use of hinterland and undulating topography of the site. The causal interference has been represented through the geospatial technique. A policy recommendation has been proposed to provide better railway infrastructure for the passengers.

Keywords: Synthetic Indicator, Alternative Synthetic Indicator, Station Infrastructure, Railway Geography, Causality of Infrastructure

JEL Codes: O18, R11, D62

Resumo

Uma classificação de uma infraestrutura é uma Unidade de Tomada de Decisão (DMU) para os provedores de serviços fornecerem uma melhor infraestrutura. Este estudo pretende classificar as infraestruturas das estações ferroviárias oferecidas aos passageiros em Tripura, Índia, através de um indicador sintético alternativo. O estudo é baseado em dados primários e secundários. O indicador sintético existente também é aplicado e a generalização do indicador denominado indicador sintético generalizado é enquadrada de acordo com a natureza do conjunto de dados observados. Um indicador sintético robusto, de natureza linear do indicador sintético alternativo existente e proposto, foi desenvolvido para classificar as estações ferroviárias de Tripura com base nas infraestruturas existentes. O estudo revela que as estações são classificadas em quatro categorias de infraestrutura (muito bom, bom, mau e muito mau) devido à mobilidade facultada aos passageiros, à proximidade aos centros urbanos, à localização das unidades industriais, ao uso do solo do interior e à topografia ondulada do equipamento. A interferência causal tem sido representada por meio da técnica geoespacial. Foi formulada uma recomendação de política para proporcionar uma melhor infraestrutura ferroviária aos passageiros.

Palavras-chave: Indicador Sintético, Indicador Sintético Alternativo, Infraestrutura da Estação, Geografia Ferroviária, Causalidade da Infraestrutura.

Códigos JEL: O18, R11, D62

1. INTRODUCTION

A railway station is a place where trains are stopped to exchange passengers, goods and control of train movement (Upadyay and Gupta, 2012). Railway stations are an integral part of the railway transport system which is considered as the pillar of economic development, socio-cultural interaction and industrial growth as well as infrastructural development of any country, region and state (Roy and Mitra, 2020; Choudhary and Rao, 2018; Skorobogatova and Merlino, 2017; Wagner, 2012). The development of the transport system depends on the social and economic development of a country (Lingaitis and Sinkevičius, 2014). Convex topography and environmental vibrations also have an impact on the development of railway transport systems (Lu et al., 2019). The railway transport system is considered as the key factor of development and essential feature of all modern economies (Aldagheiri, 2010). Banerjee et al. (2020) argue that infrastructure development is a worthwhile object of policy and it plays an important role for determining the economic benefits.

Petrović et al. (2010) developed a cross-sectional profile of the existing supplementary amenities at railway stations and suggested to provide new facilities among the existing passengers for staying longer at the railway station as well as attracting new passengers in the railway stations. Goal et al. (2016) have shown the importance of the satisfaction paradigm on existing passenger amenities at the railway station. The operation and development of stations are the integration of multiple actors and interests (Bertolini, 1996). The infrastructural development of the railway stations may not be symmetrically distributed because of uneven traffic mobility, urban dynamics, industrial development, land use pattern (Brusinsma, 2009; Kasraian et al., 2016; Polom et al., 2018). Bruinsma (2009) focused on railway station area development and urban dynamics with internal and external effects through Cost Benefit Analysis (CBA) framework. It has been found that the development of a high-speed train station depends on large infrastructure projects like real-estate development projects. The railway systems of most countries have played an important role in the growth of cities. The direction of the urban system is expanded towards the railway stations (Pels, 2007).

Zemp et al. (2011) had classified the railway stations based on the demands and conditions of the site. Stoilova and Nikolova (2016) developed a methodological approach for classifying the railway passenger stations based on the potentiality of the location, infrastructure and transport volumes using principal component and cluster analysis. Jarocka and Glinska (2017) developed a synthetic indicator to present the state of development of railway transport infrastructure in Eastern Poland. Many researchers have been contributed to infrastructural development in the railway stations. But very few attended has been made to classify the railway stations with regard to the existing infrastructural facilities. The major problem of the Indian Railway in Tripura is inadequate infrastructural service delivery (Ministry of Railway, Government of India, 2009). Single track stations with inadequate infrastructural facilities like the non-existence of goods shed, insufficient working staff, poor passenger service etc. are the major issues for the development of the railway transport system in Tripura (Roy and Mitra, 2016 a). After 2016, few numbers of railway stations like Agartala, Udaipur, and Belonia have been designed for better infrastructural facilities, on the contrary, Jawaharnagar, Nadiapur and Nalkata railway stations have nominal infrastructural support (Mitra and Roy, 2020).

To address the infrastructural adequacy of the stations, proper classification has been required. This study intends to classify the railway stations in Tripura over existing infrastructure facilities and analyse the causality of differential infrastructural development for railway stations in Tripura.

2. LOCATION

The Indian railway is the fourth-longest railway network in the world with 123236 km route length and 7349 railway stations. The network is carried about twenty-three billion passengers (the highest in the world) and three million tons of freight (fourth highest in the world) in 2019-20 (Ministry of Railways, 2020). Indian railways provide services to all most all parts of the country with its eighteen zones and seventy divisions (Press Trust of India, 2019). Tripura, the second smallest state of Northeast India after Sikkim, was connected with other parts of the country in 2008 after a long socio-political struggle through meter gauge track (Roy and Mitra, 2020). After the intervention of Broad Gauge (1.676 m) in 2016 many infrastructural changes had been taken place at the different railway stations in Tripura.

