Regional Classification of Serbian Railway Transport System Through Efficient Synthetic Indicator

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Abstract: The railway transport system is one of the most important elements in the development of the economy and the social space of any area. The main objective of the study is to analyse the regional differentiation in railway development in Serbia with causal interference. The research has been conducted based on secondary data collected from multiple sources, and the existing synthetic Indicator was applied to classify eight states based on their railway infrastructural status. An alternative synthetic Indicator approach has been proposed and found to be more efficient than the existing synthetic Indicator. The causality of such unequal development has been analysed through a correlation test by defining the composite infrastructure index. The analysis revealed that railway infrastructure significantly influences Serbia's economic and social development. The service area of railway infrastructure indicates the potential zone for future growth.

Keywords: Railway geography; Spatial differentiation; Regional disparity; Railway infrastructure; Transport policy

1. Introduction

The Serbian railway is one of the oldest railway networks in Europe, with a 3,819 km route length and 546 railway stations. The chronological development of railway transport in Serbia started in the middle of the nineteenth century, during the Austro-Hungarian and Ottoman Empires still contribute a significant role in the Serbian surface transport system [1, 2]. The Governments of Serbia had effectively taken over management of the building of new railway lines in their respective countries by 1890, seeing this as a way to increase their sovereignty [3]. The contemporary study reveals the structural and ideological ambiguities that characterised the 19th-century European imperial endeavours, in contrast to traditional historiography that portrayed empires as "the prison houses of nations." Therefore, the emphasis has changed from "popular longings" for national independence to "national indifference" situations [4]. The growth of railway infrastructure in Serbia has occurred rather organically due to a deliberate approach to that nation's economic development [5]. Railway infrastructure and services are essential factors in reducing regional imbalance and improvising sustainable development [6]. The railway infrastructure is considered the key developmental factor for economic growth [7]. Regional and economic development mostly depend on railway infrastructure [8]. But the contribution of railway infrastructure is not homomorphically distributed to all parts of Serbia [9]. The railway infrastructure development is generally influenced by a country's social and economic development [10]. Few negative externalities, i.e., complex physiographic structure and environmental vibrations, impact the railway infrastructure's development as well [11]. Due to diverse geographical and socio-economic variability, Serbia has a different growth pattern of railway infrastructure [12].

The obsolescence and dilapidation of the tracks and equipment in general of the railway infrastructure in Serbia

affects the quality of the service, i.e., the increase in travel time. The possibility of modernising the railway makes the mismatch of free profiles on some sections difficult. The maximum permitted speed of trains on only 2.6% of the network is greater than 100 km/h, while about 50% of the network is less than 60 km/h. On about 38% of the total track length, the load capacity is less than 200 kN. In larger cities, there is a problem of unsolved nodes, the problem is the reliability of the system in general, the possibility of using tracks on the railway network, as well as the availability and characteristics of the vehicle fleet in passenger and freight traffic.

In the hypothesis, it stated that the level of railway development varies between NUTS 3 regions in Serbia. The study's research question is about which factors are mainly responsible for diversified railway infrastructural development in Serbia. The present study, therefore, aims to classify regional differentiation in railway development in Serbia and to analyse the reasons for different development patterns of railways among the different NUTS3 regions in Serbia (for Autonomous Province of Kosovo and Metohija no data availability) [13].

