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Use of TOPSIS method based on Entropy weights for determining the disparities in the developmental pattern: A study of North Bengal region, West Bengal

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Abstract:

The concept of development is very dynamic, it varies over space and time. The reasons behind this variation or inequality in the development of any region may be natural or anthropogenic or combination of both. It is not reasonable to determine the level of development of any region with only one parameter because it depends on multiple criteria. Thus, making it a necessary consideration to understand the developmental pattern of any region. This paper aims to study the pattern of regional disparities in the districts of North Bengal (West Bengal) in terms of its development. A district level analysis is considered to achieve the aim using 27 selected parameters under three distinct categories namely economic, infrastructural and socio-demographic indicators. Entropy Method is applied to weigh the parameters and finally the districts are ranked according to the performance score obtained by applying the TOPSIS model. A significant inequalities are observed in terms of development between the districts. On the basis of selected parameters Jalpaiguri (CI score 0.703) and Darjeeling district (CI score 0.560) stands at the highest level of development among the six districts of North Bengal and the remaining four falls under the low level of development (below average CI score 0.385).

Keywords: Level of development, Regional disparities, Shannon's entropy, Multi-criteria decision making, Spearman's rank correlation

1.0 Introduction:

The developing nations like India are experiencing an accelerating rate of growth in every aspect of economic, social and cultural development (Mishra & Chatterjee, 2017) but due to various natural and human centric causes, this rate of development is very uneven. According to (Rao, 1984), the unchecked and uncontrolled process of growth is responsible for this regional unevenness. Disparities in the developmental pattern is regarded one of the toughest challenges for the researchers and the policy makers (Mishra & Chatterjee, 2017). Development is a process of improving the quality of life and standard of living of the people. In India, the history of developmental plans could not show enthusiastic results as most of them were terminated through the partial achievements of the desired target (Mishra & Chatterjee, 2017). Post-independence, developmental plans in India were taken up in the form of Five Year Plans¹ initially which were based on the economic theories of development (Harrod-Domar model² and Mahalanobis model³). After the 10th FYP (2002-07), emphasis was given on the other social parameters like gender inequality in education, skill development, environmental sustainability, child nutrition, safe drinking water services, banking services, village electrification, and improvement of greeneries. It was the 10th plan when the Indian government started to follow the regional approach instead of sectoral approach to bring down the regional imbalance of development

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(Planning Commission, 2002). Removal of regional inequalities in the developmental pattern has remained the avowed goal of planning in India (Mohan, 2005). The idea of development is not new, it has always been a great concern to the social scientist. But the parameters taken into consideration in order to determine the levels of development have manifested over time. When the subject began in the 1940s, it was primarily driven by the progression in economic growth theory (Asia Society, 2004). During the 1950s and 1960s also, the word development was to a great extent alluded to as improvement in economic conditions, which implied an objective rather than subjective change in economic performance (Rabie, 2016). Amartya Sen has challenged the mainstream concept of measuring development by economic growth (Evans, 2002). According to Sen's capability approach, development consist of the removal of various types of unfreedom that leave people with little choice and opportunity for exercising their reasoned agency (Sen, 1987; Sen, 1999; Morris, 2009; Clifton, 2013). He has focused on crucial instrumental freedoms such as: economic opportunities, political freedom, social facilities, transparency guarantees and protective security (Clifton, 2013). United Nations Development Programme (1990) portrays two different sides of human centric development, one is the creation of human capacities to have an improved health, required knowledge and access to the needed resources (UNDP, 1990). The second one is to utilize these capabilities for gainful. As per this idea of human development, "income is just one alternative that individuals might want to have, though a significant one. Yet, it isn't sufficient for the human development" (UNDP, 1990). So, development must be more than just the increase in individual's income and wealth. The development pattern of any region must be analysed using more than one criteria. Thus, it is reasonable to consider the concept of development as a multi-faceted and multi-dimensional aspect.

2.0 Study Area:

The present study has been carried out in the six northern districts of West Bengal namely: Darjeeling, Jalpaiguri, Cooch Behar, Uttar Dinajpur, Dakshin Dinajpur and Malda (as per 2011 census year). This northern part of the state is well known as North Bengal, located in eastern part of India covering an area of 21855 square kilometers. The geographical extension of the state is stretched between 24° 39' 23" north to 27° 13' 17" north latitude and 87° 45' 34" east to 89° 52' 37" east longitude (Fig 1). The region shares its international boundaries with Bangladesh, Bhutan and Nepal and State boundaries with Assam, Sikkim, Bihar, and Jharkhand. Agriculture and allied activities are the primary sources of income for the people of North Bengal and a significant proportion of the population are directly or indirectly associated with plantation and agricultural activities.

