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Assessment of the socioeconomic development levels of six economic corridors in the Belt and Road region

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Abstract: Recent years have witnessed rapid and widespread economic growth in regions involved in China's Belt and Road Initiative (BRI), mainly due to the construction of six economic corridors. This paper aims to quantify the levels of six economic corridors according to the socioeconomic development levels in the BRI regions. Here, a gridded socioeconomic development index was first created, and a dividing line was drawn to reveal the distribution characteristics of socioeconomic development in the BRI regions. A classification method was then applied to identify local development levels. Finally, we created an economic corridor development index (ECDI) to evaluate the progress of six economic corridors. The results reveal spatial heterogeneity within the socioeconomic groups of BRI regions, which can be roughly divided into offshore (or Part A, 50.54%) and inland (or Part B, 49.46%) areas. Although both parts comprise roughly the same area, over 95% of the population is located in offshore regions. The China–Mongolia–Russia Economic Corridor has the highest development index due to a stable political environment and long-running cooperation. The China–Pakistan Economic Corridor suffers from the lowest ECDI but with strong development potential. Our methods can provide critical reference and practice for the future evaluation of the level of regional development. The results of this study can offer policymakers some insight into reducing socioeconomic inequality in the BRI regions.

Keywords: socioeconomic development levels; gridded socioeconomic development index; socioeconomic dividing line; six economic corridors; Belt and Road region

1 Introduction

The assessment of social and economic development levels is a foundational task of sustainable development research. In 2013, Chinese President Xi Jinping proposed the Belt and

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Road Initiative (BRI) with the principles of "openness and inclusiveness" and "wide negotiation, joint development, and sharing benefits," expecting to further strengthen the economic collaboration among the BRI countries, which have attracted worldwide attention (Shrestha, 2017; Han *et al*., 2018; Liu *et al*., 2018; Song *et al*., 2018; Taewoo *et al*., 2018; Shi *et al*., 2019; Liu *et al*., 2020; Calabrese and Cao, 2021; Carrai, 2021), particularly in the establishment of six economic corridors, namely, the Bangladesh–China–India–Myanmar Economic Corridor (BCIMEC), the China-Central Asia–West Asia Economic Corridor (CCAWAEC), the China–Indochina Peninsula Economic Corridor (CIPEC), the China–Mongolia–Russia Economic Corridor (CMREC), China–Pakistan Economic Corridor (CPEC), and the New Eurasian Continental Bridge (NECB). These economic corridors represent the critical frame of the BRI, which have made significant contributions to local trade, tourism development, and cultural exchange, and provide a clear direction for future investments, cross-border cooperation, and the construction of transportation links (Battamo *et al*., 2021; Zhao *et al*., 2022). Global ongoing initiatives like the 2030 United Nations identified 17 sustainable development goals (Fischer, 2021) which are closely compatible with the principles of the BRI. Within this context, determining effective ways to scientifically evaluate the level of regional socioeconomic development and to reasonably gauge the condition of economic corridors along the BRI regions is of great significance (Lélé, 1991; Harrison, 1997; Solar *et al*., 2016; Fan *et al*., 2021; Schindler *et al*., 2021).

The gross domestic product (GDP) per capita and gross national product per capita are the earliest and most commonly used indicators of regional economic status and standard of living (UN, 1954; Yang, 2000; Le Gallo and Ertur, 2003; Arkhangel'skii, 2009; Mujtaba *et al*., 2013). However, neither indicator can adequately reflect the social welfare of citizens (Castaneda, 1999; Mazumdar, 2003). Therefore, many scholars began to improve upon the GDP indicator by adding social indicators. For instance, Daly and Cobb (1989) proposed an index of sustainable economic welfare. It spans income inequalities, household labor, and damage to natural capital, providing corrections to the GDP. Then Castaneda (1999) applied sustainable economic welfare to Chile and found a close relationship between economic growth and the depletion of natural resources. In particular, the United Nations Development Programme (UNDP) creatively proposed the Human Development Index (HDI) in 1990, which measures income, education, and life expectancy. Although the HDI has been accepted by many scholars, policymakers, and development agencies (Sanusi, 2008; Eren *et al*., 2014), it has also faced criticisms: some have suggested that it does not perform well in measuring development due to the poor data quality and other limitations of available data (Srinavasan, 1994; Spangenberg, 2016), while others have criticized technical aspects of the HDI (Gormely, 1995; Noorbakhsh, 1998; Tofallis, 2013). Chaaban *et al*. (2016) proposed a Composite Global Well-Being Index to address these deficiencies, including socioeconomic indicators and survey data. Since this index considers ten well-being aspects (e.g., safety and security, health, and education), it is less sensitive to income fluctuation than the HDI. More importantly, You *et al*. (2020) formulated a socioeconomic development index based on 17 sub-indices covering human development, transportation accessibility, and urbanization. They concluded that the HDI performs well in reflecting the developmental status in regions with low levels of socioeconomic development in the BRI regions. At the same time, urbanization and transportation accessibility accurately expresses the developmental phase of high socioeconomic development level regions. However, since most studies focus on the level of socioeconomic development based on the statistical data of administrative units, there are some challenges that include limitations on data quality and availability and lack of adequate spatial distribution information. These drawbacks can be effectively resolved with raster data having spatial attributes characterized by massive and multi-source datasets.