2. Methodology

To test the hypothesis and to answer the research question, data normality test has been conducted through Shapiro-Wilk's test as Shapiro-Wilk's test provides better power than the K-S test and Anderson-Darling test [14]. 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 is discarded.
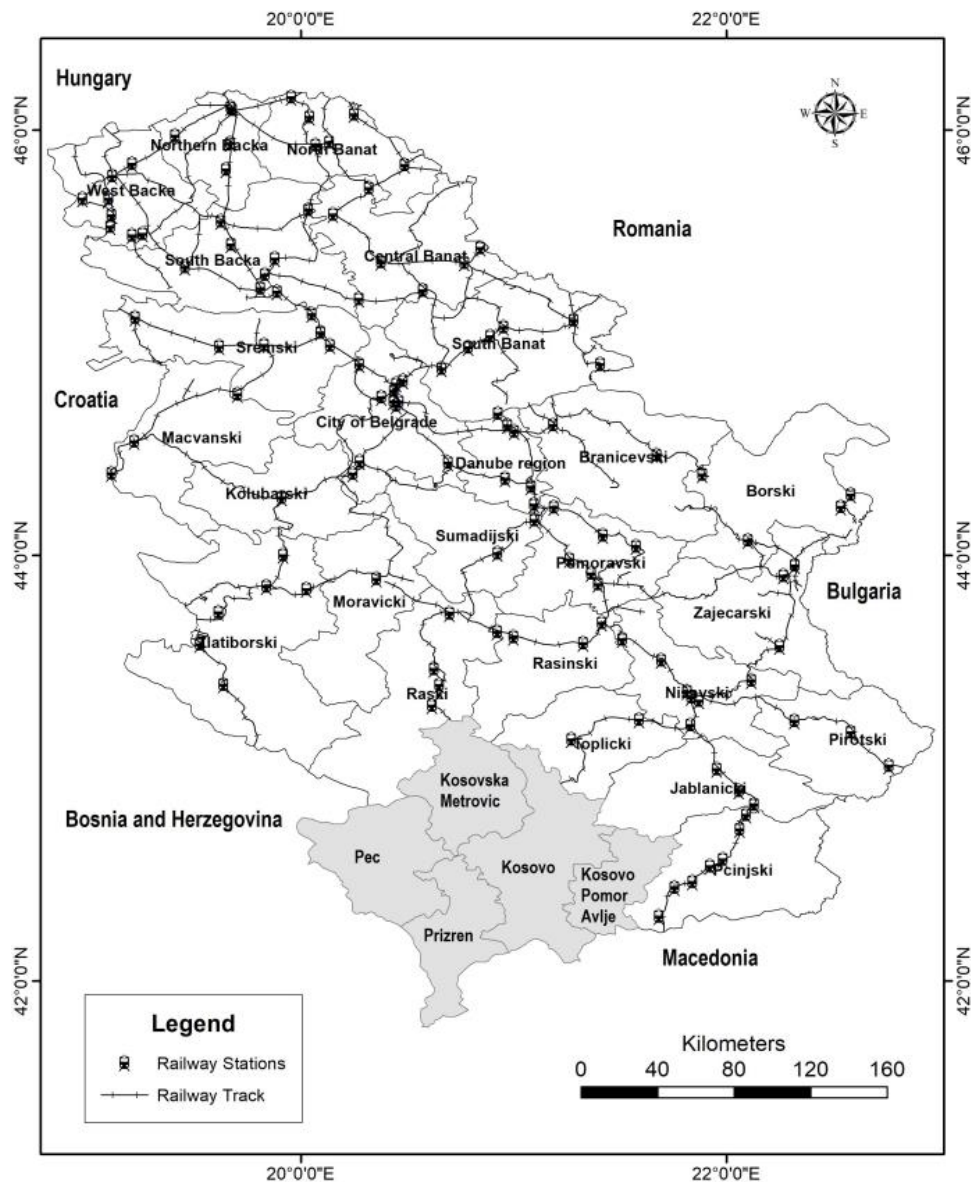
Figure 1. Railway infrastructure of Serbia

The Quantile-Quantile Plots (Q-Q plots) of the observational data set (Railway Track Length and No. of Railway Stations) are also carried out to assess the normality assumptions of the observational data set through the graphical presentation in Figure 1. If the data follows the assumptions, then the data observations will be plotted at 450 angles of the (0,0) point, corresponding to the Q-Q plot [15, 16].

The Weighted Percentage Index (WPI) for each state has been used based on railway track length and railway stations with corresponding weights w and 1-w, respectively, 0<w<1. The WPI has been formulated as:

Weighted Percentage Index (WPI)=(p1×xw)+(p2×(1-w)), where p1=percentage of railway track and p2=percentage of railway stations. With the loss of generality, we have considered w=0.5, i.e., equal weightage (0.5) has been given to both the railway track and stations [15].

The synthetic Indicator is a linear equation consisting of the arithmetic mean and standard deviation. GSI for has been carried out as a linear combination of the standardised measure of respective variables. The general standardisation of the ith variable is denoted by g_i, where,

$$g_i = y_i = \frac{x_i - median(x)}{MD_{\bar{x}}(x)} \tag{1}$$

$$g_i = z_i = \frac{x_i - mean(x)}{\sigma(x)} \tag{2}$$

with I=1,2,…,t for 't' variables. The Eqns. (1) or (2) will be considered according to the nature of each of the 't' variables. If the non-normality of the respective variable is found through the Shapiro-Wilks test, then Eq. (1) is considered general standardisation; otherwise, we adopt Eq. (2) [15-17]. A frequentist statistician's test for normalcy is the Shapiro-Wilk test. Martin Wilk and Samuel Sanford Shapiro released it in 1965. While the Kolmogorov-Smirnov test is employed for n 50, the Shapiro-Wilk test is more appropriate for small sample sizes (50 samples), however, it can also handle larger sample sizes. The null hypothesis for the two tests mentioned above states that the data are drawn from a population that is normally distributed.

The causality of the unequal development of railway transport has been analysed through correlation analysis. Physical hindrances on railway development in Serbia have been analysed through Digital Elevation Modelling (DEM) and Relative Relief (RR) to understand physical hindrances [18]. The composite infrastructure Indicator has been developed to capture broader dimensions of infrastructural development. The socio-economic development of each region has been measured through Composite Infrastructure Index (CII). CII_j for region 'j' has been calculated by using the following formula:

$$CII_j = \sum_{k=1}^{v} \frac{\partial_{kj}}{v}, \text{ for } j = 1, 2, ..., s$$

where, s=number of regions, v=number of development parameters,

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

X_{kj}=jth 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 CII_j is [0,1]
Proof: Let us consider a state 'M', which consists the highest value of observation for each of the corresponding 'v' development parameters, i.e., $X_{kM}=X_{k(n)}$, for k=1,2,…,v. So, $\partial_{kM} = \frac{X_{k(n)}-X_{k(1)}}{X_{k(n)}-X_{k(1)}} =1$ for k=1,2,…,v, hence $CII_M = \sum_{k=1}^{v} \frac{1}{v} = \frac{v}{v} = 1$. Similarly, we may consider another state say 'm', which always consists only the lowest value of observation for each of the corresponding 'v' development parameters ($X_{km}=X_{k(1)}$, for all k). So, ∂_{km}=0, hence $CII_m = \sum_{k=1}^{v} \frac{0}{v} = 0$.