3.0 Objective:

The objective of the present study is to find out the variability and disparities in developmental pattern among the districts of North Bengal in terms of its economic, socio-demographic and infrastructural aspects using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)⁴ and Shannon's Entropy method⁵.

4.0 Data and methods:

The data and information used in the study are entirely based on secondary sources which have been collected from different published government reports during the year 2011-12 such as Census of India (2011), Bureau of Applied Economics and Statistics, West Bengal World Bank Group, Directorate of Micro and Small Scale Enterprises, West Bengal, District Elementary Education Report Card (NUEPA), Economic Review (RBI), District Information System for Education (DISE) and All India Survey on Higher Education (AISHE).

Table 1: Selected parameters of development

Sl. No.	Variables	Category
1	Work participation rate ^a	Economic
2	Per capita income ^b	
3	Population below poverty line ^c	
4	Net cropped area ^b	
5	Crop intensity ^b	
6	Total crop production ^b	
7	Employment in factories ^d	
8	Employment in MSME ^d	
9	Population density ^a	Socio-demographic
10	Decadal growth rate of population ^a	
11	Level of urbanization ^a	
12	Sex ratio ^a	
13	Effective literacy rate ^a	
14	Gender gap in literacy ^a	
15	Total enrollment in school education ^e	
16	Student teacher ratio in school education ^e	
17	Total fertility rate ^a	Infrastructural
18	Under five mortality rate ^f	
19	Number of factories ^d	
20	Number of MSMEs ^d	
21	Density of health care centres ^b	
22	Bed density in hospitals ^b	
23	Density of schools ^g	
24	Number of general degree colleges ^h	
25	Number of commercial banks ⁱ	
26	Number of post offices ^b	
27	Road density ^b	

Data sources ^aCensus of India (2011); ^bBureau of Applied Economics and Statistics, West Bengal (2011-12); ^cWorld Bank Group (2012); ^dDirectorate of Micro and Small Scale Enterprises, West Bengal (2011-12); ^eDistrict Elementary Education Report Card: 2011-12, NUEPA; ^fAhuja (2011); ^gDISE report 2011-12; ^hAISHE 2011-12; ⁱEconomic Review, RBI (2011-12)

Table 1 shows the selected parameters for the combined analysis to estimate the development pattern. These twenty seven parameters (sub-indicators) are major interacting components of development of any region. Out of twenty seven parameters first eight are economic indicator, Sl. No. 9 to 18 are socio-demographic indicator and the last nine parameters are included in infrastructural indicator of development. There are several statistical methods used to estimate the levels of development but most of the methods have their own limitations and advantages. The major limitation arises from the assumptions made about the development indicators themselves and their weightage in combined analysis (Narain, Bhatia, & Rai, 2011). Keeping in view the limitations of different methods, the following procedures are applied to weigh and rank the districts of North Bengal.

5.0 Criteria Weighting:

The weight coefficients for the selected criteria are calculated using an objectives approach i.e. Entropy method (Çalışkan, Kurşuncu, Kurbanoglu, & Güven, 2013). Generally this method is used to measure the uncertainty in the data set using probability theory. According to which a broad distribution illustrates more uncertainty compared to the shapely peaked distribution (Rao, 2007). Entropy based method helps to compute unbiased relative weights of the selected criteria and assist to perform TOPSIS method to rank scenarios appropriately (Shannon & Weaver, 1947). The following formula shows the decision matrix *A* with *n* as the numbers of criteria and *m* as the numbers of alternatives of a multi criteria problem (Chou, Yen, & Sun, 2011).

$$A = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{1,1} & \cdots & x_{1,n} \\ \vdots & \ddots & \vdots \\ x_{m,1} & \cdots & x_{m,n} \end{bmatrix} \quad (\text{Eq. 1})$$

where, x_{ij} is the performance value of the i^{th} alternative to the j^{th} criteria ($i = 1, 2, \dots, n$ and $j = 1, 2, \dots, m$). As the measuring unit of the variables differ significantly, the values might not be suitable for a combined analysis (Narain, Bhatia, & Rai, 2011). Therefore, a normalised decision matrix P_{ij} is calculated to obtain the weight coefficients of the criteria this Entropy method (Rao, 2007).

$$P_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (\text{Eq. 2})$$

The Entropy (E_j) value is obtained through the equation 3 for the j^{th} criteria.

$$E_j = -k \sum_{i=1}^m P_{ij} \ln(P_{ij}) \quad (\text{Eq. 3})$$

where, k is a constant ($1/\ln m$) that ensures $0 \leq E_{ij} \leq 1$. m is the number of alternatives and n is the number of criteria.

