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# DELINEATING REGIONAL DIFFERENTIATION ON THE DEVELOPMENT OF THE RAILWAY INFRASTRUCTURE IN NORTHEAST INDIA THROUGH AN EFFICIENT SYNTHETIC INDICATOR

**Summary.** The north-eastern region of India presents intra-regional disparity, which is reflected in every aspect of development. The transport sector, especially railway transportation, is one of the important aspects, and the development of railway infrastructure seems to be very different in every region. The research question addressed in this study was "Which factors, geo-physical or socio-economic, influenced the variation in the level of railway development in Northeast India?" The aim of the study was to delineate regional differentiation on railway development in Northeast India and to analyse the reasons for different development patterns of railway lines among the north-eastern states. The research was based on secondary data collected from multiple sources, and the existing synthetic indicator was applied for the classification of eight states based on their railway infrastructural status. An alternative approach called the alternative synthetic indicator has been proposed and found to be more efficient than the existing synthetic indicator. The degree of inequality among the northeastern states by considering railway infrastructural variables was measured by plotting a Lorenz curve; the corresponding Gini coefficient specifies the unequal distribution of railway infrastructure among all the northeastern states. The causality of such unequal development has been analysed through a correlation test by defining the composite dimension index. The analysis revealed that all the externalities of regional inequality significantly influence the development of railway lines in northeastern states. Environmental determinism plays a crucial role in railway development in Northeast India, but political willingness is also crucial for creating an actual state of differentiation and will play a special role in the future.

## 1. INTRODUCTION

The Indian railway is the fourth-longest railway network in the world, with a 123,236-km route length and 7,349 railway stations. The network carried about twenty-three billion passengers (the most in the world) and three million tons of freight (the fourth highest in the world) in 2019-20 [1]. Indian railways provide services to almost all parts of the country with its eighteen zones and seventy divisions [2]. Northeast Frontier Railway (NFR) provides services to all eight Northeastern states, namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, as well as a small part of West Bengal and Bihar. Out of eight states of the northeastern region, operational rail

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network connectivity now exists in seven states: Arunachal Pradesh (26 km), Assam (3450 km), Manipur (18 km), Meghalaya (13 km), Mizoram (6 km), Nagaland (12 km) and Tripura (264 km). For, Sikkim, the new project for the construction of the railway between Sevoke and Rangpo (44.98 km) has also been sanctioned [3].

Initially in 1881, Assam Railway and Trading Company established a 65-km-long metre-gauge line from Dibrugarh (27˚28′ N. and 94˚54′ E.) to Margherita (27˚17′ N. and 95˚40′ E.) under the Guarantee System of British Parliament [4]. The Britishers' main goals in railway development in India was to export raw materials like cotton, jute, coal, and other agrarian products and industrial raw materials to support the industrial development of Britain, as well as to rule India smoothly [5-8]. The beginning of the exploration of the resources from Assam Province was associated with the Treaty of Yandaboo, which was signed between the British and the king of Myanmar on 24 February 1826 [9]. The region was nature's storehouse in this region, containing mineral resources, forest resources, water resources, and plant resources. As a result, the Britishers were captivated to explore the region [10, 11]. In 1912, the Britishers created Assam Province by separating from Eastern Bengal Province, including Shillong, then the capital of Assam Province [12].

The regional geo-political structure of northeast India has continuously changed since 1947, after independence. Princely states of this region, Manipur and Tripura joined in Indian Union in 1947 and 1949, respectively. Meghalaya, Nagaland and Mizoram were separated from Assam in 1972, 1963 and 1987, respectively, with an independent statehood of the Union of India [13]. In 1975, a referendum in Sikkim approved the merger of the state with India, abolishing the monarchy [14]. At present, the northeast is an officially recognised name for a region comprising seven contiguous states, including the detached state of Sikkim [15]. However, locational isolation, undulating physiography, rugged topography, diversified climatic conditions, incommensurable social demand, erratic economic activities, inadequate industrial development, political instability, and other factors cumulatively created an inter and intra-regional disparity within the northern region of India [16-23]. As a result, different development patterns have originated in the region.

Transport infrastructure and services are important factors in reducing the degree of regional imbalance and improvise sustainable development [24]. Moreover, the railway transport system is considered the key factor of development, economic growth [25, 26], the pillar of socio-cultural interaction and industrial growth, as well as infrastructural development of any country, region and state [27-29]. Therefore, it seems essential to feature all modern economies [30]. However, the railway is not always a cause of homogeneous regional development [31]. The development of the transport system depends on the social and economic development of a country [32], and convex topography and environmental vibrations have an impact on the development of the railway transport system as well [33]. As the studied region of Northeast India is geographically very diverse, the following research hypothesis was stated: The level of railway development varies between states in the region. Then, the research question was stated: Which factors, geo-physical or socio-economic, influenced the variation in the level of railway development in Northeast India? Therefore, the present study aimed to delineate regional differentiation in railway development in Northeast India and to analyse the reasons for different development patterns of railways among the northeastern states.