The study is encompassed of all twenty-seven stations within the state of Tripura. About 264 km long operational railway track extends between Churaibari Railway Station (24˚26′ N. and 92˚14′ E.) in the North to Sabroom (23° 0' N. and 91°42' E.) in the South with twenty-five intermediate stations namely Nadiapur (24˚23′ N. and 92˚12′ E.), Dharmanagar (24˚22′ N. and 92˚10′ E.), Panisagar (24˚16′ N. and 92˚09′ E.), Pecharthal (24˚11′ N. and 92˚06′ E.), Kumarghat (24˚09′ N. and 92˚02′ E.), Nalkata (24˚03′ N. and 92˚00′ E.), Manu (23˚59′ N. and 91˚59′ E.), S.K. Para (23˚58′ N. and 91˚58′ E.), Jawaharnagar (23˚55′ N. and 91˚54′ E.), Ambassa (23˚55′ N. and 91˚51′ E.), Mungiakami (23˚53′ N. and 91˚42′ E.), Teliamura (23˚51′ N. and 91˚37′ E.), Jirania (23˚49′ N. and 91˚25′ E.), Jogendranagar (23˚48′N. and 91˚18′E.), Agartala (23˚47′N. and 91˚16′E.), Sekerkote (23°44' N. and 91°16'E.), Bishalgarh (23°40' N. and 91°16' E.), Bishramganj (23°35' N. and 91°21' E.), Udaipur (23°30' N and 91°28' E.), Garjee (23°25' N, and 91°29' E.), Santirbazar (23°19' N. and 91°31' E.) Belonia (23°14' N. and 91°29' E.), Jolaibari (23°11' N. and 91°35' E.), Thailik Twisa (23°7' N. and 91°36' E.) and Manu Bazar (23° 3' N. and 91°38' E.) Railway Station (Fig. 1 and Table 1).

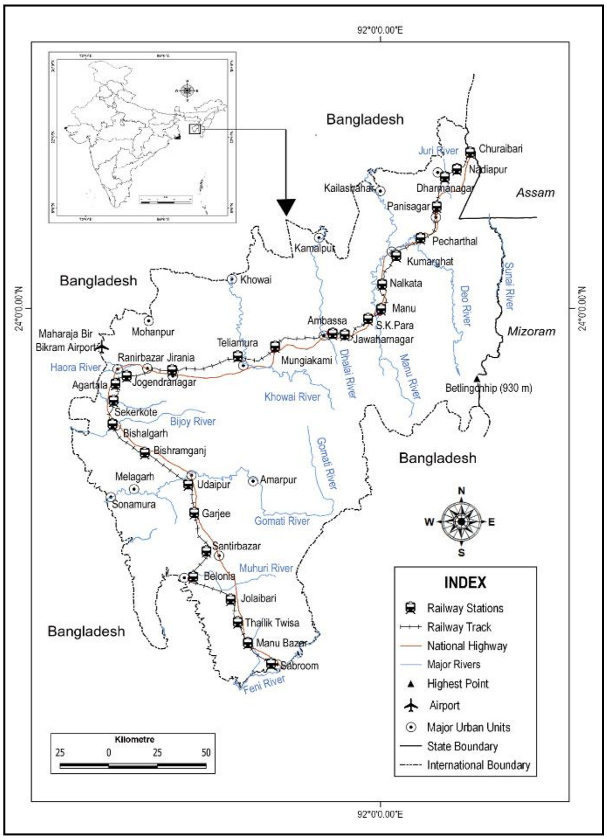
The railway moves north to south across three major hill ranges namely Baramura, Atharamura and Longtharai and the state has 11 major rivers name Longai (98 km), Juri (79 km), Deo (98 km), Manu (167 km), Dhalai (117 km), Khowai (70 km), Haora (53 km), Bijoy (26 km), Gomati (95 km), Muhuri (64 km) and Feni (116 km) (Fig. 1). The Road network of Tripura is very poor during the monsoon season because of landslides, the common phenomenon in this hilly terrain region (Sen et al., 2013). After a long socio-political struggle, the capital city Agartala connected with the rest of India through a meter gauge line (1000 mm) in 2008 (Roy and Mitra, 2016 a). Gradually railway becomes the prime mode of transportation in Tripura by connecting Northeast India (Roy and Mitra, 2016 b). During 2016, gauge conversion (Meter Gauge [1000 mm] to Broad Gauge [1676 mm]) took place under the uni-gauge project of the Ministry of Railways, Government of India (Roy et al., 2019).

Table 1. Basic Geographical Information of the Railway Stations in Tripura

Name of the Station	*Station Code*	*Latitude*	*Longitude*	*Elevation (m)*	*Distance from Churaibari (km)*
Churaibari	CBZ	24˚26′ N	92˚14′ E	44	0
Nadiapur	NPU	24˚23′ N.	92˚12′ E.	37	5
Dharmanagar	DMR	24˚22′ N.	92˚10′ E.	24	10
Panisagar	PASG	24˚16′ N.	92˚09′E.	36	22
Pecharthal	PEC	24˚11′ N.	92˚06′ E.	49	34
Kumarghat	KUGT	24˚09′ N.	92˚02′ E.	42	43
Nalkata	NLKT	24˚03′ N.	92˚00′ E.	44	54
Manu	MUNU	23˚59′ N.	91˚59′ E.	47	64
S.K. Para	SKAP	23˚58′ N.	91˚58′ E.	81	67
Jawaharnagar	JWNR	23˚55′ N.	91˚54′ E.	89	79
Ambassa	ABSA	23˚55′ N.	91˚51′ E.	80	84
Mungiakami	MGKM	23˚53′ N.	91˚42′ E.	110	102
Teliamura	TLMR	23˚51′ N.	91˚37′ E.	46	113
Jirania	JRNA	23˚49′ N.	91˚25′ E.	32	133
Jogendranagar	JGNR	23˚48′N.	91˚18′E.	31	147
Agartala	AGTL	23˚47′N.	91˚16′E.	27	151
Sekerkote	SEKE	23°44'N.	91°16'E.	29	157
Bishalgarh	BLGH	23°40'N.	91°16'E.	17	165
Bishramganj	BHRM	23°35'N.	91°21'E.	43	178
Udaipur	UDPU	23°30'N.	91°28'E.	19	193
Garjee	JRJE	23°25'N.	91°29'E.	32	203
Santirbazar	STRB	23°19'N.	91°31'E.	46	217
Belonia	BENA	23°14'N.	91°29'E.	40	227
Jolaibari	JLBRI	23°11'N.	91°35'E.	41	240
Manu Bazar	MUBR	23° 3'N.	91°38'E.	35	255
Sabroom	SBRM	23° 0'N.	91°42'E.	31	264

Source: Primary Survey, 2019

Figure 1. Location map of the study area



(Source: Prepared by the authors, 2021)

3. MATERIALS AND METHODOLOGY

The study is based on both primary and secondary data collected from every individual railway station of the state using survey instruments like measuring tape, digital distance meter, total station and hand-held GPS receivers (Garmin etrex 30x). Based on Indian Work Manual, 28 infrastructural variables like number of platforms, number of tracks, average platform length (m), average platform width (m), average platform height (m), size of the passenger shed (sq.m), size office area (sq. m), length of the foot over bridge (m), the width of the foot over bridge (m), the height of the footover bridge from railway track (m), no. of stairs in footover bridge, number of ticket counters, drinking water collection (taps) points, number of taps, number of water purifiers, number of bathrooms, lights, number of light posts, fans, mobile charging points, size of the waiting hall (sq. m.), size of the waiting room (sq. m.), sitting arrangement, public addressing system, number of dustbins, size of the parking area, number of trees, number of registered and non-registered vending stalls have been taken for station wise infrastructural development (Ministry of Railways, 2000).