Research that focuses on the BRI regions or economic corridors has been increasing, including international relations (Shrestha, 2017), environment (Zhang *et al*., 2017; Ascensão *et al*., 2018), trade (Taewoo *et al*., 2018), health (Tang *et al*., 2017), transportation (Shi *et al*., 2019), urbanization (Liu *et al*., 2018), and other issues. For instance, Li *et al*. (2017) explored the spatial and temporal city development of the BRI regions by using the DMSP/OLS nighttime light data from 1993 to 2012. The results suggest that nighttime light increased in most countries along the BRI, and the distribution of urban land has become more concentrated. Liu *et al*. (2018) studied the changes in population and urbanization in BRI counties from 1950 to 2050 through spatial auto-correlation analysis and hierarchical cluster analysis. The mean center of the population was displaced from northwest to southeast before 2000 but has been on a southern path since then. Between 2015 and 2030, Thailand, China, Laos, and Albania will be urban population hotspots, and urban coldspots will include Kuwait, Cyprus, Qatar, and Estonia. Subsequently, Shi *et al*. (2019) developed a transportation accessibility index to probe the relationship between accessibility and population distribution. The link between accessibility and population dispersion is positive. However, their relationship tends to be weaker with increasing socioeconomic development. Regarding research on economic corridors, Karim and Islam (2018) discoursed the prospects and challenges of the BCIMEC, while Ali *et al*. (2018) shared their ideas about the development of the CPEC, which mainly include four positive points: (1) it can enhance the relationship between Pakistan and neighboring nations thereby improving trade relations; (2) Pakistan may be able to significantly benefit from transit fees; (3) most backward regions can be developed; (4) the living quality of less-developed areas can be improved. Considering most existing studies related to economic corridors are not from political or economic perspectives, Battamo *et al*. (2021) considered geographical factors. They mapped the socio-ecological resilience of BRI economic corridors pertaining to river basins. Their results showed striking social and environmental differences among corridors. For example, the Bangladesh–India–Myanmar and China–Pakistan corridors were characterized by relatively low resilience. As most BRI routes currently struggle with resource limits, the socioeconomic growth of those corridors may be impeded in some way. Also, Rippa (2020) also gave some perspective on the economic corridor between China and Pakistan, and Bian *et al*. (2021) developed a mountain green cover index along the BRI economic corridors. However, research addressing the assessment of regional socioeconomic development and quantification of the developmental state of the six economic corridors remains surprisingly lacking.

This study comprehensively applies big earth data and interdisciplinary knowledge such as geographic information, remote sensing, economics, and statistics to achieve data fusion. Specifically, we use a raster dataset with a 10 km^2 resolution as the basic unit and produce a gridded index of human development, transportation, and urbanization. Based on this output, we simulate a BRI socioeconomic dividing line. To measure the developmental phases of economic corridors, we propose a new classification method using a coefficient of variation

(CV) to identify local development levels in the BRI regions by identifying 15 sub-levels to create an economic corridor development index (ECDI) based on the classification results. Our results can provide insight for the future assessment of developmental conditions of economic corridors, and the results can be used to design targeted strategies to alleviate the socioeconomic disparity in BRI regions.

2 Study area

There is no specific list of BRI countries or regions, for it is open to all interested countries. Generally, there is a commonly used group of 65 countries (Zhang *et al*., 2019), including six economic corridors, i.e., the Bangladesh–China–India–Myanmar Economic Corridor (BCIMEC), the China-Central Asia–West Asia Economic Corridor (CCAWAEC), the China–Indochina Peninsula Economic Corridor (CIPEC), the China–Mongolia–Russia Economic Corridor (CMREC), the China–Pakistan Economic Corridor (CPEC), and the New Eurasian Continental Bridge (NECB) (Figure 1). According to World Bank statistics, the contribution of those 65 countries to global GDP is around 30%, and their GDP per capita increased by 132% from 2015 to 2020 (Liu, 2019), significantly exceeding the global GDP per capita rise. In 2013, the BCIMEC proposed to bring benefits to Bangladesh, China, India, and Myanmar while also spurring prosperity in South, Southeast, and East Asia. The CCAWAEC starts in Xinjiang, China, and extends through Central Asia to the Persian Gulf, Mediterranean Sea, and the Arabian Peninsula. The CIPEC connects China to the Indochina Peninsula, passing through Vietnam, Laos, Cambodia, Thailand, Myanmar, and Malaysia to strengthen China’s ties with the Association of Southeast Asian Nations. The CMREC has two main traffic arteries: (1) from the Beijing–Tianjin–Hebei region of China to Hohhot and then to Mongolia and Russia, and (2) from the Chinese cities of Dalian, Shenyang, Changchun, Harbin, and Manzhouli to Chita, Russia. At the same time, the CPEC links the Silk Road Economic Belt in the north and the 21st Century Maritime Silk Road in the south, from Kashi, China, to Gwadar, Pakistan. The NECB is an international passageway connecting the Pacific and the Atlantic. It extends from the coastal cities of Lianyungang and Rizhao, China to Rotterdam, Holland, and Antwerp, Belgium.

Figure 1 shows the spatial distribution of the population and locations of six economic corridors (i.e, the BCIMEC, CCAWAEC, CIPEC, CMREC, CPEC, and NECB) in the BRI region. As the Maldives lacks transportation data, only 64 countries are included in the upcoming analysis.