## 2. MATERIALS AND METHODS

### 2.1. Geographical context of the study area

Understanding the specificity of the development of railway infrastructure in the studied region requires the characterisation of its specific terrain and climate conditions. This research has been conducted in the northeastern states of India, including eight states, namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, covering a total geographical area of 262,179 sq. km (Fig. 1). This region is located in between 20° North to 29°30′ North latitudes and 89°46′ East to 97°30′ East longitudes. The great Himalayan mountains and Patkai hill range draw natural boundaries in the north and east, respectively, but the southern and western boundaries of the region are more political than natural [34]. Northeastern states share 5660 km long (about 99 per cent of the total boundary of Northeastern states) international borders with neighbouring countries like Bangladesh (1880 km), China (1346 km), Myanmar (1638 km), Bhutan (699 km) and Nepal (97 km). Three major physiographical landforms, viz. the Archaean plateau (Meghalaya plateau and Karbi Plateau), the young folded mountains of Tertiary origin (Dibong-Lohit Knot, Patkai-Tirap-Nagaland-North Cachar and Manipur Hill, Mizoram-Tripura range and valley) and the young alluvial plains (Brahmaputra Plain, Manipur Plain, Barak Plain, Tripura Plain) are found in this region [35]. Geo-environmentally, northeastern states are conglomerated territories of different climatic realms [36]. The northeastern states of India, especially in the valley region, show, to a large extent, the character of a tropical climate. In Northeast India, heavy to very heavy monsoonal rainfall is experienced from June to September. This region broadly experiences three seasons: summer, monsoon and winter. There is a significant climatic difference between the valleys and the hilly region. While the average temperature in January in the low-lying areas of Assam is around 16 °C, the temperatures in the hilly part of Arunachal Pradesh and Nagaland however, are around a maximum of 14 °C and the lowest temperatures are below 0 °C. The summer temperatures in the plain land vary between 30 °C and 33 °C, while the hills have a mean summer temperature of about 20 °C, with the average lowest temperature of 15 °C. Nowhere in the region is there substantial snowfall, excluding the higher parts of Arunachal Pradesh, like in the west Kameng (27º18′ N. and 92º16′ E) and Tawang (27º 35′ N. and 91º51′ E) areas. All parts of North-east India receive rainfall above 1,000 mm. Shillong plateau, with its southern limit marked by a 1200-m-high scarp overlooking the Bangladesh plain, receives very heavy rains. Cherrapunji (25º12′ N. and 91º43′ E), situated on the top of the scarp, receives a mean annual rainfall of 11,465 mm [10]. Topographical characteristics are one of the determining factors of drainage systems [37]. The whole North-East of India is drained into the Bay of Bengal, mainly through the two major rivers of the region, Brahmaputra and Barak. The Brahmaputra has over two dozen tributaries, joining from the north, as well as from the south, and about 178,000 sq. km (27 per cent) is a drainage area that lies in North-East India. About 70 per cent of the area of northeastern states lies in the catchment of Brahmaputra [10].

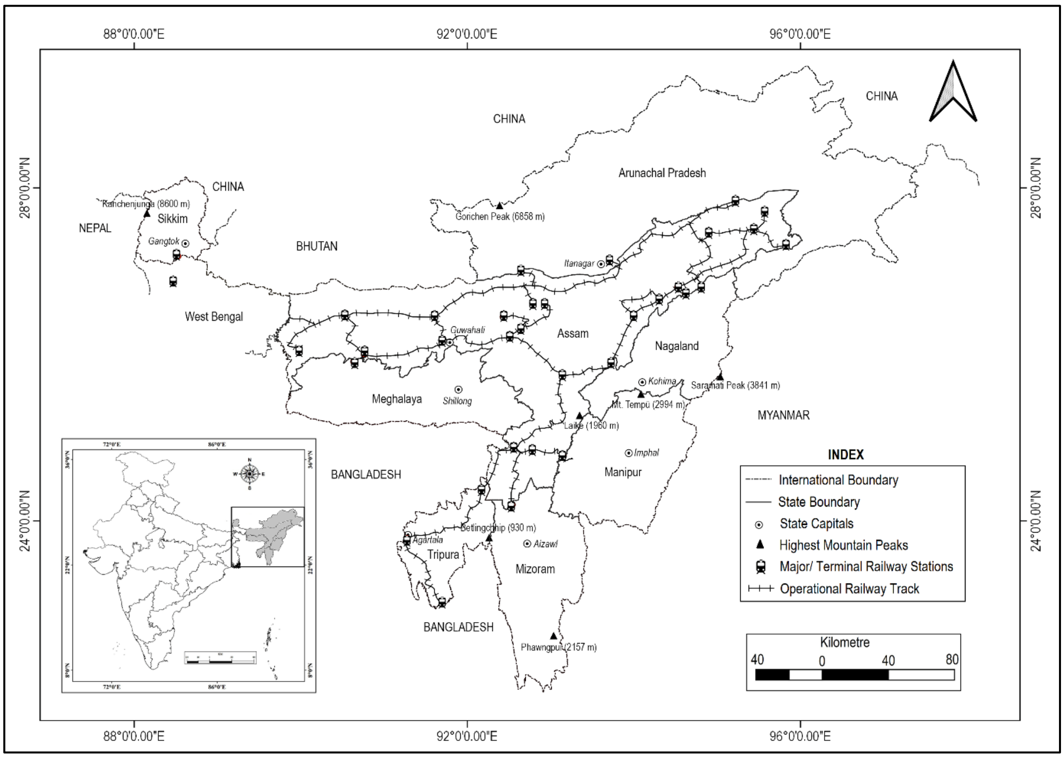


Fig. 1. Location map of the study area
Source: Prepared by the authors

Geographically, apart from the Brahmaputra, Barak and Imphal valleys, some flatlands lie between the hills of Meghalaya and Tripura. The remaining two-thirds of the area are hilly terrain interspersed with valleys and plains. The altitude varies from almost sea level to over 7,000 meters above the mean sea level.

### 2.2. Materials

The study was constructed based on secondary data collected from multiple sources. The data of railway stations and tracks of all northeastern states was collected from the office of the general manager (construction), Guwahati. A system map and operational data of all railway divisions were collected from the office of all concerned railway divisions (i.e., Tinsukia, Lumding, Rangiya, Alipurduar and Katihar). State area and population data were collected from the Census of India, 2011. State GDPs were computed from the Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India, 2016-2017. Data of industrial distribution, especially medium and large-scale industries in northeastern states, were obtained from the Development Commissioner Ministry of Micro, Small and Medium Enterprises, Government of India, and the Centre for Monitoring Indian Economy Pvt. Ltd. Numbers of urban settlement and rural settlement by state were extracted from the Census of India, 2011. Geo-spatial data like relief, slope, drainage, and forest cover, were extracted from satellite imagery using the USGS earth explorer platform. Images were processed and analysed in Global Mapper v.18, Arc GIS v10.7.1.