Spearman's Rank Correlation coefficient has been measured to assess the significance of the relation between the most efficient Indicator and composite infrastructure index.

The study is based on secondary data collected from different sources i.e., data of railway stations and track of all national regions collected from DIVA GIS, region-wise Area and population data of Serbia have been collected from the Republic Institute of Statistics, Census of Serbia, 2011 whenever state-wise GDP has been computed from the Republic Institute of Statistics Central Statistics Office, Ministry of Statistics and Programme

Implementation, Government of Serbia, 2016-2017, Geo-spatial data like relief were extracted from satellite imagery using USGS earth explorer platform. Images have been processed and analysed in Global Mapper v.18, Arc GIS v10.8.

3. Results

25 National regions are situated in Serbia with diversified railway infrastructure (Figure 2). Total length of railway tracks in Serbia is 3390.52 km with 121 railway stations. The city of Belgrade area has a maximum 307.010 km railway track with 11 railway stations, whereas the minimum railway infrastructure found in Moravicki with 35.628 km railway track and only one railway station, namely Cacak (43°53'23.76"N and 20°21'21.66"E) located in the right bank of river Zapadna Marava. The region-wise average length of the railway track is 135.6 km with a standard error of 15.3and the average railway station is 4.840 with a standard error of 0.519 (Table 1).

Table 1. Descriptive statistics of railway infrastructure of Serbia

Variable	Number of regions	Mean	SE Mean	Trim Mean	St. Dev	Variance	Coef. Var	Sum
Length of rail (km)	25	135.6	15.3	132.5	76.7	5877.1	56.53	3390.5
No. of Railway Station	25	4.840	0.519	4.739	2.593	6.723	53.57	121.000

Variable	Sum of Squares	Minimum	Q1	Median	Q3	Maximum	Range	IQR
Length of rail (km)	600873.7	35.6	79.2	111.8	184.6	307.4	271.8	105.5
No. of Railway Station	747.000	1.000	2.500	5.000	6.500	11.000	10.000	4.000

Variable	N for Mode	Skewness	Kurtosis	MSSD
Length of rail (km)	0	0.95	0.19	3615.7
No. of Railway Station	6	0.39	-0.28	5.521

Shapiro-test Wilk's was used to determine whether the two variables' data were normal (i.e., railway track length and the number of railway stations). The railway track length was discovered to have a Shapiro-parameter Wilk's value of 0.906 and a corresponding p-value of 0.025 (<0.05), whereas railway stations had a Shapiro-parameter Wilk's value of 0.950 and a corresponding p-value of 0.251. Since the corresponding p-values for railway tracks are substantially lower than 0.05, the observed data sets' normality assumptions were disregarded and railway stations are following the normality assumption. The quantile-quantile graphs (Q-Q plots) in Figure 2 that follow further bolster the aforementioned claim.
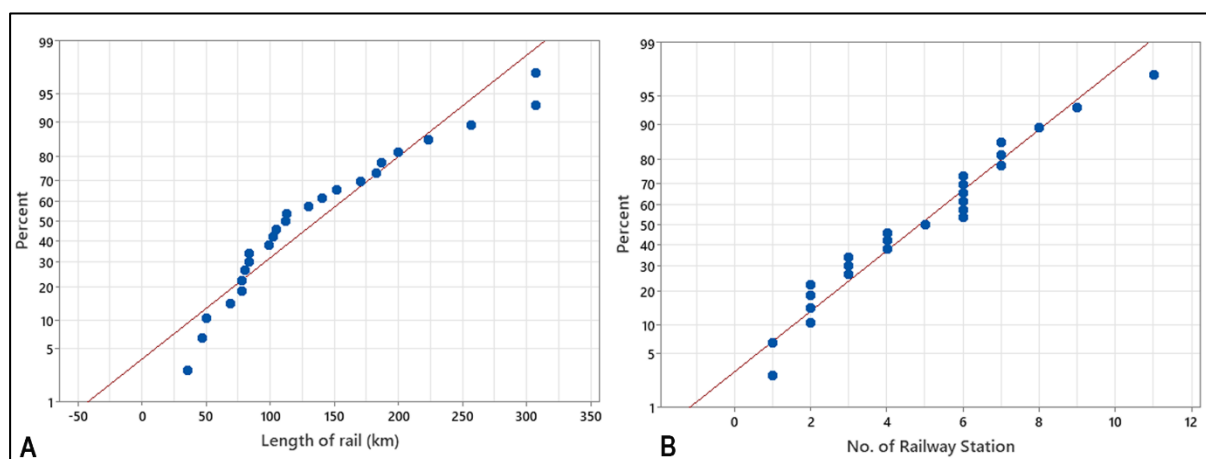

Figure 2. Q-Q plot of railway track and railway stations data of Serbia

It has been observed that 32 per cent (8 out of 25) regions of Serbia i.e., City of Belgrade (9.07%), South Backa (8.25%), West Backa (6.60%), South Banat (6.26%), Sremski (5.59%), Zlatiborski (5.43%), Nisavski (5.13%) and Central Banat (5.00%) have comparatively better railway infrastructure (Table 2). More than 3 per cent of total Serbian railway infrastructure is found in 28 per cent regions like Northern Backa (4.82%), North Banat (4.40%), Pomoravski (4.15%), Danube (4.13%), Pcinjski (4.13%), Raski (3.72%) and Borski (3.19%). According to WPI poorest railway infrastructure found in Moravicki (0.94%) followed by Kolubarski (1.15%), Jablanicki (1.93%), Sumadijski (1.98%), Macvanski (2.01%) and Toplicki (2.05%) region of Serbia (Table 2).