6.0 District ranking method:

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method developed by Hwang and Yoon (1981) is applied to obtain the final ranking of the districts in terms of their development score (Hwang & Yoon, 1981). The method is used to get a solution depending upon the Euclidean distance from ideal and negative ideal solutions. The method needs information on relative importance of properties that are considered in solution process (Sharma, Aggarwal & Gupta, 1993). The TOPSIS model consists of the following steps (which are adoption of the corresponding steps of the ELECTRE method) (Shanian & Savadogo, 2006a; Shanian & Savadogo, 2006b; Krimi, Yusop, & Hook, 2010; García-Cascales & Lamata, 2012).

Normalization of decision matrix

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}, \quad (i = 1, 2, \dots, n \text{ and } j = 1, 2, \dots, m) \quad (\text{Eq. 4})$$

Weighted normalised decision matrix

$$v_{ij} = n_{ij} w_j, \quad (i = 1, 2, \dots, n \text{ and } j = 1, 2, \dots, m) \quad (\text{Eq. 5})$$

The ideal solution

$$\{v_1^+, v_2^+ \dots \dots \dots v_n^+\} = \{(max_i v_{ij} | j \in k, min_i v_{ij} | j \in k',) | i = 1, 2, \dots, m\} \quad (\text{Eq. 6})$$

The nadir ideal solution

$$\{v_1^-, v_2^- \dots \dots \dots v_n^-\} = \{(min_i v_{ij} | j \in k, max_i v_{ij} | j \in k',) | i = 1, 2, \dots, m\} \quad (\text{Eq. 7})$$

Estimation of Euclidian distance

$$S_i^+ = \{\sum_{j=1}^n (v_{ij} - v_j^+)^2\}^{0.5}, \quad (i = 1, 2, \dots, n \text{ and } j = 1, 2, \dots, m) \quad (\text{Eq. 8})$$

$$S_i^- = \{\sum_{j=1}^n (v_{ij} - v_j^-)^2\}^{0.5}, \quad (i = 1, 2, \dots, n \text{ and } j = 1, 2, \dots, m) \quad (\text{Eq. 9})$$

Relative closeness to the ideal solution

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad (i = 1, 2, \dots, n) \quad (\text{Eq. } 10)$$

Greater value of C_i indicated the high level of development and lower value indicated low level of development.

7.0 Results and Discussion:

7.1 Levels of development:

The levels of development and intra-district disparities are estimated separately for economic, infrastructural, socio-demographic indicators (Table 1) using the TOPSIS method. The final results are shown in the table 2 and figure 2 to 4. Based on the obtained C_i score, districts are ranked accordingly from highest level of development to least developed one. The average C_i score of three indicators is used to get the overall ranking of the districts. The result shows that Jalpaiguri District is ranked first in case of first two indicators i.e. economic and infrastructural indicators (Table 2). Because of its high performance in agricultural production, net cropped area and employment in MSMEs and factories. For the socio demographic indicator, Darjeeling district is ranked first due to its highest performance rate in urbanization, sex ratio, student teacher ratio in schools, total fertility rate and under five mortality rate. Both the Dinajpur districts are ranked last in all the indicators because of their very poor performance in the selected parameters. Dakshin Dinajpur is the least ranked district in terms of overall development pattern and Uttar Dinajpur ranked second last among all the six districts. According to the average score of C_i , Jalpaiguri District is ranked first followed by Darjeeling, Malda and Cooch Behar. It is quite appropriate to consider the C_i value to estimate different stages of development for all the districts. The district having C_i score more than the average (0.385) are the most developed district and on the other hand the districts having less than average C_i score (0.385) are less developed districts (Table 2).

Table 2: C_i scores based on TOPSIS method and ranking of the districts in North Bengal (2011-12)

Districts	Development Scores						Average C_i	Overall ranks
	Economic		Infrastructural		Socio-demographic			
	C_i	Ranks	C_i	Ranks	C_i	Ranks		
Uttar Dinajpur	0.229	5	0.116	6	0.353	4	0.233	5
Dakshin Dinajpur	0.204	6	0.149	5	0.272	6	0.208	6
Malda	0.250	4	0.307	3	0.433	3	0.330	3
Jalpaiguri	0.802	1	0.768	1	0.540	2	0.703	1
Darjeeling	0.467	2	0.585	2	0.627	1	0.560	2
Cooch Behar	0.291	3	0.231	4	0.305	5	0.276	4

Source: Calculated by the author

7.2 Correlation among the selected development indicators:

It is quite essential to evaluate the correlation between the development indicators and sectors. The development in different sectors should flourish together which will enhance the level of living standards of the people in the region. The correlation coefficient between the economic and infrastructural indicator of development is highly positive and the correlation is statistically significant at the 0.05 level (two tailed). Whereas the correlation coefficient of economic and socio-demographic indicator of development is also highly positive but for this specific study the correlation is not statistically significant at any level (Table 3).