### 2.3. Methods

The main research hypothesis was that the level of railway development varies between states in the region. Following the hypothesis verification, the research question was stated: Which factors, geo-physical or socio-economic, influenced the variation in the level of railway development in Northeast India?

Synthetic Indicator has been widely applied to assess railway development. For example, Jarocka and Glinska analysed the state of development of railway transport infrastructure in Eastern Poland by formulating the synthetic indicator. This indicator was carried out to rank the provinces by identifying the regions of Eastern Poland, which vary from others, concerning the expansion of rail infrastructure [38]. Lu et al. classified the hierarchical structure of railway networks in China through the Z-score (synthetic indicator) based on timetable data, like time of arrival, departure and stoppage time of the train [33]. Yang et al. explored the statistical distribution model of high-speed railway train delays. They also used different statistical models (i.e., lognormal, exponential, gamma, uniform, logistic, and normal distribution). The Kolmogorov-Smirnov (K–S) test was used to test the goodness of fit and determine the most appropriate distribution [39]. Yahya et al. classified the railway stations in Klang city of Malaysia. In their study, travel cost and attractiveness of the station were considered. They calculated the station-wise accessibility by using Z-score to classify the railway stations and represented them through the Geographical Information System (GIS) technique [40]. Gasparik et al. applied a gravitational model for the estimation of regional rail transportation. The transport potential coefficient has been standardised through a synthetic indicator [41].

The synthetic indicator is a linear equation consisting of the arithmetic mean and standard deviation. Our study assumes that the railway track and number of railway stations are the indicators of the development of the railway transport system. An index called the weighted percentage index (WPI) for each state was proposed based on railway track length and railway stations with corresponding weights $w$ and $w-1$, respectively, $0 < w < 1$. The proposed WPI has been formulated as shown in Equation (1):

$$WPI = (p_1 w) + \left(p_2(1-w)\right) \tag{1}$$

where $p_1 = percentage\ of\ railway\ track$ and $p_2 = percentage\ of\ railway\ stations$. With the loss of generality, we considered $w = 0.5$ (i.e., an equal weightage of 0.5 has been given to both the railway track and stations.)

In our study, the variables (the length of the railway track and number of railway stations) are discrete data, and it was found that the data observations did not follow the normality assumptions. There are several normality tests that could have been used for the observed data sets, such as the Kolmogorov-Smirnov test, Shapiro-Wilk's test and Anderson-Darling test. In this study, the Shapiro-Wilk's test was used, as it provides better power than the K-S test and Anderson-Darling test [42]. 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 less than 0.05, then the assumption of normality of the corresponding data set is discarded. The quantile-quantile plots (Q-Q plots) of the observational data set (railway track length and number of railway stations) were also carried out to assess the normality assumptions of the observational data set through the graphical presentation in Fig. 2. If the data followed the assumptions, then the data observations were plotted at 450 angles of the (0,0) point, corresponding to the Q-Q plot.

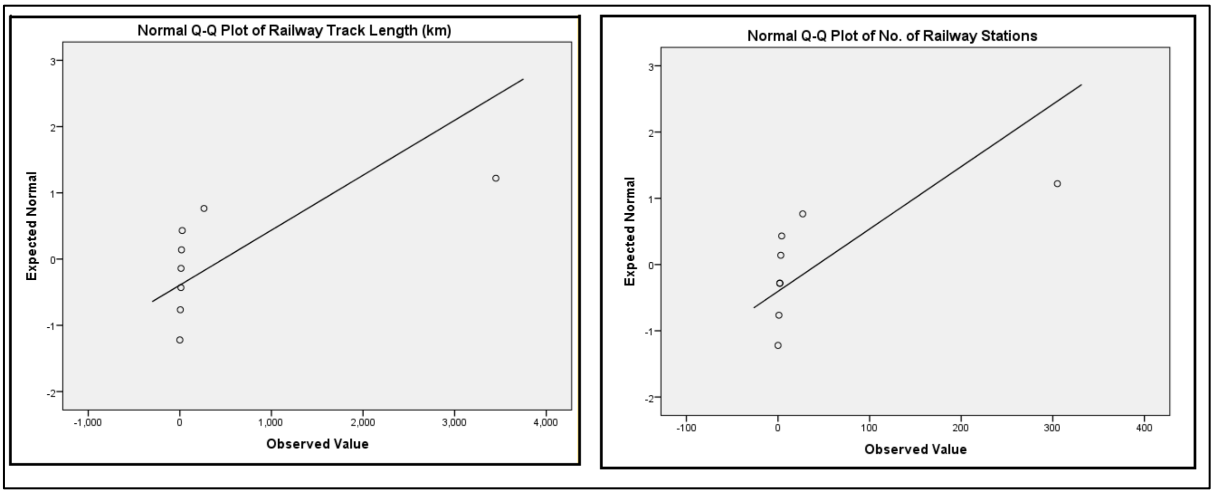


Fig. 2. Q-Q plot of railway track and railway stations data of Northeast India
Source: Prepared by the authors, using SPSS v.20

It has been observed that among the total of 3789 km railway track length in the north-eastern states, 3450 km (91.05%) are in Assam, and the remaining (339 km, 8.95%) are extended among the six states, excluding Sikkim (0 km). Similar observations were also made for other variables (i.e. the number of railway stations). It has been reported that a total of 344 stations are in the north-eastern states, with 305 (88.66%) in Assam and 39 in the other six north-eastern states (with none in Sikkim). These observations indicate the skewness (asymmetric) of the data set. Therefore, the mean may not be considered the appropriate measure of central tendency.