3 Methodology

3.1 Gridded socioeconomic development index (GSDI)

According to sustainable development theory, location theory, critical minimum affect theory, and the big-push theory (Pearce and Atkinson, 1993; Isard, 1954; Rosenstein, 1961), we suggest that regional socioeconomic development condition concerns not only income but also residential living standards, local transportation and infrastructure conditions, and modernization processes (You *et al.*, 2020). Therefore, our proposed GSDI integrates indicators such as the Human Development Index (HDI), a Global Transportation Accessibility Index

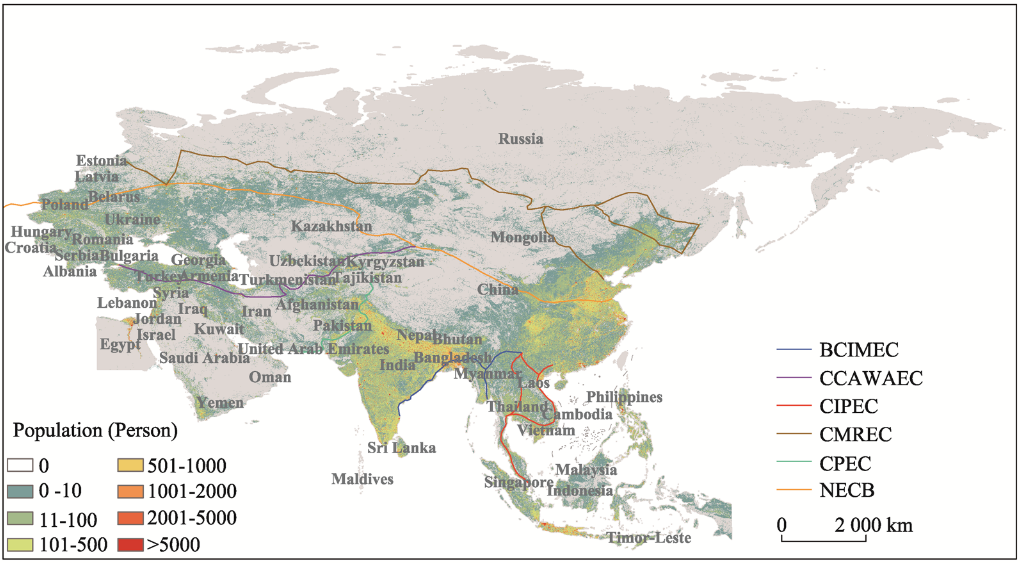

Figure 1 Spatial distribution of population and locations of six economic corridors in the BRI regions

(GTAI), and an Urban Modernization Index (UMI). However, since the length ratio method is sensitive to some extreme values (You *et al.*, 2020), we establish a three-dimensional model based on volume ratio to calculate GSDI. The workflow is depicted in Figure 2, which also illustrates that the GSDI value is the normalized ratio of the volume of the red cube to the importance of the ideal (black) cube, then multiplied by 100.

3.1.1 GSDI dimension 1: Human Development Index (HDI)

The HDI has been widely used to evaluate the socioeconomic development levels of countries (Singariya, 2014; Wong *et al.*, 2017). It comprises three sub-indices: life expectancy, education index, and GNI per capita (UNDP, 1990). Because the UNDP usually reports country-level HDI, which is not beneficial to spatial analysis, Kummu *et al.* (2018) established a 10 km^2 resolution gridded global dataset for the HDI based on sub-national data from the UNDP Human Development Report. Since only a few countries were missing data, an almost complete global dataset based on the old calculation in 2009 was applied. The entire dataset spans 25 years, from 1990 to 2015, and the 2015 dataset of the gridded HDI was used in this study.

3.1.2 GSDI dimension 2: Global Transportation Accessibility Index (GTAI)

Feng *et al.* (2009) and Shi *et al.* (2019) reported that traffic conditions are an essential consideration when evaluating a region's infrastructure level, while Feng *et al.* (2009) also regarded infrastructure development as a critical indicator for assessing the local socioeconomic situation. This study aggregates seven variables to generate the GTAI (see Figure 2).

Specifically, the GTAI includes two main sub-indices that are assigned the same weights. Firstly, the transportation density index, consisting of the aggregation of the road density (RDI), railway density (RWDI), and waterway density (WDI). Since various transportation modes may contribute differently to accessibility in different countries, correlation analysis was performed to probe the connection between the population and three transportation den-