Secondary data related to railway stations like monthly passenger flow, traffic volume, are collected from the office of the Station Manager or Station Master. Geo-spatial data like relief, slope, drainage, forest cover etc. were extracted from satellite imageries. The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) has been collected from using the United States Geological Survey (USGS) earth explorer platform. Sentinel Images data have been collected from Copernicus Open Access Hub. Images are processed and analysed by Global Mapper v.18, Arc GIS v10.7.1 softwares.

To identify the nature of the collected date sets, normality of each observed data has been tested through Shapiro-Wilk's test (Razali and Yup, 2011). The Shapiro-Wilk's test is based on the correlation between the observational data and the corresponding normal scores, and if the p-value of the test is found less than 0.05, then the assumption of normality of the corresponding data set has been discarded.

To assess state-wise railway development, Synthetic Indicator (Jarocka and Glinska, 2017) is widely applied. This indicator is a linear order of several variables, which are standardised by its arithmetic mean and standard deviation. In our study, the twenty-four variables are discrete data and we found that the data observations do not follow the normality assumptions, wherever only four variables follow the normality assumptions (carried out through Shapiro-Wilk's test and reported in Table 2). A new Synthetic Indicator, called Alternative Synthetic Indicator (ASI), has been proposed in Roy et al. (2022) for non-normal data observations, where the indicator is structured as the linear order of the median (as a measure of central tendency) and mean deviation about median (as a measure of dispersion). Roy et al. (2022) also suggested a generalisation of the synthetic indicator, called as Generalised Synthetic Indicator (GSI), where the Synthetic Indicator is appropriate for the normality assumptions of the observational data sets and Alternative Synthetic Indicator (ASI) is for the non-normal data sets.

In our data sets of twenty-eight variables, only four variables follow the normality assumption and the remaining twenty-four variables follow non-normality. A robust synthetic indicator has been introduced here to classify the railway stations according to their corresponding infrastructural facilities. The robust indicator is formulated as standardisation (normalisation) of corresponding linear additivity of SI and ASI values.

Physical hindrances on railway development in Tripura have been analysed through Digital Elevation Modelling (DEM) and Relative Relief (RR) for understanding physical hindrances. Geo-spatial data like relief, slope, drainage extracted from SRTM DEM data using USGS earth explorer platform. Sentinel-2 satellite Images have been used to formulate Normalised Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) and Build-up Index (BI). These indices are processed and analysed to find the causality of differential infrastructural development at the railway stations (Mohammad et al., 2019).

NDVI is equal to the difference in the intensities of reflected light in the red (Band-4) and infrared (Band-8) range divided by the sum of these intensities, calculated by using following formula:

$$NDVI = \frac{B8(VNIR) - B4(\mathrm{Re}\,d)}{B8(VNIR) + B4(\mathrm{Re}\,d)} \ ,$$

where

B8 is Visible and Near-Infrared with 10 m resolution and 842 nm central wavelength,

and B4 is red band with 10 m resolution and 665 nm central wavelength.

NDVI of the railway stations and surrounding areas indicate the density of forest (canopy) as well as indicate urban and water features. NDBI emphasises the higher reflectance in the shortwave-infrared (SWIR) region, compared to the near-infrared (NIR) region, which applies to predictions urban or settlement areas (He et al., 2010). Here we have used NDBI to understand the nature of the hinterland of the railway stations which induce passenger mobility and its required infrastructural facilities. NDBI has been calculated by using the following formula:

$$NDBI = \frac{B11(SWIR) - B8(VNIR)}{B11(SWIR) + B8(VNIR)} \ ,$$

where

B11 is Short Wave Infrared (SWIR) with 20 m resolution and 1610 nm central wavelength,

and B8 is Visible and Near-Infrared with 10 m resolution and 842 nm central wavelength.

For more accuracy in Build-up area identification, Build-up Index (BI) has been calculated by using the following method

$$BI = NDVI - NDBI$$

Global Mapper v.18, Arc GIS v10.7.1. software has used to process the data.

4. SYNTHETIC INDICATOR AND ALTERNATIVE SYNTHETIC INDICATOR

Data normality has been tested through Shapiro-Wilk's Test for all twenty-eight variables of the study. It has been found that data of only four variables, namely width of the platform, number of the light, size of the waiting hall and parking area, are normally distributed. On the other hand, data of remaining twenty-four variables are found non-normality (Table 2).

The details of the Shapira-wilk's test for all twenty-eight variables with the value of parameter lambda and corresponding p-value are reported in Table 1. If the p-value of the respective variable is found more than 0.05, then the normality of corresponding observations is resumed otherwise, non-normality is considered.

Table 2. Normality Assumption of Observed Data Sets through Shapiro-Wilk's Test

Infrastructural Variables	Value of Lambda	P Value	Nature of Data Set
Number of platforms	0.7578	0.000027	Non-normal
Number of tracks	0.77	0.000043	Non-normal
Average platform length	0.8628	0.002085	Non-normal
Average platform height	0.8707	0.003051	Non-normal
Passenger shed	0.8305	0.0004843	Non-normal
Office area	0.849	0.0011	Non-normal
Length of the footover bridge	0.6537	0.000001109	Non-normal
Width of the footover bridge	0.7592	0.00002907	Non-normal
Height of the footover bridge	0.6021	0.000000219	Non-normal
Stairs in footover bridge	0.6272	0.0000004364	Non-normal
Number of ticket counters	0.5986	0.0000001991	Non-normal
Drinking water collection (taps) points	0.8024	0.0001509	Non-normal
Number of taps	0.7912	0.00009686	Non-normal
Number of water purifiers	0.5879	0.0000001496	Non-normal
Number of bathrooms	0.7991	0.000132	Non-normal
Numbers of light post	0.7856	0.00007781	Non-normal
Numbers of fan	0.7602	0.00003015	Non-normal
Numbers of mobile charging points	0.8171	0.0002751	Non-normal
Size of the waiting room	0.739	0.00001423	Non-normal
Seating arrangement	0.6634	0.000001248	Non-normal
Numbers of public addressing system	0.8365	0.00006298	Non-normal
Number of dustbins	0.8286	0.00004467	Non-normal
Number of trees	0.9006	0.01382	Non-normal
Registered and Non-Registered Hawkers and Vendors	0.8033	0.000156	Non-normal
Width of the platform	0.9714	0.6393	Normal
Number of lights	0.9352	0.09295	Normal
Size of the waiting hall	0.9469	0.1806	Normal
Parking area	0.9385	0.1119	Normal