A new synthetic indicator called the alternative synthetic indicator (ASI) has been proposed here for asymmetric or skewed data sets, where the indicator is structured as the linear combination of the median (as a measure of central tendency) and mean deviation about median (as a measure of dispersion). For the asymmetric nature of the data set, the median has been preferred over the mean as a measure of the central tendency to divide the data set into two equal distributions. Therefore, we have also proposed a generalisation of the synthetic indicator, called a generalised synthetic indicator (GSI), where the synthetic indicator is appropriate for the normality assumptions of the observational data sets, and the ASI is appropriate for asymmetric or skewed data sets.

The GSI has been carried out as a linear combination of a standardised measure of respective variables. The general standardisation of the $i^{th}$ variable is denoted by $g_i$, where:

$$g_i = \begin{cases} y_1 = \dfrac{x_i - median(x)}{MD_{\tilde{x}}(x)} & (2) \\ \\ z_i = \dfrac{x_i - mean(x)}{\sigma(x)} & (3) \end{cases}$$

with i=1,2,…,t for ‘t’ variables. Equations (2) and (3) were considered according to the nature of each of the ‘t’ variables. If the non-normality of the respective variable was found through Shapiro-Wilks’s test, then Equation (2) was considered a general standardisation; otherwise, we adopted Equation (3).

A Lorenz curve has been plotted, and the corresponding Gini coefficient has been measured to understand the degree of inequality in terms of railway development among the north-eastern states. The Gini coefficient is definite as a ratio of the areas on the Lorenz curve. If the area between the line of perfect equality and a Lorenz curve is A, and the area under the Lorenz curve is B, then the Gini coefficient is A/(A+B). Since A+B= 0.5, the Gini coefficient G=2A=1-2B. The reasons for the unequal development of railway transport have been analysed through correlation analysis. Physical hindrances to railway development in north-eastern states have been analysed through digital elevation modelling (DEM) and relative relief for understanding physical hindrances. Socio-economic development has been measured through a composite dimension index (CDI) for each state. $CDI_j$ for state ‘j’ was calculated using Equation (4):

$$CDI_j = \sum_{k=1}^{v} \frac{\partial_{kj}}{v}, \text{ for } j=1,2\ldots\ldots s \quad (4)$$

where s=number of states, v= number of development parameters, and

$$\partial_{kj} = \frac{X_{kj} - X_{k(1)}}{X_{k(n)} - X_{k(1)}} \quad (5)$$

$X_{k\,j}$= j[th] observational value of corresponding development parameter $X_k$
$X_{k(1)}$ = minimum value of corresponding development parameter $X_k$
$X_{k(n)}$ = maximum value of corresponding development parameter $X_k$
Remarks: Range of $CDI_j$ is [0,1]

Proof: Consider a state ‘M’, which contains the highest value of observation for each of the corresponding ‘v’ development parameters (i.e. for k=1,2,…,v).

In this case,

$$\partial_{kj} = \frac{X_{kj} - X_{k(1)}}{X_{k(n)} - X_{k(1)}} = 1 \text{ for } k=1, 2,\ldots,v, \text{ hence}$$

$$CDI_M = \sum_{k=1}^{v} \frac{1}{v} = \frac{v}{v} = 1$$

Similarly, another state, say ‘m’, may be considered, which always contains only the lowest value of observation for each of the corresponding ‘v’ development parameters ($X_{km} = X_{k(1)}$, for all k). So, $\partial_{km} = 0$, hence

$$CDI_m = \sum_{k=1}^{v} \frac{0}{v} = 0.$$

## 3. RESULTS AND DISCUSSION

Data normality was tested through Shapiro-Wilk’s test for the two variables (i.e. railway track length and number of railway stations). It was found that the value of the Shapiro-Wilk’s parameter was 0.4634 and the corresponding p-value was 0.0000037 (<0.05) for railway track length, whereas for railway stations, the Shapiro-Wilk’s parameter was 0.4724 and the corresponding p-value was 0.0000048 (<0.05). As the corresponding p-values for both the variables are much less than 0.05, normality assumptions of the observed data sets were discarded. The following quantile-quantile plots (Q-Q plots) in Fig. 2 also support the above statement.

The WPI has been proposed to understate the development of railway transport infrastructure. Equal weightage has been given to railway tracks and all railway stations. It was found that about 91.05 per cent of the railway track of Northeast India was in Assam. Tripura holds the second position with 6.97 per cent of the railway track. All other states have less than one per cent of the railway track (Table 1). About 88.66 per cent of railway stations are located in Assam. Tripura and Nagaland have 7.85 and 1.16 per cent of the railway stations in Northeast India, respectively. According to WPI, Assam holds both the most railway track and the most stations. The WPI value of Tripura is about 7.41. WPI scores of other northeastern states are below one, which reflects that Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Sikkim have very poor railway infrastructural facilities (Tab. 1).