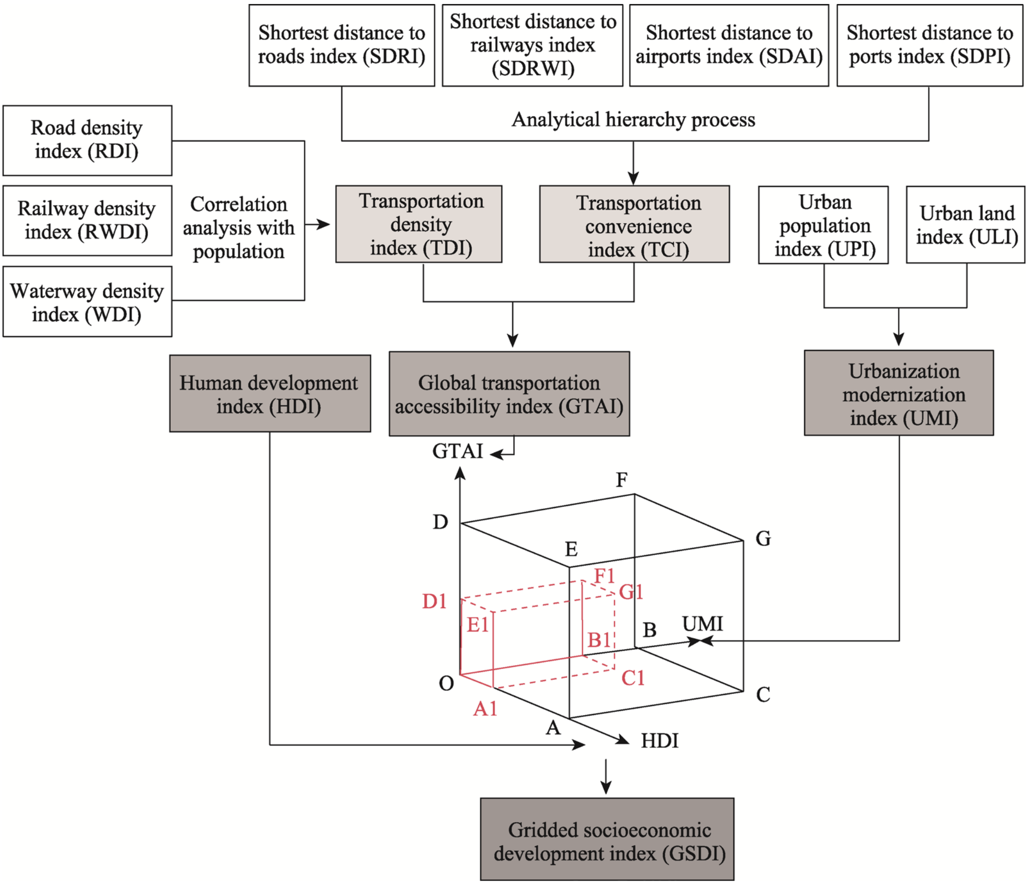

Figure 2 Schematic of the GSDI model

sity variables for each country (RDI, RWDI, and WDI). The weights were based on the Pearson correlation coefficient (see Section 3.2 in Shi *et al*. (2019)). Secondly, the transportation convenience index is a combination of normalized shortest distances from each grid cell to roads (SDRI), railways (SDRWI), airports (SDAI), and ports (SDPI). The process is given below:

After discussion with experts and regional investigations, the SDRI, SDRWI, SDAI, and SDPI were variables impacting transportation accessibility. Hence, we created a matrix of pairwise comparisons for those four indicators and then computed its eigenvector, maximum eigenvalue, and consistency ratio. Additional details are given in Shi *et al*. (2019).

3.1.3 GSDI dimension 3: Urban Modernization Index (UMI)

Urbanization is widely used for measuring the modernization process, typically combining two elements, i.e., urban land and urban population. Although we could easily acquire land cover data for 2015 from the European Space Agency and calculate the urban land rate using ArcGIS 10.X, several steps are required to obtain the gridded urban population rate. First, we collected the reported urban population for each country from the World Bank. Next, considering the close relationship between urban activities and nighttime lights (Amaral *et al*., 2006; Savory *et al*., 2017), we downloaded DMSP/OLS Nighttime Lights (NTL) data from the Earth Observation Group. We then conducted a correlation analysis to test the connection between NTL and the urban population.

Since China has a large area with uneven development, we chose it as a pilot site to test this correlation. Specifically, we extracted county-level urban population data from the 2010 census in China, calculated the sum of digital number (DN) values for each county based on the NTL data for the same year, and used correlation analysis to test their association. The result shows a strong positive relationship between DN values and the urban population, with a correlation coefficient of 0.87. This justifies using NTL data as a proxy for the gridded urban population. The formula can be expressed as follows:

$$UP_i = \frac{DN_i}{\sum_{i=1}^{n} DN_i} \times TUP_j \quad i=1, 2, ..., n; j=1, 2, ..., 65 \tag{1}$$

where UP_i is the urban population of grid cell i, DN_i represents the DN value of grid cell i, TUP_j is the total urban population of country j, and n is the number of grid cells in that country. Although the DMSP/OLS NTL data were last updated in 2013, it is safe to assume that the urban population distribution has changed little over the following 2 years. Therefore, we used NTL data from 2013 and World Bank urban population statistics from 2015 to obtain gridded urban population data. After that, LandScan population data for 2015 were used to calculate the urban population rate.

3.2 Economic corridor development index (ECDI)

To quantify the development state of economic corridors, we built an ECDI based on the GSDI using a CV-based classification approach (see Figure 3). The CV measures the dispersion of a probability or frequency distribution, which is widely used to determine the degree of data dispersion (Brown, 1998; Reed *et al.*, 2002). It is computed as the standard deviation divided by the mean, generally expressed as a percentage (Abdi, 2010). The formulas can be defined as follows:

$$CV = \frac{STD}{\overline{x}} \times 100\% , \tag{2}$$

$$STD = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \overline{x})^2} , \tag{3}$$

where CV denotes the coefficient of variation, STD is the standard deviation, $\{x_1, x_2, \ldots, x_n\}$ are the GSDI values of the selected pixels, $\overline{x}$ indicates the mean GSDI value of these pixels, and n is the number of selected pixels. If the CV value is larger than 15%, the data may be abnormal and have a high degree of dispersion (Runlong, 2010).

In light of this, we developed a classification method to determine socioeconomic development levels in the BRI regions. Since a mean value close to zero would result in an inflated CV value, we included the mean and CV values together (see Figure 3). If the CV value is larger than 15% and the mean value is larger than 1, the data will be regarded as dispersed and then divided into three groups. The data in the first group are less than or equal to the $MEAN - (0.5 \times STD)$, the data in the second group are between $MEAN - (0.5 \times STD)$ and $MEAN + (0.5 \times STD)$, and the data in the third group are larger than $MEAN + (0.5 \times STD)$. The dispersion of data in each group will then be determined by CV and mean values again until their data meet the above conditions (15 levels are generated for this study). Table 1 contains statistics for each of the 15 levels of socioeconomic development.