Source: Computed by the researchers using R v. 4.0.3

Classification of railway stations through Synthetic Indicator is reported in Table 2 for four normal variables i.e., average platform width (m), numbers of lights, size of the waiting hall and parking area. The calculated mean and standard deviation of the Synthetic Indicator are 0 and 2.96, respectively.

Table. 3. Classification of railway stations through Synthetic Indicator (SI)

Class	Method of Calculating Class	Class Range	Characteristic of Class	Class of the Stations
I	$z_i \geq \bar{z} + \sigma_{\bar{z}}$	$z_i \geq 2.91$	Very good infrastructure	Agartala, Udaipur and Sabroom
II	$\bar{z} \leq z_i < \bar{z} + \sigma_{\bar{z}}$	$0 \leq z_i < 2.91$	Good infrastructure	Garjee, Dharmanagar, Belonia, Bishramganj, Santirbazar, Jirania, Jogendranagar, Manu Bazar and Ambassa
III	$\bar{z} - \sigma_{\bar{z}} \leq z_i < \bar{z}$	$-2.91 \leq z_i < 0$	Poor infrastructure	Thailik Twisa, Bishalgarh, S. K. Para, Teliamura, Manu, Joliabari, Kumarghat, Sekerkote and Churaibari
IV	$z_i < \bar{z} - \sigma_{\bar{z}}$	$z_i < -2.91$	Very poor infrastructure	Panisagar, Mungiakami, Nalkata, Pecharthal, Jawaharnagar and Nadiapur

Source: Computed by the authors, 2021

The value of Synthetic Indicator of the respective station is reported below in bracket. For the stations, Panisagar (-3.04), Mungiakami (-3.23), Nalkata (-3.29), Pecharthal (-3.46), Jawaharnagar (-4.12) and Nadiapur (-4.63) are found with very poor infrastructure. Wherever for Thailik Twisa (-0.01), Bishalgarh (-0.03), S. K. Para (-1.81), Teliamura (-0.24), Manu (-0.33), Joliabari (-1.42), Kumarghat (-1.59), Sekerkote (-1.81) and Churaibari (-2.79), poor infrastructure is observed. Nine railway stations, namely Garjee (2.64), Dharmanagar (2.61), Belonia (2.57), Bishramganj (1.84), Santirbazar (1.83), Jirania (0.55), Jogendranagar (0.50), Manu Bazar (0.38) and Ambassa (0.24) have been found with good infrastructure and Agartala (7.63), Udaipur (5.95) and Sabroom (3.32) are with very good infrastructure (Table 3). In a nutshell, 3 (11.11%) stations are found with very good infrastructure, 9 (33.33%) are in good infrastructure, other 9 (33.33%) stations are also with poor infrastructure and the remaining 6 (22.23%) stations are reported with very poor infrastructure.

Table 4. Classification of railway stations through Alternative Synthetic Indicator (ASI)

Class	Method of Calculating Class	Class Range	Characteristic of Class	Class of the State
I	$y_i \geq \tilde{y} + MD_{\tilde{y}}$	$y_i \geq 24.39$	Very good infrastructure	Agartala, Dharmanagar, Udaipur and Belonia
II	$\tilde{y} \leq y_i < \tilde{y} + MD_{\tilde{y}}$	$7.07 \leq y_i < 24.39$	Good infrastructure	Sabroom, Ambassa and Kumarghat, Manu, Jirania, Teliamura, Garjee, Bishramganj, Santirbazar and Manu Bazar
III	$\tilde{y} - MD_{\tilde{y}} \leq y_i < \tilde{y}$	$-10.25 \leq y_i < 7.07$	Poor infrastructure	Joliabari, Churaibari, Bishalgarh, Panisagar, Pecharthal, Mungiakami
IV	$y_i < \tilde{y} - MD_{\tilde{y}}$	$y_i < -10.25$	Very poor infrastructure	Jogendranagar, Thailik Twisa, Nalkata, Sekerkote, Jawaharnagar, Nadiapur and S. K. Para

Source: Computed by the authors, 2021

On the other hand, for twenty-four non-normal railway infrastructural variables, Alternative Synthetic Indicator (ASI) has been calculated and found that 7 (25.93%) stations have very poor infrastructure. The stations are Jogendranagar (-12.43), Thailik Twisa (-23.55), Nalkata (-24.69), Sekerkote (-24.70), Jawaharnagar (-25.27), Nadiapur (-27.83) and S. K. Para (-30.08). Poor infrastructures are found in 6 (22.22%) stations: Joliabari (3.96), Churaibari (2.29), Bishalgarh (2.05), Panisagar (-0.42), Pecharthal (-0.70), Mungiakami (-8.57) railway stations. Only 10 (37.04%) railway stations have good infrastructure i.e., Sabroom (24.13), Ambassa (20.06), Kumarghat (17.95), Manu (17.13), Jirania (14.10), Teliamura (9.63), Garjee (7.69), Bishramganj (7.60), Santirbazar (7.49) and Manu Bazar (7.07). About only 4 (14.81%) railway stations of the state have very good infrastructure. Agartala (80.22), Dharmanagar (36.26), Udaipur (28.49) and Belonia (27.02) fall under this category (Table 4).

A Robust Synthetic Indicator (RSI) value for each station has been calculated by adding the corresponding normalised value of SI and ASI. RSI classification of railway stations over infrastructural facilities is reported in Table 4. Agartala (87.85), Dharmanagar (38.86), and Udaipur (34.44) railway stations are found with very good infrastructural facilities. There are 11 (40.74%) railway stations namely Belonia (29.59), Sabroom (27.45), Ambassa (20.30), Manu (16.80), Kumarghat (16.35), Jirania (14.65), Garjee (10.32), Bishramganj (9.44), Santirbazar (9.32), Teliamura (9.12) and Manu Bazar (7.45) railway station being observed with good infrastructure.