Table 2. Weighted Percentage Index (WPI) of the railway infrastructure of Serbia

Region	Length of Railway Track (km)	Percentage of Railway Track (P1)	No. of Railway Station	Percentage of Railway Station (P2)	Weighted Percentage Index (WPI)	Rank
City of Belgrade	307.010	9.055	11	9.091	9.07	1
South Backa	307.405	9.067	9	7.438	8.25	2
West Backa	223.227	6.584	8	6.612	6.60	3
South Banat	256.535	7.566	6	4.959	6.26	4
Sremski	182.608	5.386	7	5.785	5.59	5
Zlatiborski	200.136	5.903	6	4.959	5.43	6
Nisavski	151.527	4.469	7	5.785	5.13	7
Central Banat	170.644	5.033	6	4.959	5.00	8
Northern Backa	186.645	5.505	5	4.132	4.82	9
North Banat	129.907	3.831	6	4.959	4.40	10
Pomoravski	112.979	3.332	6	4.959	4.15	11
Danube region	111.804	3.298	6	4.959	4.13	12
Pcinjski	83.758	2.470	7	5.785	4.13	13
Raski	140.426	4.142	4	3.306	3.72	14
Borski	104.544	3.083	4	3.306	3.19	15
Zajecarski	102.072	3.011	3	2.479	2.74	16
Rasinski	68.536	2.021	4	3.306	2.66	17
Pirotski	78.141	2.305	3	2.479	2.39	18
Branicevski	98.679	2.910	2	1.653	2.28	19
Toplicki	83.137	2.452	2	1.653	2.05	20
Macvanski	80.176	2.365	2	1.653	2.01	21
Sumadijski	77.954	2.299	2	1.653	1.98	22
Jablanicki	46.795	1.380	3	2.479	1.93	23
Kolubarski	50.240	1.482	1	0.826	1.15	24
Moravicki	35.628	1.051	1	0.826	0.94	25
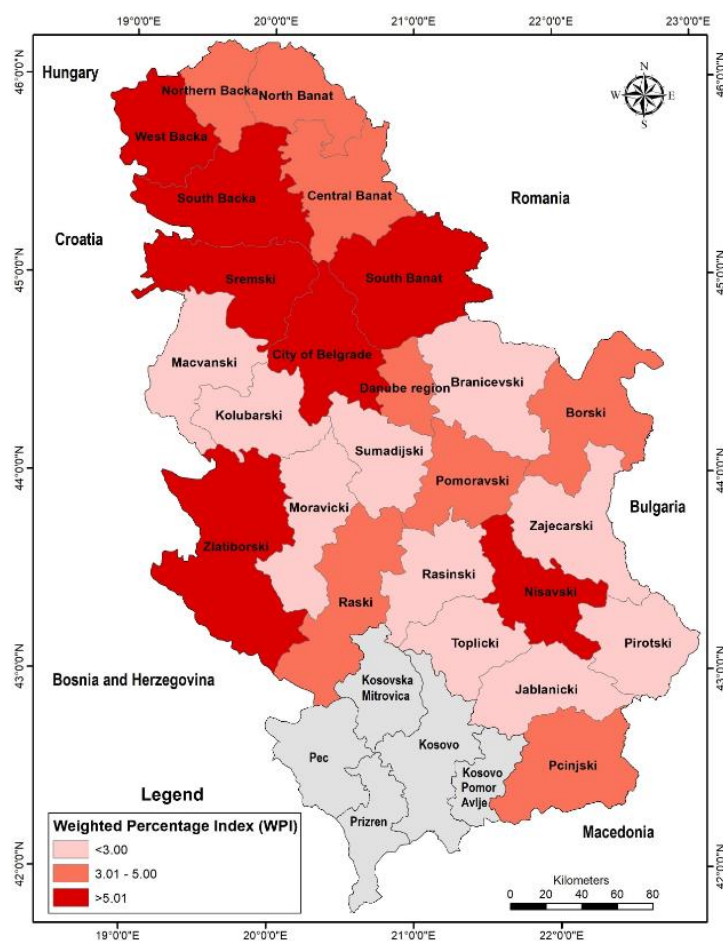
Figure 3. Railway infrastructure of Serbia through weightage percentage Indicator
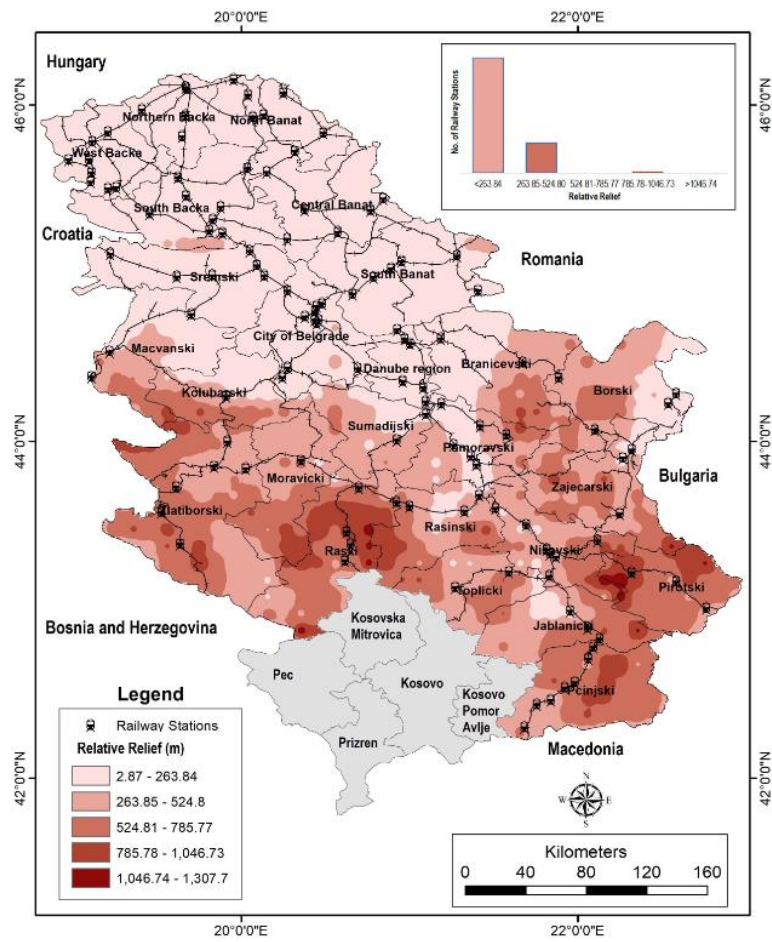
Figure 4. Relative relief of Serbia with railway infrastructure