Table 1

Weighted Percentage Index (WPI) of the railway infrastructure of Northeast India

| Name of the State | Railway Track Length (km) | Percentage of Railway Track Length (P1) | No. of Railway Stations | Percentage of Railway Stations (P2) | Weighted Percentage Index |
|---|---|---|---|---|---|
| Arunachal Pradesh | 26 | 0.69 | 3 | 0.87 | 0.78 |
| Assam | 3450 | 91.05 | 305 | 88.66 | 89.86 |
| Manipur | 18 | 0.48 | 2 | 0.58 | 0.53 |
| Meghalaya | 13 | 0.34 | 2 | 0.58 | 0.46 |
| Mizoram | 6 | 0.16 | 1 | 0.29 | 0.22 |
| Nagaland | 12 | 0.32 | 4 | 1.16 | 0.74 |
| Tripura | 264 | 6.97 | 27 | 7.85 | 7.41 |
| Sikkim | 0 | 0.00 | 0 | 0.00 | 0.00 |

Source: Northeast Frontier Railway & computed by the authors, 2021

The generalised synthetic indicator (GSI) of the railway infrastructure of Northeast India is shown in Tab. 2. The calculated mean of the synthetic indicator was 0, and the standard deviation was 1.99996. On the other hand, due to the non-normality of data sets for each of the variables, the alternative synthetic indicator was considered. For the alternative synthetic indicator, we calculated the median and the mean deviation of the mode. The value of the median and the mean deviation are 0.01090 and 1.99678, respectively. The method of classification and the class range of the synthetic and alternative synthetic methods are reported in Tab. 3 and Tab. 4, respectively.

Table 2

Generalised Synthetic Indicator (GSI) of the railway infrastructure of Northeast India

| Name of the State | Railway Track Length in km (X1) | No. of Railway Stations (X2) | Synthetic Indicator | Alternative Synthetic Indicator |
|---|---|---|---|---|
| Arunachal Pradesh | 26 | 3 | -0.7477387 | 0.034514282 |
| Assam | 3450 | 305 | 4.9345344 | 14.617658164 |
| Manipur | 18 | 2 | -0.7637863 | -0.006609802 |
| Meghalaya | 13 | 2 | -0.7679327 | -0.017342294 |
| Mizoram | 6 | 1 | -0.7831510 | -0.056319880 |
| Nagaland | 12 | 4 | -0.7499352 | 0.028415399 |
| Tripura | 264 | 27 | -0.3244505 | 1.120231232 |
| Sikkim | 0 | 0.00 | -0.7975400 | -0.093150967 |

Source: Northeast Frontier Railway & computed by the authors, 2021

As per the synthetic indicator, only Assam has very good infrastructure, and all other Northeastern states have poor railway infrastructure facilities (Tab. 3). On the other hand, according to the alternative synthetic indicator, only Assam holds very good infrastructure (Tab. 4).

Comparatively good infrastructure was found for Tripura, Nagaland and Arunachal Pradesh. In another way, the remaining four northeastern states (Manipur, Meghalaya, Mizoram and Sikkim) were found to have poor infrastructure. This reflects an overall uneven state-wise distribution of railway infrastructure was found in Northeast India. The potential advantage of the very good infrastructure found in Assam may be its locational advantage. This state is considered the gateway of the northeastern states. The remaining states of Northeast India lack well-developed transportation points, which is reflected in the classification of their railway stations. The states have been ranked to understand the comparative status of the railway infrastructure. The efficiency of the alternative synthetic indicator was estimated by carrying out an efficiency index on variance differences of the corresponding indices based on Equation (6):

$$EI = \frac{v_1 - v_2}{v_2} \tag{6}$$

where: $v_i$ = variance of the existing synthetic indicator; $v_x$ = variance of the alternative synthetic indicator

Table 3

Classification of state-wise railway infrastructure for the synthetic indicator

| Class | Method of Calculating Class | Class Range | Characteristic of Class | Class of the State |
|---|---|---|---|---|
| I | $z_i \geq \bar{z} + \sigma_i$ | $z_i \geq 1.9996$ | Very good infrastructure | Assam |
| II | $\bar{z} < z_i \leq \bar{z} + \sigma_i$ | $0 < z_i \leq 1.9996$ | Good infrastructure | |
| III | $\bar{z} - \sigma_i \leq z_i \leq \bar{z}$ | $-1.9996 \leq z_i \leq 0$ | Poor infrastructure | Arunachal Pradesh Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. |
| IV | $z_i \leq \bar{z} - \sigma_i$ | $z_i \leq -1.99996$ | Very poor infrastructure | |

Source: Computed by the authors, 2021

Table 4

Classification of state-wise railway infrastructure for Alternative Synthetic Indicator (ASI)

| Class | Method of Calculating Class | Class Range | Characteristic of Class | Class of the State |
|---|---|---|---|---|
| I | $y_i \geq \tilde{y} + MD_{\tilde{y}}$ | $y_i \geq 2.00768$ | Very good infrastructure | Assam |
| II | $\tilde{y} \leq y_i \leq \tilde{y} + MD_{\tilde{y}}$ | $0.01090 \leq y_i \leq 2.00768$ | Good infrastructure | Arunachal Pradesh, Nagaland and Tripura |
| III | $\tilde{y} - MD_{\tilde{y}} \leq y_i \leq \tilde{y}$ | $-1.99678 \leq y_i \leq 0.01090$ | Poor infrastructure | Manipur, Meghalaya, Mizoram and Sikkim |
| IV | $y_i \leq \tilde{y} - MD_{\tilde{y}}$ | $y_i \leq -1.98588$ | Very poor infrastructure | |

Source: Computed by the authors, 2021

It was found that the variances of the synthetic indicator and alternative synthetic indicator were 11.33 and 3.33, respectively. The gain in efficiency of the ASI over the synthetic Indicator was 240.40 per cent. This finding shows that our suggested alternative synthetic indicator is much more efficient than the existing synthetic indicator. The synthetic indicator misleads the classification of railway infrastructure among the north-eastern states of India, while the alternative synthetic indicator efficiently measures the classification of railway infrastructure in North-eastern India.

The areas and populations of the states significantly influence railway development [43]. Therefore, population density was calculated based on census data from 2011. Based on population density, railway infrastructure in terms of WPI inequality was measured using the Lorenz curve and Gini coefficient.