Table. 5. Classification of railway stations through Robust Synthetic Indicator (RSI)

Class	Method of Calculating Class	Class Range	Characteristic of Class	Class of the Stations
I	$z_i \geq \bar{z} + \sigma_{\bar{z}}$	$z_i \geq 30.92$	Very good infrastructure	Agartala, Dharmanagar, and Udaipur
II	$\bar{z} \leq z_i < \bar{z} + \sigma_{\bar{z}}$	$4.99 \leq z_i < 30.92$	Good infrastructure	Belonia, Sabroom, Ambassa, Manu, Kumarghat, Jirania, Garjee, Bishramganj, Santirbazar, Teliamura and Manu Bazar
III	$\bar{z} - \sigma_{\bar{z}} \leq z_i < \bar{z}$	$-20.95 \leq z_i < 4.99$	Poor infrastructure	Joliabari, Bishalgarh, Churaibari, Panisagar, Pecharthal, Mungiakami and Jogendranagar
IV	$z_i < \bar{z} - \sigma_{\bar{z}}$	$z_i < -20.95$	Very poor infrastructure	Thailik Twisa, Sekerkote, Nalkata, Jawaharnagar, S. K. Para and Nadiapur

Source: Computed by the authors, 2021

Poor infrastructure has been found in 7 (25.93%) railway stations: Joliabari (2.54), Bishalgarh (2.01), Churaibari (-0.50), Panisagar (-3.46), Pecharthal (-4.16), Mungiakami (-11.79) and Jogendranagar (-11.93). The remaining 6 (22.22%) railway stations i.e., Thailik Twisa (-23.57), Sekerkote (-26.52), Nalkata (-27.98), Jawaharnagar (-29.39), S. K. Para (-30.12) and Nadiapur (-32.47) are reported with very poor infrastructure.

The infrastructural development of the railway stations is unevenly distributed and it has been measured through RSI (Table 5). The causality of unequal infrastructural distribution varies on multifaced reasons. Tripura have unique 'Valley and Ridge' (Tilla and Lunga Topography) topography (Sen et al., 2015). Due to the physiographic hindrance surface of the state, transportation has been developed in a sluggish speed (Mitra and Roy, 2020).

Table. 6. Relation between Elevation and Station Infrastructure

<table>
<tr><th rowspan="2">Elevation Zone</th><th rowspan="2">Altitudinal Value (m)</th><th rowspan="2">Name of the Station with Infrastructural Grade (GSI)</th><th colspan="4">Percentage of Station Infrastructure</th></tr>
<tr><th>Class</th><th>No</th><th>% (within Zone)</th><th>% (Total Station)</th></tr>
<tr><td rowspan="4">I</td><td rowspan="4"><25</td><td rowspan="4">Agartala (I), Udaipur (I), and Bishalgarh (III)</td><td>Very Good</td><td>2</td><td>66.67</td><td>7.41</td></tr>
<tr><td>Good</td><td>0</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Poor</td><td>1</td><td>33.33</td><td>3.70</td></tr>
<tr><td>Very Poor</td><td>0</td><td>0.00</td><td>0.00</td></tr>
<tr><td rowspan="4">II</td><td rowspan="4">26-50</td><td rowspan="4">Dharmanagar (I), Bisramganj (II), Sabroom (II), Manu Bazar (II), Garjee (II), Santirbazar (II) Kumarghat (II), Teliamura (II), Belonia (II), Churaibari (III), Jirania (III), Panisagar (III), Jogendranagar (III), Jolaibari (III), Nadiapur (IV), Sekerkote (IV), and Thailik Twisa (IV)</td><td>Very Good</td><td>1</td><td>5.88</td><td>3.70</td></tr>
<tr><td>Good</td><td>8</td><td>47.06</td><td>29.63</td></tr>
<tr><td>Poor</td><td>5</td><td>29.41</td><td>18.53</td></tr>
<tr><td>Very Poor</td><td>3</td><td>17.65</td><td>11.11</td></tr>
<tr><td rowspan="4">III</td><td rowspan="4">51-75</td><td rowspan="4">Manu (II), Pecharthal (III), Nalkata (IV) and S. K. Para (IV)</td><td>Very Good</td><td>0</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Good</td><td>1</td><td>25.00</td><td>3.70</td></tr>
<tr><td>Poor</td><td>1</td><td>25.00</td><td>3.70</td></tr>
<tr><td>Very Poor</td><td>2</td><td>50.00</td><td>7.41</td></tr>
<tr><td rowspan="4">IV</td><td rowspan="4">>75</td><td rowspan="4">Ambassa (II), Jawaharnagar (IV) and Mungiakami (IV)</td><td>Very Good</td><td>0</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Good</td><td>1</td><td>33.33</td><td>3.70</td></tr>
<tr><td>Poor</td><td>0</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Very Poor</td><td>2</td><td>66.67</td><td>7.41</td></tr>
<tr><td colspan="4">Total</td><td>27</td><td></td><td>100</td></tr>
</table>