Table 3. Generalised Synthetic Indicator (GSI) of the railway infrastructure of Serbia

Region	Synthetic Indicator	Alternative Synthetic Indicator
North Banat	0.381	0.755
Central Banat	0.923	1.417
Northern Backa	0.742	1.215
South Banat	2.066	2.811
West Backa	2.410	3.194
South Backa	3.924	5.022
Sremski	1.476	2.073
City of Belgrade	4.706	5.939
Macvanski	-1.856	-1.898
Kolubarski	-2.648	-2.846
Zlatiborski	1.316	1.896
Moravicki	-2.843	-3.083
Danube region	0.140	0.462
Sumadijski	-1.886	-1.934
Raski	-0.267	0.003
Rasinski	-1.224	-1.164
Branicevski	-1.610	-1.598
Borski	-0.744	-0.579
Zajecarski	-1.171	-1.081
Pomoravski	0.155	0.481
Nisavski	1.062	1.568
Toplicki	-1.817	-1.850
Pirotski	-1.489	-1.470
Jablanicki	-1.907	-1.979
Pcinjski	0.160	0.468

Maximum railway infrastructural development took place in the northern part of Serbia except in Northern

Backa and North Banat regions. Apart from the northern regions of Serbia, Nisavski and Zlatiborski regions have good railway infrastructure. Moderate infrastructure is found in the 32 per cent region of the country (Figure 3). About 40 per cent of regions of Serbia, namely Zajecarski, Rasinski, Pirotski, Branicevski, Toplicki, Macvanski, Sumadijski, Jablanicki, Kolubarski and Moravicki have comparatively poor railway infrastructure (Figure 4). The maximum region with poorer railway infrastructure has been observed in the southern and western parts of Serbia.

Table 3 depicts the generalised synthetic Indicator (GSI) of the Serbian railway infrastructure. The synthetic Indicator's computed mean was zero, and its standard deviation was 1.914. However, the alternative synthetic Indicator was taken into consideration because the data sets for each of the variables were not normal. We computed the median and the mean deviation of the mode for the alternative synthetic Indicator. The mean deviation is 1.859 and the median is 0.462, respectively. The synthetic and alternative synthetic methods' classification method and class range are furnished in Tables 4 and 5, respectively.

Table 4. Classification of state-wise railway infrastructure for Synthetic Indicator (SI)

Class	Method of Calculating Class	Class Range	Characteristic of Class	Class of the Region	No. of Regions	%
I	$z_i \geq \bar{z} + \sigma_i$	$z_i \geq 1.914$	Very good infrastructure	City of Belgrade, South, Backa, West Backa and South Banat	4	16
II	$\bar{z} < z_i \leq \bar{z} + \sigma_i$	$0 < z_i \leq 1.914$	Good infrastructure	Sremski, Zlatiborski, Nisavski, Central Banat, Northern Backa, North Banat, Pomoravski, Pcinjski and Danube region	9	36
III	$\bar{z} - \sigma_i \leq z_i \leq \bar{z}$	$-1.914 \leq z_i \leq 0$	Poor infrastructure	Raski, Borski, Zajecarski, Rasinski, Pirotski, Branicevski, Toplicki, Macvanski and Sumadijski	9	36
IV	$z_i \leq \bar{z} - \sigma_i$	$z_i \leq -1.914$	Very poor infrastructure	Jablanicki, Kolubarski and Moravicki	3	12