The Gini coefficient (0.875) indicates that railway infrastructure is not equally distributed among all North-eastern states and that there is substantial inequality between railway infrastructure (track length and stations) and population density (total geographical area and population) in Northeast India (Fig. 3). The unequal distribution of railway infrastructure in Northeast India is inherent in its geographical setup and socio-economic configurations. The role of geographical setup in the unequal distribution of railway development in Northeast India was explored by employing a few morphometric analyses like relative relief, average slope, topographic ruggedness index, drainage density and forest cover were conducted. The results are reported below (Fig. 3).

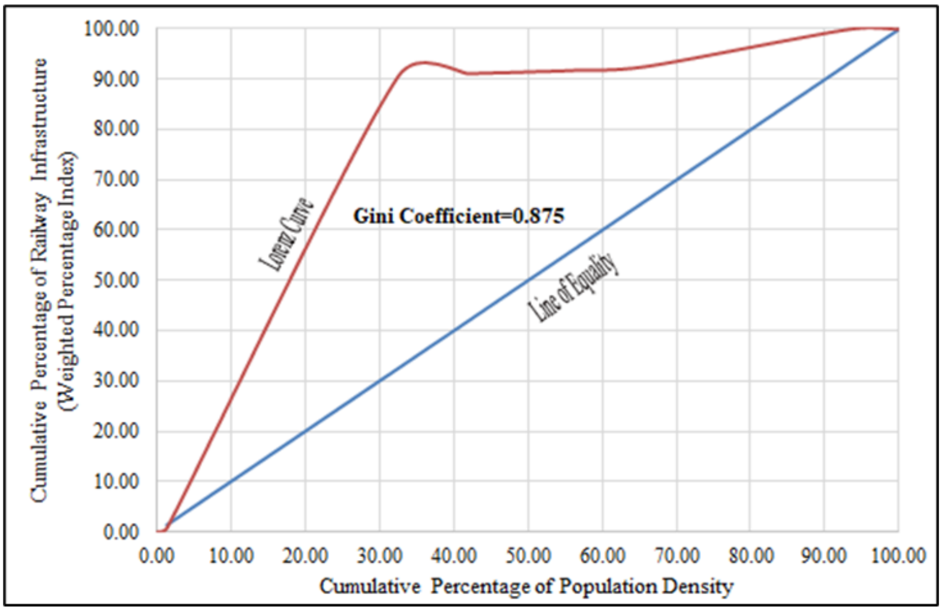


Fig. 3. Inequality between population density and railway infrastructure
Source: Prepared by the authors

Physiographically, Northeast India has three major relief features: young fold mountains, alluvial plains, and plateau regions. Most of the north-eastern region is mountainous, with many peaks reaching great heights. These are young mountains prone to frequent earthquakes and subsequent destruction. The region has an abundance of forests. Most of the Northeast Indian rivers flow into the Bay of Bengal. The two main rivers of this region are the Brahmaputra and Barak [10]. From the digital elevation model of Northeast India, it was found that the maximum stations have been developed at a height below 500 m (Fig. 4), which shows that topographical variation plays a crucial role in railway development in Northeast India.

Assam and Tripura have the plainest land with a high concentration of railway stations. Arunachal Pradesh and Sikkim have mostly rugged topography due to the eastern Himalayan mountains, and similar topographical characteristics are found in Nagaland, Manipur and Mizoram due to the Patkai hills. Karbi-Meghalaya plateau also hinders the establishment of railway infrastructure in Meghalaya and connects Brahmaputra valley with Barak valley and Tripura.

An increase in relative height significantly decreases the number of railway stations (Fig. 5). Due to relative adverse relief, railway infrastructures are not developed in Arunachal Pradesh or Sikkim. The Eastern part of Northeast India, especially Nagaland, Manipur and Mizoram, also have similar relief structures that have resulted in low railway development. It was also found that due to their comparatively abundant low-lying areas, a good quantum of railway infrastructural development has been done in Assam and Tripura.

Apart from physical hindrances, some socio-economic activities like population pressures, settlement distribution, urban growth, industrial development, and state GDP also influence railway development processes. Based on the above parameters, the composite dimension index (CDI) of each of the north-eastern states has been calculated and reported in Tab. 5. It has been observed that Assam holds a better position (rank 1) than the other north-eastern states, whereas Sikkim ranked eighth. A correlation test was performed between CDI and WPI to find out the relation between railway infrastructure and several development parameters. A significance value (p-value = 0.0000015, <0.05) with a highly positive correlation (r = 0.991617) was found.

A regression line was also fitted for the WPI over the CDI based on a linear combination of five different parameters (total population, number of settlements, number of urban centres, number of industries and state GDP). The following regression model (7) was fitted with a high R-squared value (0.98334):

$$WPI = -5.267+94.315 \times CDI \tag{7}$$

This reflects that developmental disparity exists among the states of Northeast India, which influences inequality in railway infrastructural development.