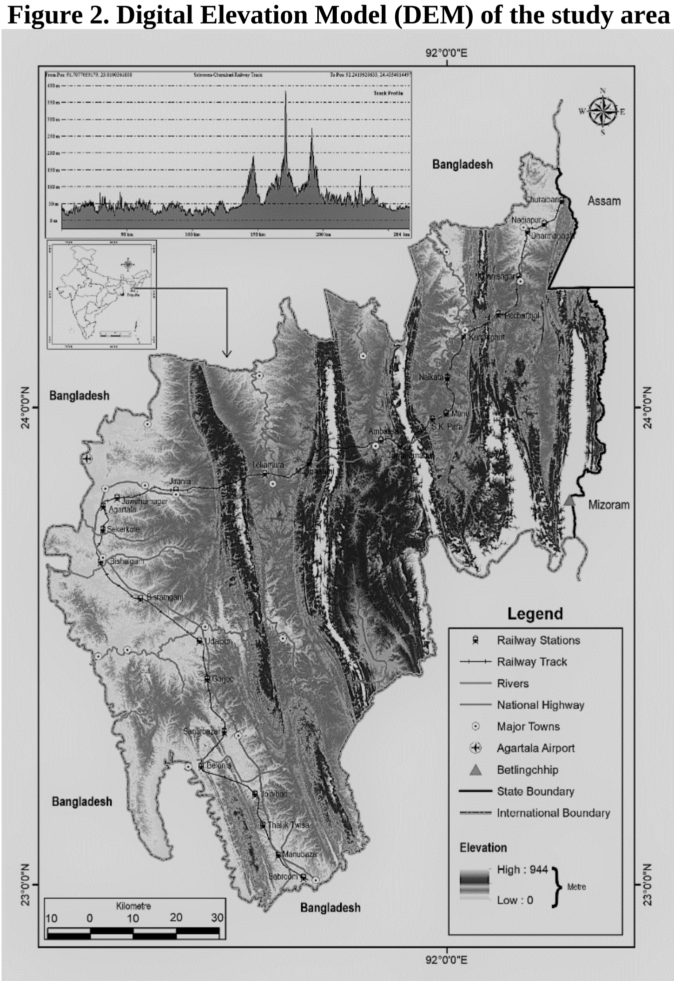
Source: Computed by the authors, 2021

It has been found that the maximum (17 out of 27, 62.97%) railway stations are located between 26 m to 50 m altitude (Table 6). Track profile of the state varies from 12 m to 360 m, and is presented its topography in Figure 2. Due to the close proximity of the Gomati and Bijoy river, Udaipur and Bishalgarh railway stations are located at 19 m above form the Mean Sea Level (MSL). But Jawaharnagar and Mungiakami railway stations are located at 101.45 m and 110.18 m from MSL in Atharamura and Longtharai hill range, respectively (Fig. 2). It has been found that such physiographic structure influences the infrastructural development of the station. Only 2 (7.41%) railway stations with very good infrastructure (Table 5) are located in below 25 m height from MSL, namely Agartala and Udaipur. Agartala is located in between 23° 45ˈto 23° 55ˈ N latitudes and 91°15ˈ to 91°20ˈ E longitudes in the flood plain of the river Haora with 526292 total population (AMC, 2018). On the other hand, Udaipur is the third largest railway station of Tripura, located at the left bank of river Gomati with 37,781 population (Census of India, 2011). Udaipur has significant value for religious tourism, archaeological tourism and heritage tourism. Bishalgarh railway station is also located at 19 m altitude due to the juxtaposition of river Bijoy (Fig 2.) Bishalgarh town is located about 21.2 km from Agartala city. Less number of trains (6) along with obnoxious departure and arrival times, peoples are compelled to travel by road which is the main causality of poor railway infrastructure has been found in Bishalgarh.

About 8 out of 17 (47.05%) railway stations between 26 m to 50 m having good infrastructure (Table 5). These stations are Sabroom (31.00 m), Manu Bazar (35.00 m), Garjee (35.39 m), Bishramganj (35.91 m), Belonia (40.00 m), Kumarghat (43.05 m), Santirbazar (46.00 m) and Teliamura

(46.54 m). Sabroom [23°00’05” N. and 91°43’11” E.] is located southernmost point of State of Tripura. Physiographically Sabroom railway station is located on the right bank of river Feni. Due to geo-strategic location with Bangladesh and socio-political demeanour are creating Sabroom has become a Geopolitical Hotspot. With respect to geo-strategic importance Sabroom railway station hold a good infrastructure (Table 4). Manu Bazar railway station is located on right bank of river Kalapania (Fig. 2). Belonia railway station is located on left bank of river Muhuri and about 3.90 km away from Indo-Bangla international border (Fig. 2). Kumarghat railway station has a good railway infrastructure, located 1.37 km northeast of Kumarghat town, where about 13,054 people resided (Census of India, 2011). This freight station not only serves Kumarghat town but also the entire Unakoti district, where the total population is about 2,98,574 according to Census of India, 2011.

Figure 2. Digital Elevation Model (DEM) of the study area



Source: Prepared by the authors, 2021

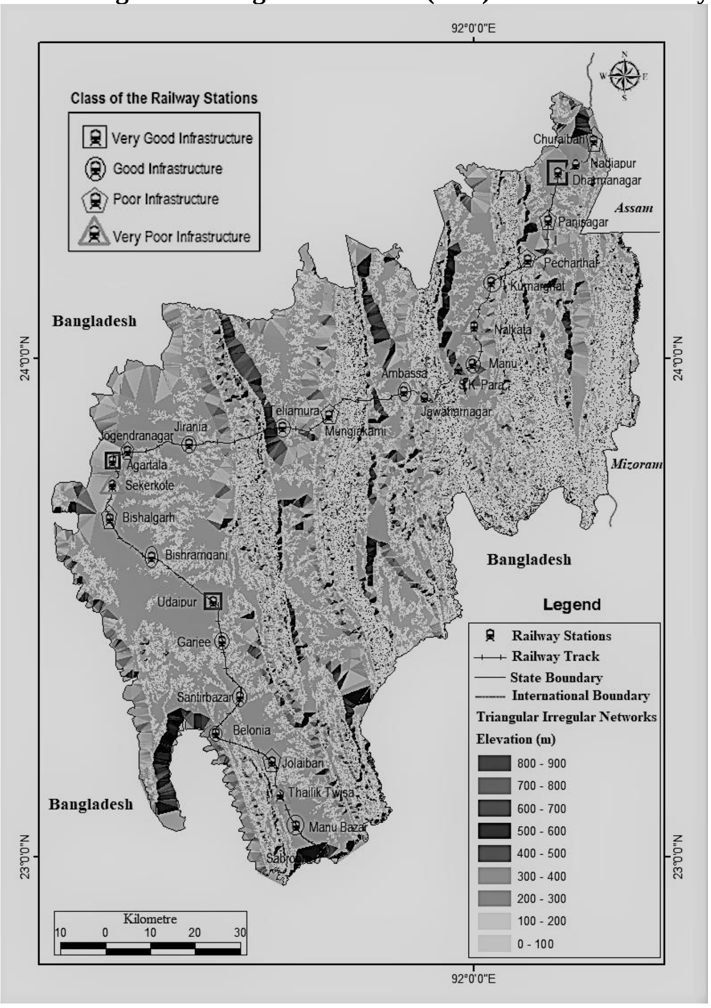
Teliamura railway station is located on left bank of river Khowai with an elevation of 46 m above MSL. This station has good station infrastructure. Two railway stations, namely Sekerkote and Nadiapur of this group have very poor station infrastructure. Those two railway stations are acted as a halt station or sub-station of Agartala and Dharmanagar, respectively. Due to the close proximity of the National Highway (NH-8) and peri-urban atmosphere, Sekerkote has huge potentiality in future (Fig. 2)

4 (14.81%) railway stations of the state fall under the elevation zone 51 m to 75 m. Among these 2 (50%) railways stations having very poor station infrastructure, Nalkata and S.K. Para railway station. Both the stations are located 65 m from MSL. Pecharthal railway station is located 51 m above the MSL. The Juri River flows from 930 m south-east of the Pecharthal railway station. Only Manu railway station of this zone has good infrastructure. Manu station is located about 59.95 m. form MSL. River Manu is passing from 856 m south of the station (Fig. 2).