Table 5. Classification of state-wise railway infrastructure for Alternative Synthetic Indicator (ASI)

| Class	Method of Calculating Class	Class Range	Characteristic of Class	Class of the Region	No. of Regions	%
I	$y_i \geq \tilde{y} + MD_{\bar{y}}$	$y_i \geq 2.320$	Very good infrastructure	City of Belgrade, South Backa, West Backa and South Banat	4	16
II	$\tilde{y} \leq y_i \leq \tilde{y} + MD_{\bar{y}}$	$0.462 \leq y_i \leq 2.320$	Good infrastructure	Sremski, Zlatiborski, Nisavski, Central Banat, Northern Backa, North Banat, Pomoravski, Pcinjski and Danube region	9	36
III	$\tilde{y} - MD_{\bar{y}} \leq y_i \leq \tilde{y}$	$-1.397 \leq y_i \leq 0.462$	Poor infrastructure	Raski, Borski, Zajecarski and Rasinski	4	16
IV	$y_i \leq \tilde{y} - MD_{\bar{y}}$	$y_i \leq -1.397$	Very poor infrastructure	Pirotski, Branicevski, Toplicki, Macvanski, Sumadijski, Jablanicki, Kolubarski and Moravicki	8	32

As per Synthetic Indicator, about 16 per cent of regions i.e., the City of Belgrade, South, Backa, West Backa and South Banat, have very good railway infrastructure. Good railway infrastructure is found in 36 per cent of regions, namely Sremski, Zlatiborski, Nisavski, Central Banat, Northern Backa, North Banat, Pomoravski, Pcinjski and Danube regions. 9 regions out of 25 regions of Serbia have poor railway infrastructure. Those regions are Raski, Borski, Zajecarski, Rasinski, Pirotski, Branicevski, Toplicki, Macvanski and Sumadijski. Three Serbian regions have very poor railway infrastructure facilities like Jablanicki, Kolubarski and Moravicki (Table 4).

On the other hand, the Alternative Synthetic Indicator in Table 5 shows that the City of Belgrade, South Backa, West Backa and South Banat regions hold very good infrastructure. Comparatively, good infrastructure is found in Sremski, Zlatiborski, Nisavski, Central Banat, Northern Backa, North Banat, Pomoravski, Pcinjski and Danube regions. It has been observed that about 16 per cent region of Serbia, like Raski, Borski, Zajeearski and Rasinski has poor railway infrastructure. In another way, the remaining eight Serbian regions i.e., Pirotski, Branicevski, Toplicki, Macvanski, Sumadijski, Jablanicki, Kolubarski and Moravicki are reported with very poor infrastructure. Regional differentiation in terms of railway infrastructure has been observed in Serbia using both methods.

To estimate the efficiency of the Alternative Synthetic Indicator, the efficiency index (EI) has been carried out on variance differences of the corresponding indices by using the formula: $EI=(v_1-v_2)/v_2$, where, v_i=variance of existing Synthetic Indicator; v_x=variance of Alternative Synthetic Indicator.

It has been found that the variance of the Synthetic Indicator and Alternative Synthetic Indicator is 7.6875 and 5.1875, respectively. The gain in efficiency of ASI over the Synthetic Indicator is 48.192 per cent. It shows that the Alternative Synthetic Indicator is much more efficient than the existing Synthetic Indicator. Synthetic Indicator misleads the classification of railway infrastructure among the regions of Serbia, while Alternative Synthetic Indicator efficiently measures the classification of railway infrastructure in Serbia.

Physiography plays a significant role in the development of railway infrastructure [15, 18]. It has been observed that southern parts of Serbia have more hilly regions as a result number of railway stations are also less in comparison to the Northern region (Figure 4). Northern and Central parts of Serbia, where relative relief is less than 263.84 m have maximum (78.51%) railway stations are situated which depicts that physiography, especially relative relief plays a significant role in railway infrastructural development (Figure 5). Apart from physiographic factors few administrative and anthropogenic aspects also play a crucial role in railway infrastructural development.
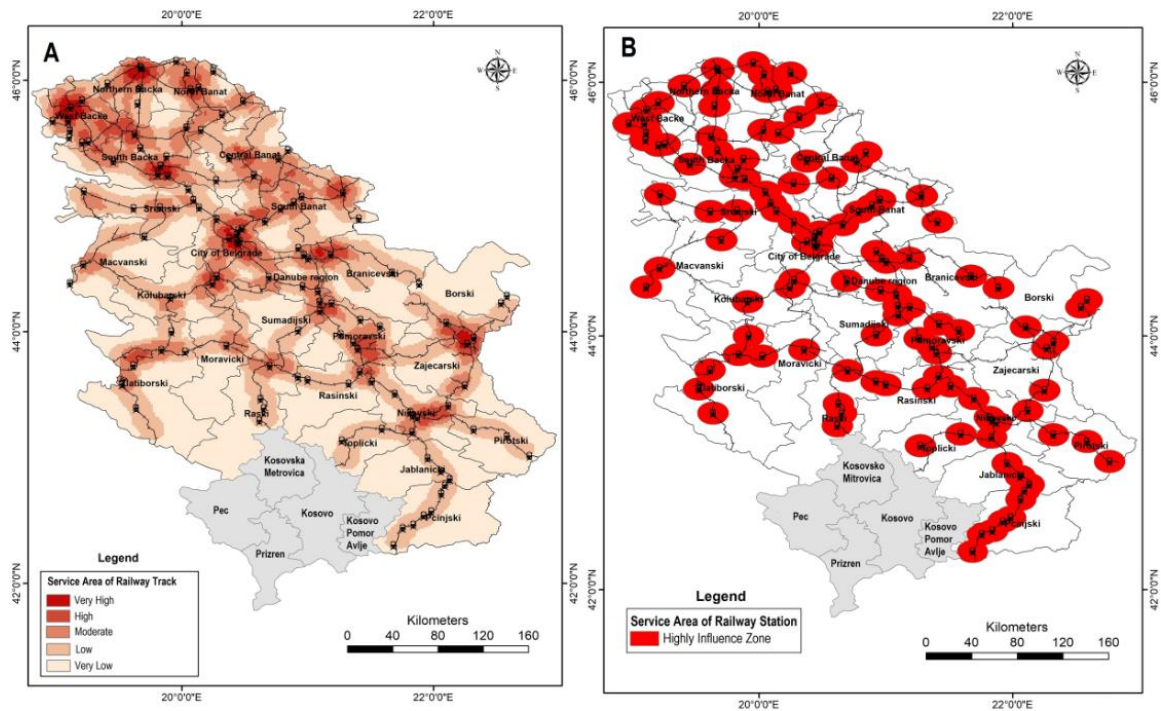
Figure 5. Service area of railway infrastructure (A. Railway track, B. Railway station)