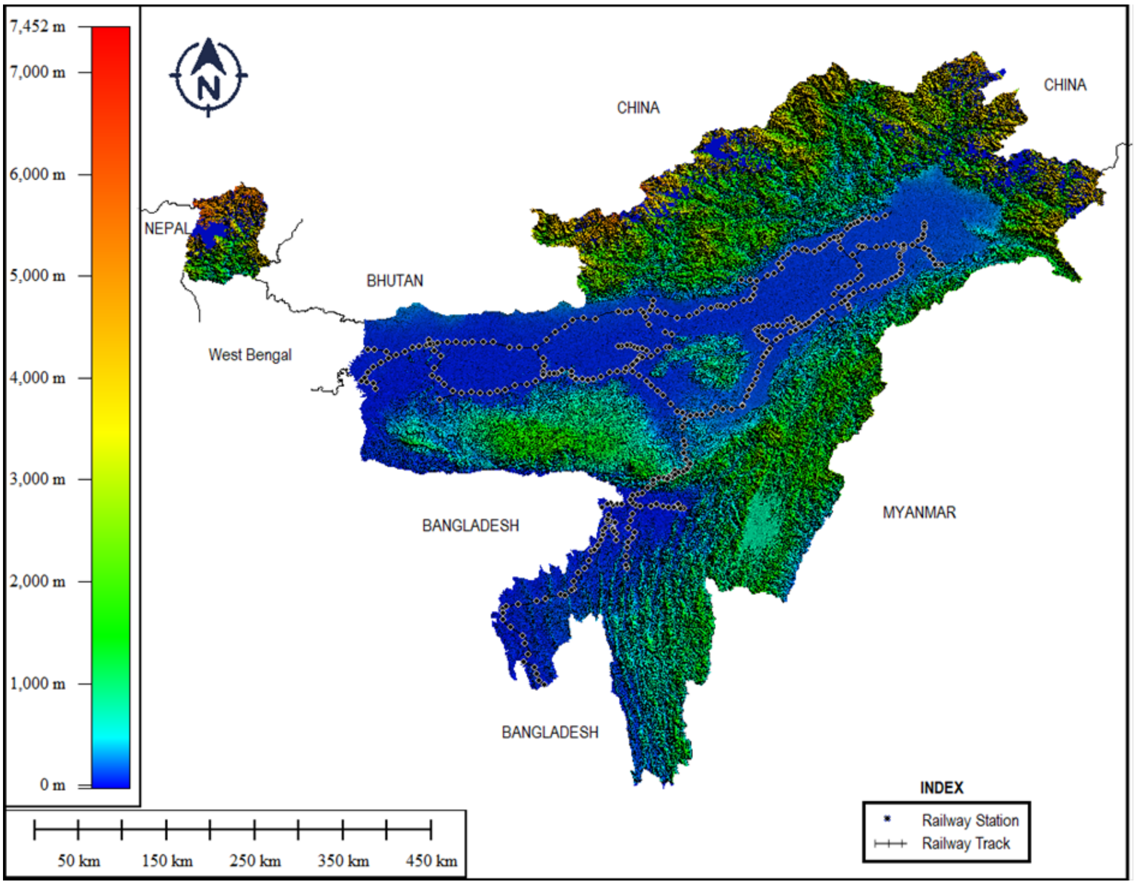


Fig. 4. Digital Elevation Model (DEM) of Northeast India with a railway map
Source: Prepared by the authors using Global Mapper V.16; data was extracted from SRTM DEM

Socio-political issues also play an important role in railway development in Northeast India. Twenty-five people representatives from Northeast India participated in the lower house of India's bicameral parliament, known as Lok Sabha (House of the People), and only 14 people representatives from Northeast India participated in the upper house, which is known as the Rajya Sabha (Council of States). The Constitution of India divided legislative authority between the union (centre) and state governments into three lists, namely a union list (97 subjects), a state list (66 subjects) and a concurrent list (47 subjects). The railway is the subject of the union list. The members of parliament (MPs) place the demand for investments in parliament. About 4.6 per cent of the members of the Lok Sabha (House of the People) and 5.71 per cent of the members of the upper house (Rajya Sabha) are from Northeast India. The demand for railways for the northeast has never become intensive in parliament due to numerical inferiority. In the last seventy years, the demand for railways in northeastern states was obstructed by political supremacy. Assam has 56 per cent and 50 per cent of the MPs in Lok Sabha and Rajya Sabha from Northeast India, respectively. The remaining seven northeastern states cumulatively have 44 per cent MPs from Northeast India in Lok Sabha and 50 per cent of MPs from Northeast India in Rajya Sabha (Fig. 6). Naturally, the demand for Assam is comparatively stronger than any other northeastern state, as reflected in railway infrastructural development.