Table 1 Statistics on 15 levels of socioeconomic development

Level	Mean	STD	CV (%)	Level	Mean	STD	CV (%)
1	0.00	0.01	898.08	9	9.09	0.50	5.49
2	0.93	0.46	49.73	10	13.00	1.79	13.81
3	2.01	0.15	7.35	11	19.10	1.70	8.92
4	2.48	0.12	4.81	12	24.43	1.42	5.81
5	2.96	0.16	5.33	13	30.14	1.68	5.58
6	4.21	0.57	13.48	14	39.43	2.98	7.55
7	6.01	0.48	7.92	15	48.98	4.98	10.16
8	7.53	0.39	5.22				

To accurately evaluate the development status of six economic corridors, we first converted line representations (layers) of economic corridors into point layers with an interval of 5 km between every two points, then created a 100-km buffer for each point, within which the highest SDI level value was captured to represent the development level of local economic corridors. Finally, the ECDI was created to quantify the development levels of six economic corridors using the following equation:

$$ECDI_n = \sum_{i=1}^{j} (p_i \times i)\,, \tag{4}$$

where $ECDI_n$ denotes the ECDI of n_{th} economic corridor, j is the number of development levels, equal to 15 in this study. p_i represents the corresponding percentage of points at each i_{th} level.

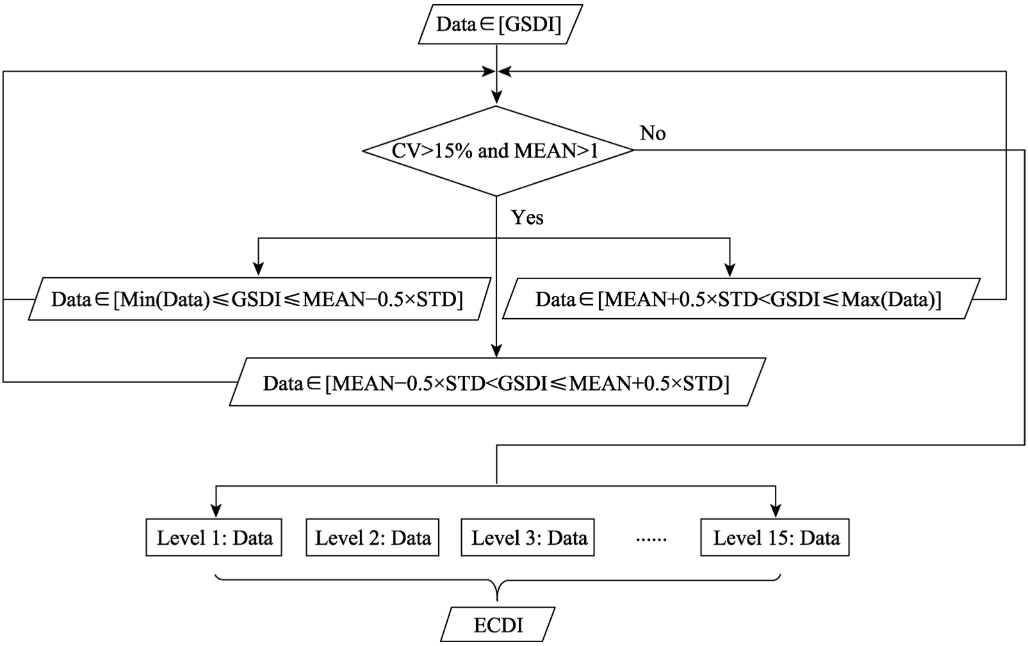

Figure 3 Flow chart of the establishment of the ECDI using a CV-based classification method

4 Results

4.1 Spatial distribution of socioeconomic development in the BRI regions

Figure 4 shows the distribution of GSDI in the BRI regions. On the whole, socioeconomic development is uneven in these areas. Specifically, regions with relatively high socioeconomic development are chiefly located in western Russia (e.g., Moscow and Saint Petersburg), Central and Eastern Europe (e.g., France, Germany, and Italy), and eastern China (e.g., the Beijing–Tianjin–Hebei region, Yangtze River Delta, and the Pearl River Delta). Residents in these areas are more likely to receive education, have access to medical care, earn high salaries, and enjoy high accessibility and modernization (Shi *et al.*, 2018). By contrast, citizens living in underdeveloped countries (e.g., Yemen, Oman, and Laos—grossly consistent with the UN Least Developed Countries), Central Asia, and the Far East generally experience low living standards, inadequate transportation facilities, and slow urbanization.

To further explore the distribution characteristics of GSDI, we drew a socioeconomic dividing line based on the first-level and second-level administrative boundaries of BRI countries. The BRI regions can be roughly divided into two parts, i.e., offshore (or Part A) and inland (Part B). The Part A areas are mainly located in western Russia, Central and Eastern Europe, West Asia and the Middle East, Southeast Asia, South Asia, and eastern China (Figure 4), all characterized by a humid and warm climate; the areas in Part B are mainly located in eastern Russia, Central Asia, Mongolia, and western China, which tend to be dry and cold. Although Part A and Part B are similar in size (around 25 million km^2), their population and mean GSDI are dramatically different (Table 2). Specifically, 95.14% of people in BRI countries live in Part A, or offshore areas, with a population density of 164.75 person/km^2,