It has been observed that Alternative Synthetic Indicator (ASI) have a significant positive correlation with The Population of the region (r=0.644, the corresponding p-value is <0.01), GDP (r=0.617, the corresponding p-value is <0.01) and GVA (r=0.614, corresponding p-value is <0.01) (Table 6). The result depicts that railway infrastructure is associated with economic growth and social development. Based on significant developmental parameter Composite Infrastructure Index has been calculated.

Table 6. Correlations between ASI and different developmental parameters

		Alternative Synthetic Indicator	Area (km²)	The estimated number of inhabitants year 2007	GDP	GVA
Alternative Synthetic Indicator	Pearson Correlation	1	.262	.644**	.617**	.614**
	Sig. (2-tailed)		.206	.001	.001	.001
Area (km²)	Pearson Correlation	.262	1	.157	.178	.105
	Sig. (2-tailed)	.206		.454	.395	.618
The estimated number of inhabitants year 2007	Pearson Correlation	.644**	.157	1	.773**	.984**
	Sig. (2-tailed)	.001	.454		.000	.000
GDP	Pearson Correlation	.617**	.178	.773**	1	.820**
	Sig. (2-tailed)	.001	.395	.000		.000
GVA	Pearson Correlation	.614**	.105	.984**	.820**	1
	Sig. (2-tailed)	.001	.618	.000	.000	

** Correlation is significant at the 0.01 level (2-tailed).

According to CII it has been observed that the City of Belgrade (0.851), South Backa (0.429) and Zlatiborski (0.354) regions have better infrastructural facilities. In contrast, the Danube region (0.038), Toplicki (0.075), Jablanicki (0.106), North Banat (0.112) and Pomoravski (0.123) region have poor infrastructural facilities. Spearman's Rank Correlation has been calibrated between ASI and CII. It has been found that significantly, ASI and CII are significantly positively associated (Table 7). The results reveal that railway infrastructure positively influences Serbia's economic and social development.

Table 7. Rank Correlations between ASI and CII

			Rank of ASI	Rank of CII
Spearman's rho	Rank of ASI	Correlation Coefficient	1.000	.438*
		Sig. (2-tailed)	.	.028
	Rank of CII	Correlation Coefficient	.438*	1.000
		Sig. (2-tailed)	.028	.

*. Correlation is significant at the 0.05 level (2-tailed).

The railway infrastructure service area has been analysed to identify the potential area for future development in Serbia. The service of the area of railway track depicts that eight major growth centres have been observed. About 62.5 per cent of potential growth centres are located in the Northern parts of Serbia. West Backa, Northern Backa, North Banat, South Backa, City of Belgrade, Pomoravski, Nisavaski and Zajecarski regions have the potential for future development. Comparatively less potentiality has been found in Borski, Pirotski, Toplicki, Jablanicki, Pcinjski and the southern part of Rasinski region (in subgraph (A) of Figure 5). On the other hand, it has been observed that continuous service area of railway stations area found in City of Belgrade region to South Banat, South Backa via Sremski. The monocentric service area has been found in Kalubarski and Moravicki regions (in subgraph (B) of Figure 5).

With the planned project and planning documentation, i.e., the reconstruction and restoration of railway tracks, traffic safety, train speed, and travel times would be shortened. With this, it would be possible to use the potential of railway traffic development based on the very spatial position of the railway network of the Republic of Serbia within the European railway network and the possibilities for establishing quality connections with EU countries as well as the development of intermodal traffic. As the construction of the Trans-European Transport Network (TEN-T) is based on the interconnection and interoperability of national transport networks, the potential of the railway Corridor H can be seen through the implementation of the Chinese project for the realisation of a high-speed land-sea connection between China and Europe, from the port of Piraeus in the south to Budapest in the north (one of the projects within the "New Silk Road" project).