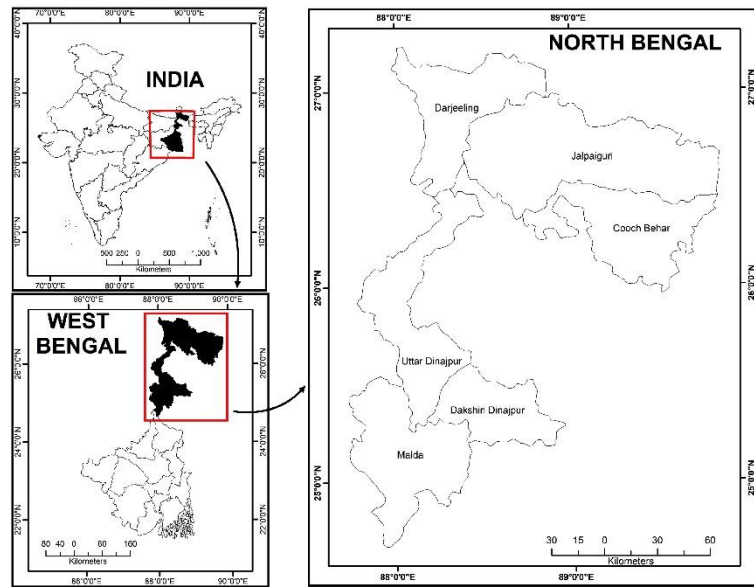
Table 3: Spearman's rank correlation among the selected development indicators

Spearman's rho		ED*	ID**	SD***
ED*	Correlation Coefficient	1.000	.886*	.771
	Sig. (2-tailed)	.	.019	.072
ID**	Correlation Coefficient		1.000	.771
	Sig. (2-tailed)		.	.072
SD***	Correlation Coefficient			1.000
	Sig. (2-tailed)			.

Source: Calculated by the author

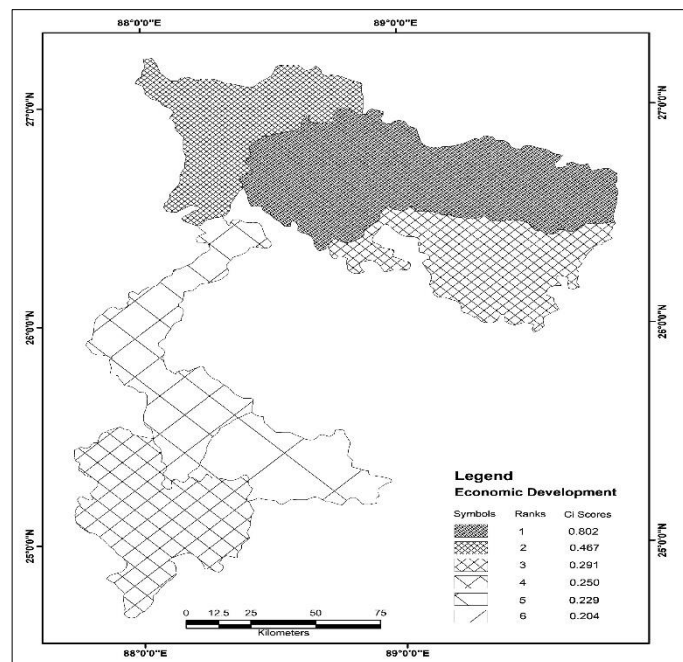
*Economic development, **Infrastructural development, ***Socio-demographic development and *Correlation is significant at the 0.05 level (2-tailed).