Only 3 (11.11%) railway stations of Tripura are located about 75 m in height. Among these, 2 (66.67%) railway stations, Jawaharnagar and Mungiakami, have very poor infrastructure located at the hill range of Atharamura and Longtharai, respectively. Mungiakami railway station is located 110.18 m above the MSL which is the highest railway station in the state. Due to physiographic hindrance, passenger mobility is very few in Jawaharnagar (less than 300 passengers per month) resulted in very poor station infrastructure. Ambassa (79.29 m) is one of the high-altitude railway stations of Tripura, located right bank of river Dhalai (Fig. 2). However, due to functional activities like a district (administrative) headquarter, 11th largest populated town of the state and the location of Border Security Force (BSF) camp, Ambassa has good station infrastructure.

It has been observed that maximum stations with very good infrastructure are located in the low altitude. With the increase of height from MSL, station infrastructure has been reduced significantly.

Figure 3. Triangulated Irregular Network (TIN) Model of the study area



Source: Prepared by the authors, 2021

Triangulated Irregular networks represent the surface morphology of the state (Fig. 3). As we know, Tripura is land of Tilla and Lunga. Polymeric surfaces like Tilla and Lunga are characterised by the development of station infrastructure. It has been found that maximum railways are located in the valley region. Agartala, Dharmanagar, Udaipur railway stations with the very good infrastructure located in the valley of river Haora, Juri and Gomati, respectively (Fig 3). The stations with good infrastructure namely Belonia, Sabroom, Ambassa, Manu, Kumarghat, Jirania, Garjee, Bishramganj, Santirbazar, Teliamura and Manu Bazar are also located in the valley region.

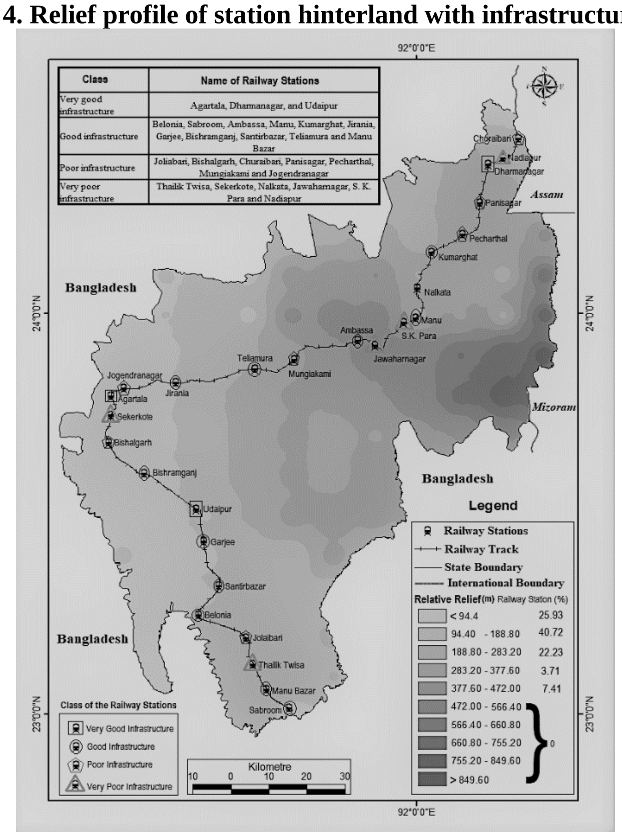
Table. 7. Relation between Relative Relief and Station Infrastructure

Zone	Height (m)	Name of the Station with Infrastructural Grade (GSI)	Percentage of Station Infrastructure			
			Class	No	% (Within Zone)	% (Total Station)
I	<94.4	Agartala (I), Udaipur (I), Bisramganj (II), Garjee (II), Sabroom (II), Jogendranagar (III), Bishalgarh (III) and Sekerkote (IV)	Very Good	2	25.00	7.41
			Good	3	37.50	11.11
			Poor	2	25.00	7.41
			Very Poor	1	12.50	3.70
II	94.40-188.80	Dharmanagar (I), Santirbazar (II), Manu (II), Belonia (II), Manu Bazar (II), Churaibari (III), Jirania (III), Jolaibari (III), Nadiapur (IV) and Thailik Twisa (IV)	Very Good	1	10.00	3.70
			Good	4	40.00	14.81
			Poor	3	30.00	1.11
			Very Poor	2	20.00	7.41
III	188.80-283.20	Teliamura (II) Kumarghat (II), Panisagar (III), Pecharthal (III), Nalkata (IV) and Mungiakami (IV)	Very Good	0	0.00	0.00
			Good	2	33.33	7.41
			Poor	2	33.33	7.41
			Very Poor	2	33.33	7.41
IV	> 283.20	Ambassa (II), Jawaharnagar (IV) and S. K. Para (IV)	Very Good	0	0.00	0.00
			Good	1	33.33	3.70
			Poor	0	0.00	0.00
			Very Poor	2	66.66	7.41
Total				27		100

Source: Computed by the authors, 2021

Only 2 (7.41%) railway stations with very good infrastructure are found in less than 94.4 m relative relief area. With the increase of relative relief number of the railway station with very good infrastructure facilities are reduced. 10 (37.04%) railway stations are found between 94.40 m to 188.80 m relief zone.