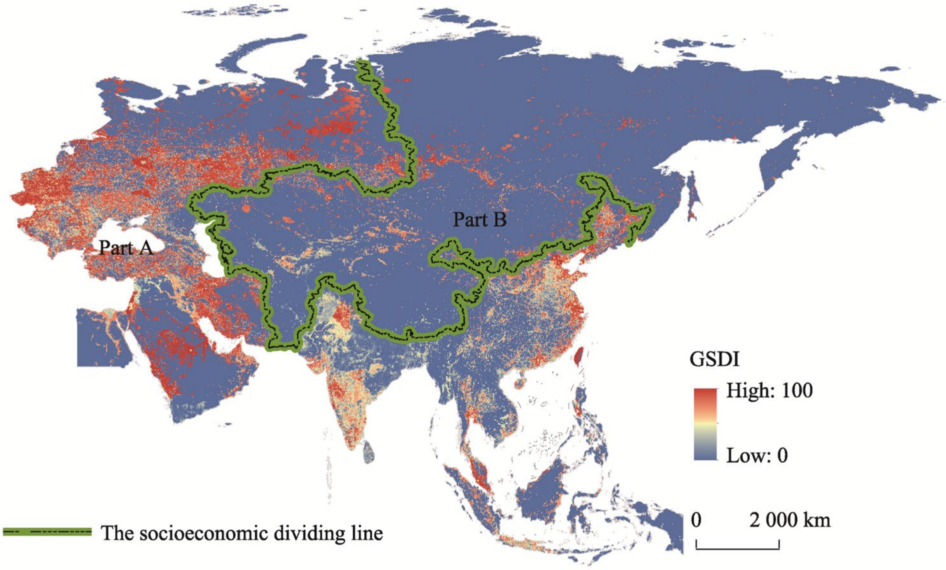

Figure 4 Spatial distribution of socioeconomic development levels in the BRI regions

Table 2 Land and population statistics of the offshore (Part A) and inland (Part B) parts on either side of the socioeconomic dividing line

	Land		Population			GSDI
	Area (million km^2)	Proportion (%)	Number (million)	Proportion (%)	Density (person/km^2)	Mean
Part A	25.54	50.54	4207.78	95.14	164.75	14.22
Part B	25.00	49.46	214.79	4.86	8.59	2.08

while only 4.86% live in Part B or inland regions. Moreover, the mean GSDI of Part A is about seven times that of Part B.

4.2 Classification of socioeconomic development in the BRI regions

For in-depth analysis of the distribution characteristics of GSDI and accurate assessment of the developmental status of economic corridors, we applied a classification method based on the CV to identify regional socioeconomic development levels in BRI countries (Figure 5). Moreover, Table 3 compares the natural conditions and population density under different socioeconomic levels.

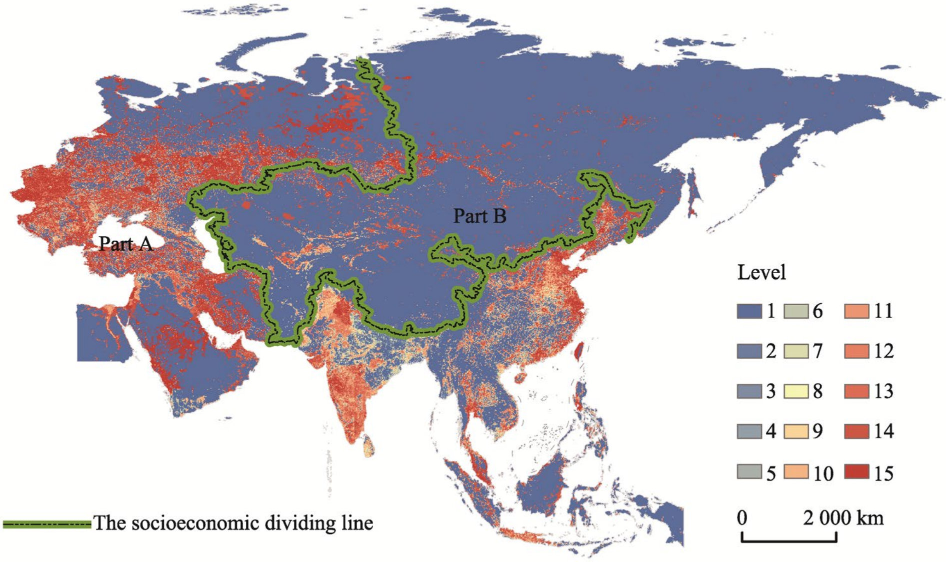

Figure 5 Spatial distribution of 15 levels of GSDI in the BRI regions

(1) Low socioeconomic development regions are mainly located inside the socioeconomic dividing line (Part B), including eastern Russia, Central Asia, Mongolia, and western China. Their GSDI values range from 0 to 0.23, and they all fall within one level. Even though these regions occupy more than 70% of the total BRI area, they are home to less than one in ten people, thus having the lowest population density among all categories (12 person/km^2). This is mostly because much of their land is alpine and characterized by harsh natural conditions (with a mean elevation of 860.52 m and annual mean temperature of less than 4 ℃), making them unsuitable for human habitation (You *et al.*, 2020).

(2) Middle-low socioeconomic development regions are mainly located in eastern India and central China, with GSDI values between 0.23 and 3.23. These regions (with a mean elevation of 457.57 m and annual mean temperature less than 18.5 ℃) are barely influenced by the natural environment. They account for 1.77% and 8.88% of the BRI area and population, respectively, and include four levels. Specifically, the second level, whose mean value of GSDI is 0.93, accounts for the largest area and population, with a high population density of 464 person/km^2. In comparison, regions in the third, fourth, and fifth levels are much smaller and have lower population densities. Most regions with relatively low GSDI in this