Fig. 1: Location map of the study area



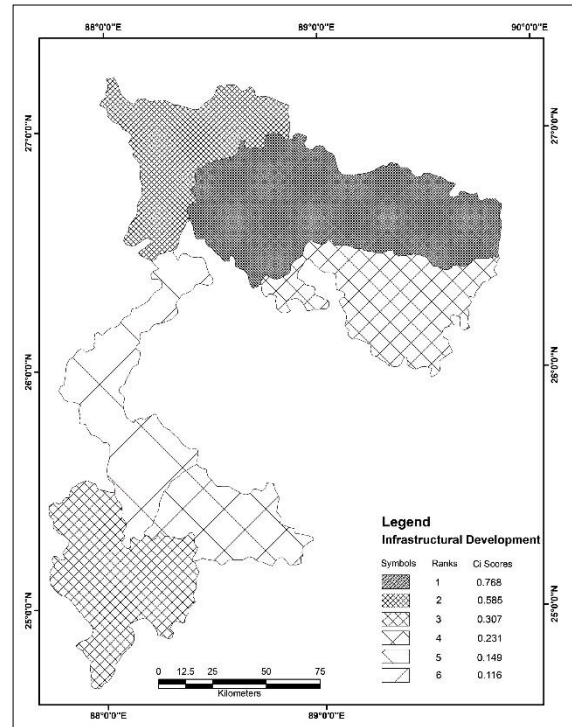
(Source: Prepared by the author)

Fig. 2: District – wise disparities of economic development in North Bengal (2011).



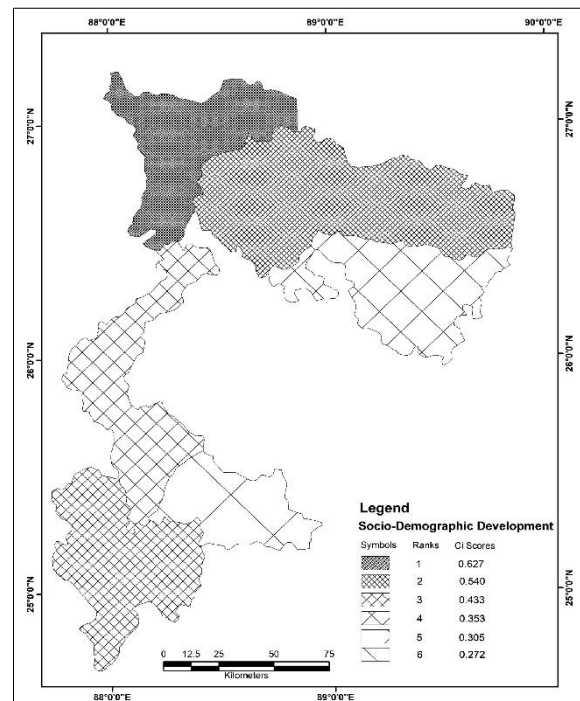
(Source: Prepared by the author)

Fig. 3: District – wise disparities of infrastructural development in North Bengal (2011).



(Source: Prepared by the author)

Fig. 4: District – wise disparities of socio-demographic development in North Bengal (2011).



(Source: Prepared by the author)

8.0 Conclusion:

In the developing economies like India, the idea of development is somehow misleading as most of the planning procedure are solely focused on the agricultural and economic growth. Rather the strategies and planning of development should be strategized by considering economic, infrastructural and social progress of the people. Consideration of both the Entropy and TOPSIS method would be significant for measuring the regional disparities of development of any region. For the present study, district Jalpaiguri topped in the list because of its high performance in the

economic and infrastructure sector. Whereas the Darjeeling district is most advanced in terms of its socio-demographic profile.

End Notes:

¹Five-Year Plans are centralized and integrated national economic programmes. In the late 1920s, Joseph Stalin implemented the first FYP in the Soviet Union. 1st Five-Year Plan (1951-56) was launched in India under the leadership of then Prime Minister Jawaharlal Nehru in the year of 1951 and continued up to 12th Five-Year Plan (2012-17).

See: http://mospi.nic.in/sites/default/files/Statistical_year_book_india_chapters/Five%20Year%20Plan%20writeup_0.pdf

²A Keynesian model of economic growth to explain the growth rate in terms of total saving and capital. According to the theory, growth in total output (g) will be equal to the savings ratio (s) divided by the capital-output ratio (k); i.e., $g = s/k$. See: <https://www.romeconomics.com/harrod-domar-model-explained/>

³A Neo-Marxian model of economic development created by Indian statistician P. C. Mahalanobis.

See: <http://library.isical.ac.in:8080/jspui/bitstream/10263/2015/1/258.pdf>

⁴A multi-criteria decision analysis method, originally developed by Ching-Lai Hwang and Yoon in 1981 with further improvements by Yoon in 1987, and Hwang, Lai and Liu in 1993.

⁵Also known as information entropy. Shannon's entropy quantifies the amount of information in a variable, thus providing the foundation for a theory around the notion of information.

See: <https://arxiv.org/ftp/arxiv/papers/1405/1405.2061.pdf>

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