Figure 4. Relief profile of station hinterland with infrastructural class



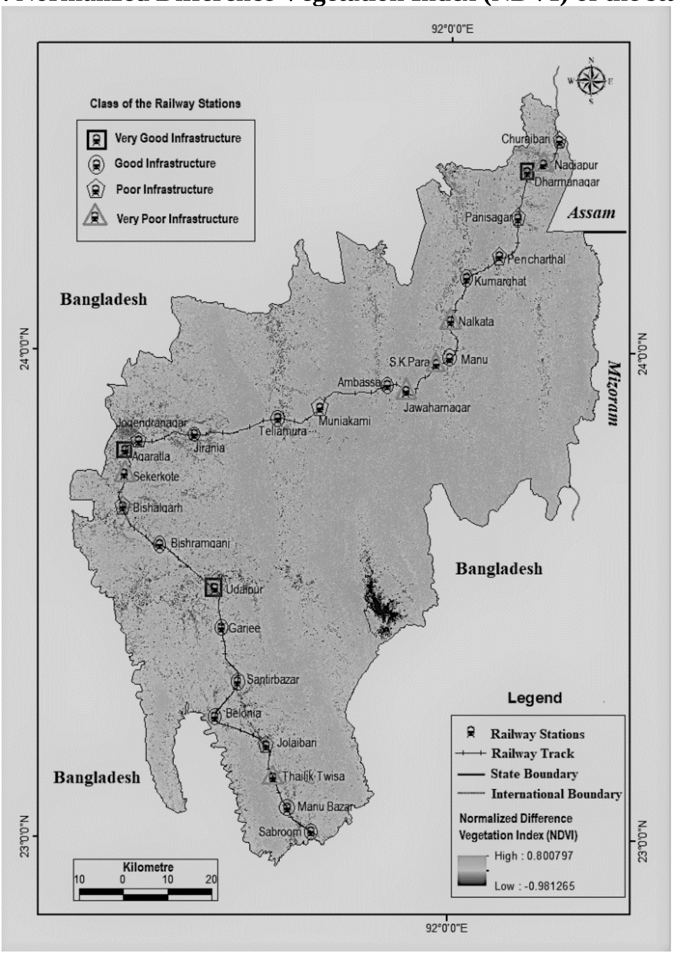
Source: Prepared by the authors, 2021

Above 283.20 m relative height, 2 out of 3 (66.67%) railway stations with poor infrastructure are observed. It explicates that with the increase of relative height from MSL, infrastructural facilities of the station has been reduced significantly (Table 7).

Relief of the stations and the surrounding area has been reflected through relative relief. It helps to understand the hinterland of the station. The hinterland of 7 (25.93%) railway stations are located below 94.40 m. (Fig. 4). Relative relief of 11 (40.72%) railway stations and surrounding area fall under 94.40 to 188.80 m. 6 (22.22%) railway stations relative relief are above 188.80 m. Relative relief of only 1 (3.70%) railway station is more than 283.20 m (Fig. 4).

Forest cover also play a significant role in station infrastructure. Nalkata, S.K. Para, Jawaharnagar and Thailik Twisa are located in the forested land and the infrastructural facilities of those stations are considerably very poor (Fig. 5).

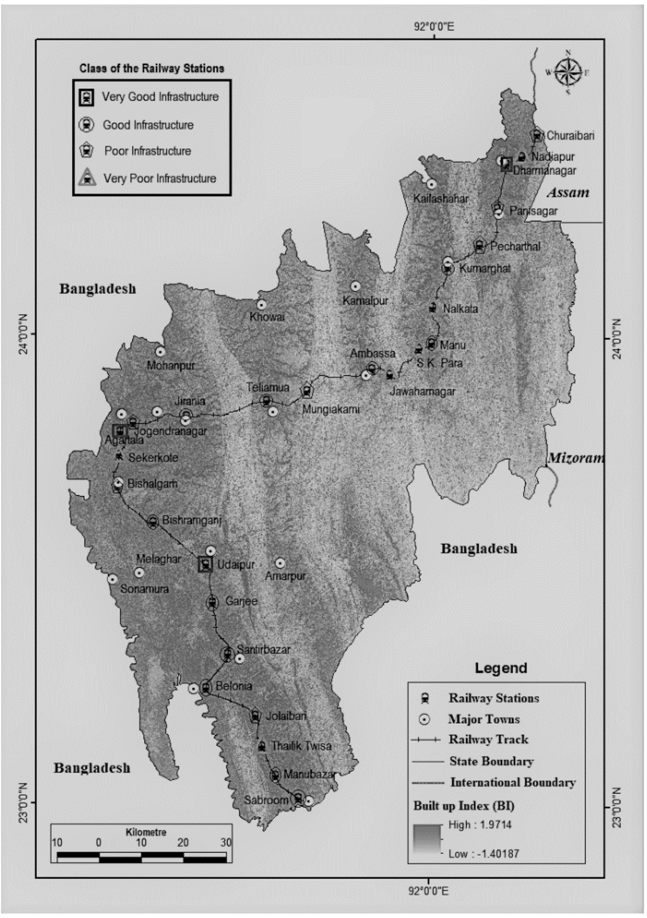
Figure 5. Normalized Difference Vegetation Index (NDVI) of the study area



Source: Prepared by the authors, 2021

On the other hand, those stations are located in urbanised area like Agartala and Dharmanagar having very good infrastructure. Udaipur, Belonia, Sabroom, Kumarghat, Manu, Teliamura, Jirania are located in the peri-urban area found with good infrastructural facilities. Build-up Index (BI) illustrates that those station surrounding areas have more build-up (majorly settlement) area and good infrastructure except Bishalgarh and Panisagar (Fig. 6)

Figure 6. Built up Index (BI) of hinterland with infrastructural class of railway stations



Source: Prepared by the authors, 2021

5. CONCLUSION

The infrastructural facilities of the railway stations are not equally distributed in Tripura. The causalities of differential development are surface topography, relief structure, forest cover, distance from the nearest urban centre, passenger mobility etc. A robust synthetic indicator has been induced to classify the infrastructural development of railway stations in Tripura. This indicator is structured a linear combination of Synthetic Indicator (for normal data observations) and Alternative Synthetic Indicator (for non-normal data). Agartala, Dharmanagar and Udaipur have very good stations infrastructure which needs to maintain for more passenger mobility. Suburban or Periurban railway stations like Jogendranagar, Sekerkote, Teliamura, Jirania, Manu, Panisagar etc. have huge potentiality for future development. Thailik Twisa, Nalkata, Jawaharnagar, S. K. Para and Nadiapur railway stations are needed to provide more infrastructural facilities to attract more passengers.

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