Table 3 Statistics for different socioeconomic development regions

Category and Level		GSDI	DEM (m)	Annual mean temperature (℃)	Land	Population	
					Proportion (%)	Proportion (%)	Density (person/km^2)
Low socioeconomic development regions	1	0.00	860.52	3.94	72.76	9.90	12
	Total	0.00	860.52	3.94	72.76	9.90	12
Middle-low socioeconomic development regions	2	0.93	447.45	18.77	1.00	5.30	464
	3	2.01	473.86	18.39	0.28	1.33	418
	4	2.48	459.90	18.16	0.22	1.05	415
	5	2.96	477.07	17.64	0.27	1.20	392
	Total	1.60	457.57	18.47	1.77	8.88	439
Middle socioeconomic development regions	6	4.21	475.62	17.57	0.93	4.54	429
	7	6.01	447.86	17.40	0.71	3.94	484
	8	7.53	459.65	16.94	0.57	3.54	542
	9	9.09	453.30	16.88	0.70	4.13	514
	Total	6.48	460.35	17.24	2.91	16.15	485
Middle-high socioeconomic development regions	10	13.00	436.97	16.71	2.54	18.70	644
	11	19.10	418.53	16.52	2.19	14.24	568
	12	24.43	427.70	16.35	1.69	8.93	463
	Total	18.09	428.24	16.55	6.42	41.87	570
High socioeconomic development regions	13	30.14	510.93	15.79	2.11	6.93	288
	14	39.43	463.35	10.61	7.18	9.42	115
	15	48.98	439.14	10.67	6.85	6.84	87
	Total	42.27	460.27	11.40	16.14	23.19	126

category are located in densely populated parts of India or China.

(3) Middle socioeconomic development regions cover an area of 1.47 million km^2, scattered across eastern Russia, northern India, and central and eastern China. Their GSDI values range from 4.21 to 8.23 and have a relatively high mean population density of 485 person/km^2. These regions can be subdivided into four levels. Unlike in the middle-low socioeconomic development regions, a positive relationship is observed between socioeconomic development status and population density at all four levels, consistent with the common knowledge that high economic development regions are more likely to attract population.

(4) Middle-high socioeconomic development regions are scattered across eastern Russia, Central and Eastern Europe, India, and eastern China, with a mean GSDI value of 18.09 (about three times that of middle socioeconomic development regions) and a mean population density of 570 person/km^2. There are three levels within this category. The mean population density peaks at 644 person/km^2 in the 10th level but is smaller in the 11th and 12th levels. This pattern is mostly due to central and eastern European regions having relatively high socioeconomic development but smaller populations than China and India.

(5) High socioeconomic development regions have the second largest area (8.16 million km^2). They are chiefly distributed in western Russia, Central and Eastern Europe, New Delhi, and eastern China (particularly the Beijing–Tianjin–Hebei region, Yangtze River Delta, and Pearl River Delta). Even though their GSDI values are high, the mean population density in these regions is only 126 person/km^2, less than a quarter of the mean value for middle-high socioeconomic development regions. The 15th level, which contains regions with the high-

est socioeconomic levels, has a mean population density of 87 person/km^2. Most regions in this category are located in western Russia and Central and Eastern Europe, which are generally sparsely populated.

4.3 Evaluation of the development levels of six economic corridors

The progression of economic corridors in BRI regions has been mapped in Figure 6, and the corresponding proportion of each level of corridors and the ECDI are presented in Table 4. The development index is the sum of the products of levels (from 1 to 15) and corresponding percentages.

On the whole, about 78.29% of regions along six economic corridors are well-developed, with a whole development index of 14.61. The CMREC, NECB, and CCAWAEC have the highest development indexes (Figure 6), 14.98, 14.87, and 14.86, respectively, although a small part of the NECB is marked by yellow or orange due to the backward areas in the northwestern region of China. This is chiefly due to the stable political atmosphere among China, Mongolia, and Russia, the construction of the NECB beginning in 1992, and the deepening of bilateral relations among the CCAWAEC countries. Nevertheless, we can also observe that the BCIMEC and the CPEC are relatively underdeveloped compared to other economic corridors.

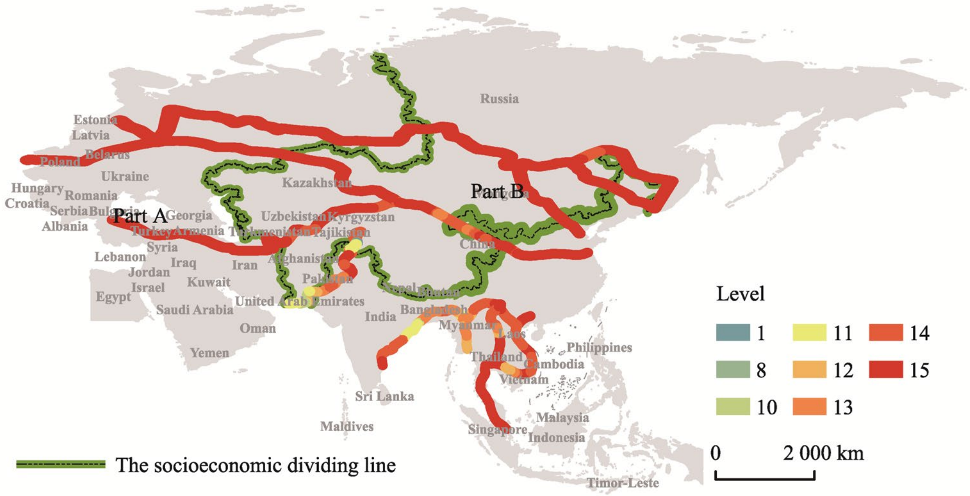

Figure 6 Spatial distribution of development levels of six economic corridors

The CPEC is the corridor with the lowest development index (12.83), within which about 1.77% belonged to the 1st level (around Kashmir), and only 19.76% were classified as 15th level (Table 3). This is chiefly because the geopolitical environment is unstable along the CPEC, and various international, regional, ethnic, religious, and other factors are intertwined, which may trigger interference activities, hence affecting the construction of corridors. In addition, the border areas between China and Pakistan exist under poor natural conditions, increasing the construction difficulty and resulting in high infrastructure costs.