4. Conclusions

The alternative synthetic Indicator is a lot more effective than the one that is currently in use. While Alternative Synthetic Indicator accurately measures the classification of railway infrastructure in Serbia, Synthetic Indicator misclassifies it among the various areas of the country. The reasons for Serbia's unequal socio-economic development, including population, GDP, and GVA, are tied to physiographic risk factors, including the country's harsh topography. The development of Serbia's railways is significantly influenced by physiographic determinism. The railway transport system influences the infrastructure expansion of development activities, and vice versa; development activities speed up the growth of the railway transport system. Analysis of the railway infrastructure's service area helped Serbia identify possible areas for future growth. The servicing of the railway track area indicates that eight significant growth centres have been formed. The regions of Serbia with the greatest potential for growth are in the north. This efficient synthetic Indicator provides better approach of regional classification. In future combinatorics, approach will be used to improve robustness of method.

Data Availability

The data supporting our research results are included within the article or supplementary material.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] "Ottoman roads to the present: Infrastructure development in southeast Europe," TRAFO, 2021, https://trafo.hypotheses.org/31887.

[2]   P. R. Magocsi, *Historical Atlas of Central Europe: Third Revised and Expanded Edition*, Toronto: University of Toronto Press, 2018.

[3]   K. Stanev, E. J. Alvarez, and J. Marti-Henneberg, "Railway development and the economic and political integration of the Balkans, c. 1850-2000," *Europe-Asia Stud.,* vol. 69, no. 10, pp. 1601-1625, 2017. https://doi.org/10.1080/09668136.2017.1401592.

[4]   S. Malesevic, "Forging the nation-centric world: Imperial rule and the Homogenisation of discontent in Bosnia and Herzegovina (1878-1918)," *J Hist Sociol*, vol. 34, no. 4, pp. 665-687, 2021. https://doi.org/10.1002/johs.12350.

[5]   F. Erdosi and V. Ivanic, "Infrastructure as an instrument of regional development," In Centre for Strategic Economic Studies, Budisava, 2011.

[6]   E. Załoga and D. Milewski, "The impact of transport on regional development," Research Papers of the Wroclaw University of Economics/Prace Naukowe Uniwersytetu Ekonomicznego We Wroclawiu, vol. 2013, no. 286, pp. 71-78, 2013.

[7]   A. Banerjee, E. Duflo, and N. Qian, "On the road: Access to transportation infrastructure and economic growth in China," *J. Dev. Econ.*, vol. 145, Article ID: 102442, 2020. https://doi.org/10.1016/j.jdeveco.2020.102442.

[8]   L. Bali, "The role of the railway in regional development in Austro-Hungary and in Hungarian-Croatian relations today, especially with regard to the availability of Rijeka (Fiume)," *Central Europ Papers*, vol. 2, no. 1, pp. 160-166, 2014. https://doi.org/10.25142/cep.2014.011.

[9]   Z. Popvic, L. Lazarevic, and L. Izvolt, "Potential of the railway infrastructure in Serbia," *Railway Transport Logist.*, vol. 2013, pp. 9-22, 2013.

[10] V. Lingaitis and G. Sinkevičius, "Passenger transport by railway: evaluation of economic and social," *Procedia Soc Behav. Sci.*, vol. 110, pp. 549-559, 2014. https://doi.org/10.1016/j.sbspro.2013.12.899

[11] H. Lu, Z. Gao, L. Xu, and B. Wu, "Effects of the convex topography on railway environmental vibrations," *Computer Model. Eng. Sci.*, vol. 118, no. 1, pp. 177-205, 2019. https://doi.org/0.31614/cmes.2019.04169.

[12] M. S. Pantić, "Sustainable development perspectives for Serbian mountain," Doctoral Dissertation, University of Belgrade, Belgrade, 2014.

[13] "Administrative districts of Serbia," WIKIPEDIA, 2023, https://en.wikipedia.org/wiki/Administrative_districts_of_Serbia#cite_ref-status_1-3.

[14] N. M. Razali and Y. B. Wah, "Power comparison of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests," *J Stat Model. Anal.*, vol. 2, no. 1, pp. 21-33, 2011.

[15] S. Roy, S. Hore, S. Mitra, and G. Chaberek, "Delineating regional differentiation on the development of the railway infrastructure in Northeast India through an efficient synthetic Indicator," *Transport Probl*, vol. 17, no. 3, pp. 149-162, 2022. https://doi.org/10.20858/tp.2022.17.3.13.

[16] S. Roy, T. Dentinho, S. Hore, and S. Mitra, "A robust approach for the infrastructural classification of railway stations in Tripura, India," *RPER*, vol. 2023, no. 63, pp. 27-43, 2023.

[17] M. Jarocka and E. Glińska, "The state and prospects for development of railway transport infrastructure in Eastern Poland–secondary data analysis," *Procedia Eng.*, vol. 182, pp. 299-305, 2017. https://doi.org/10.1016/j.proeng.2017.03.198.

[18] S. Roy and S. Mitra, "Infrastructural status of railway transport system in North East India: A geographical analysis," *Asian J. Spat Sci.*, vol. 4, no. 1, pp. 89-100, 2016.