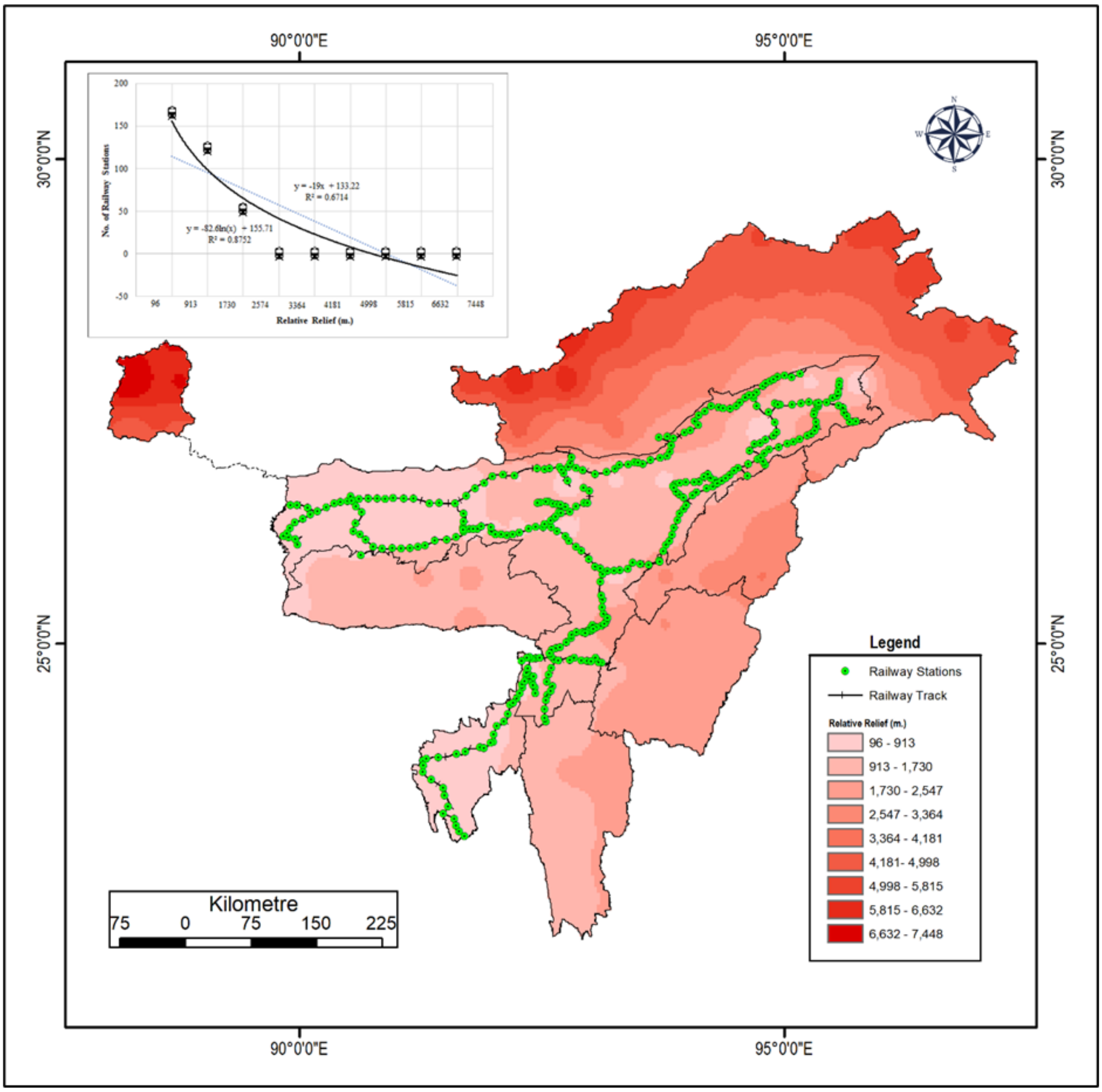


Fig. 5. Distribution of relative relief of Northeast India with a railway map
Source: Prepared by the authors, using ArcGIS V.10.7.1; Data has been extracted from SRTM DEM

## 4. CONCLUSIONS

Regional inequality in terms of railway infrastructure was found among the north-eastern states of India. The Gini coefficient represents the degree of inequality between railway infrastructure and population density. An alternative synthetic indicator was proposed for use on an asymmetric data set and found to be more efficient than the existing synthetic indicator for delineating the railway transport system in India's north-eastern states. The reasons for the differential growth of the railway transport system in Northeast India are related to physiographic averseness, like rugged topography, and uneven socio-economic variables like population, number of settlements, number of urban centres, number of industries and state GDP. Environmental determinism plays a crucial role in railway development in Northeast India, as does political willingness. Developmental activities influence the infrastructural expansion of the railway transport system, and the railway transport system accelerates the growth of development activities and vice versa.

Table 5

Composite dimension index (CDI) of developmental parameters of north-eastern states

| Name of the State | Total Population | Total No. of Settlements | Total No. of Urban Centres | Total No. of Industries | State GDP (Billion $) | CDI | Rank |
|---|---|---|---|---|---|---|---|
| Arunachal Pradesh | 0.03 | 0.20 | 0.21 | 0.05 | 0.01 | 0.099 | 4 |
| Assam | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.000 | 1 |
| Manipur | 0.07 | 0.08 | 0.23 | 0.12 | 0.01 | 0.103 | 3 |
| Meghalaya | 0.08 | 0.21 | 0.15 | 0.09 | 0.04 | 0.115 | 2 |
| Mizoram | 0.02 | 0.02 | 0.16 | 0.09 | 0.00 | 0.057 | 7 |
| Nagaland | 0.04 | 0.04 | 0.20 | 0.00 | 0.01 | 0.058 | 6 |
| Tripura | 0.10 | 0.02 | 0.13 | 0.01 | 0.07 | 0.065 | 5 |
| Sikkim | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 | 0.010 | 8 |

Source: Computed by the Authors, 2021

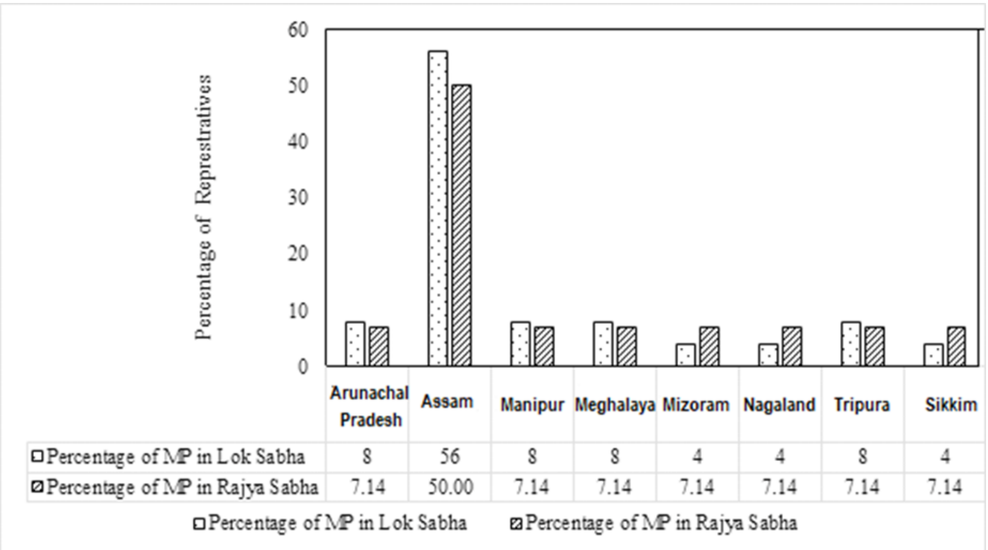


Fig. 6. Political representation of the Northeastern states
Source: Computed by the Authors

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