For the BCIMEC, only 6.48% of the parts are divided into the highest level (15th), and 25.69% belong to middle-high socioeconomic development regions, mainly located in the southeastern part of India (Figure 6). This is mainly attributed to fairly inadequate transportation infrastructure and intense competition between Bangladesh, India, and Myanmar. The conflicts of their interests appear to slow down the BCIMEC development somehow, as evidenced by a development index of only 13.11.

Table 4 Percentage of each development level for six economic corridors

Economic corridors	Percentage of each development level based on the GSDI (%)								ECDI
	1	8	10	11	12	13	14	15	
BCIMEC	0.00	0.00	0.69	10.65	14.35	31.94	35.88	6.48	13.11
CCAWAEC	0.00	0.00	0.00	0.00	0.00	0.00	14.30	85.70	14.86
CIPEC	0.00	0.00	0.00	0.46	5.47	2.13	35.26	56.69	14.42
CMREC	0.00	0.00	0.00	0.00	0.00	0.00	2.06	97.94	14.98
CPEC	1.77	0.29	5.31	18.88	8.26	17.40	28.32	19.76	12.83
NECB	0.00	0.00	0.00	0.00	0.00	2.06	9.36	88.58	14.87
Total	0.10	0.02	0.36	1.92	2.14	4.08	13.10	78.29	14.61

In addition, the establishment of the CIPEC was proposed in 2015, later than that of other economic corridors, which partially explains why the development index of CIPEC (14.42) is lower than CMREC, NECB, or CCAWAEC. Furthermore, mainland Southeast Asia Peninsula is a “broken zone” of the world. The disagreement of political systems, economic development interests, and ethnic customs in these countries may hinder the local import or export trades. At the same time, it is a battlefield for geopolitical and economic powers from outside the region. From a spatial perspective, the CIPEC in parts of Laos, Cambodia, and Vietnam is less developed than in Thailand. Therefore, it makes sense that Thailand has a prosperous tourism industry compared to the other three countries, which grossly stimulates local economic development.

5 Conclusion

This study proposes an innovative method to quantify the socioeconomic development status and the progress of economic corridors. Compared with existing measurement methods of vector data, our approach is interdisciplinary and integrates multi-source data, including statistical data, geographic data, and remotely-sensed data. Using raster data overcomes the limitation of administrative boundaries, thereby presenting results at a finer level of detail. This approach allows us to offer specific policy suggestions for better BRI investment and construction.

The BRI socioeconomic dividing line illustrates the spatial heterogeneity of GSDI distribution in the BRI regions. It separates the BRI regions into two parts of roughly equivalent area that house hugely different shares of the population, with less than 5% living in the inland areas (Part B) and more than 95% living in the offshore regions (Part A). This finding also reflects the significance and reliability of this dividing line, which might provide some information for future BRI-related policies.

To quantitatively evaluate the development situation of six economic corridors, we further developed a CV-based classification method. The classification results suggest that nearly three-quarters of the total BRI area have low socioeconomic development. These areas are mainly located in eastern Russia, Central Asia, Mongolia, and western China, where many of these regions suffer from high elevation and low temperatures. Meanwhile, over 16% of the total BRI area has high socioeconomic development, characterized by high living standards, extensive urbanization, and excellent infrastructure. These regions tend to be distributed in European countries and eastern China. Only about 10% of the total BRI area is classified in the middle-low, middle, or middle-high levels of socioeconomic development, implying severe polarization among the BRI regions. Our classification results are broadly similar to the spatial distribution of tourism industries, urbanization, and developmental levels from previous research efforts (Suocheng *et al*., 2015; Liu *et al*., 2018; You *et al*., 2020).

Regarding the development status of economic corridors, the CMREC, NECB, and CCAWAEC are more developed, which is partly explained by a stable political environment, long-running cooperation, or a favorable trading atmosphere. Nonetheless, it is worth noting that some nodes of BCIMEC, CPEC, and CIPEC still need investment in infrastructure. In comparison, the BCIMEC is less developed, potentially because China is challenged with cultural exchanges, and infrastructure construction has been slow. Given this inference, the governments involved should seek to strengthen political trust, build border economic zones, further develop the textile and garment industries, and give full consideration to the advantages of their large populations. Furthermore, the CPEC seems underdeveloped, but it has strong development potential because mutual political trust is high. We recommend strengthening the connection between western China and Pakistan within this context by constructing roads, railways, ports, and especially energy infrastructure. Last but not least, although some nodes of CIPEC (like Laos, Cambodia, and Vietnam) are lesser developed, those regions are covered by the China-Association of Southeast Asian Nations Free Trade Area and demonstrate strong potential. Under this circumstance, it is most important to standardize trade rules, to leverage the China–Laos Railway, to ensure the continuation of the Rubber-Rice Pact for the promotion of the rubber and rice industries, and strengthen investments in transportation, water irrigation, water, and power supply facilities in those countries as they are holding different standards towards imports and exports and suffering from poor infrastructure.

Considering the large scale of our study, gridded data with a 10 km^2 resolution were used to determine regional socioeconomic development levels in the BRI regions. Since our index was constructed using raster data, its resolution can be adjusted to satisfy research requirements in the future. For instance, higher-resolution data could be used to examine one economic corridor in the future, such as the BCIMEC or the CIPEC.

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