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Delineation of influence of functional region of Siliguri Metropolitan Area (SMA) using gravity model (Breaking point analysis): Case study of North Bengal in India

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Abstract
Service centres does not existed independently at all and all internal exchanges of goods and services of human societies are depend on inter linkages with other geographical units which developed through network system of connected nodes. There are some important linkages inside network system of any functional region of different sectors which are associated to each other, but the intensity of inter linkages relationship is not same. However, Siliguri Metropolitan Area is considered as a big network of functional regional of North Bengal, where more than 50 small and big national and international urban centres are surrounded and have interrelations with it. The study focused on functional boundary of Siliguri Metropolitan Area (SMA) with its adjacent cities which have been ascertained on Gravity model concept (Breaking point analysis) by considering relevant units of variables. The discussions and results suggests that the gravitation power of Siliguri Metropolitan Area (SMA) is comparatively higher around North Bengal, North-Eastern state, Sikkim and Eastern part of Bihar than other functional region.

Keywords: Functional Region, Gravity model, Siliguri Metropolitan Area, North Bengal, Sikkim

1. Introductions
It was the industrial revolution which dramatically upset the distribution of population between rural and urban areas. A German writer 'Justus Moeser' observed that specialized division of labour forced the workers to live in large cities (Blumenfeld, 1969) [4]. Subsequently, innovation and establishment of new industries as well as manufacturing plants in and around urban area stimulated cities to be transmuted into production and distribution center of processed goods and commodities for rural as well as urban region. In developing countries like India and China the urbanization progress is gradually increasing through very faster growing rate. Consequently, population increases due to its human welfare opportunities as well as emigration from rural to urban which gradually lead to increase the number of towns and cities. The towns, cities, satellite cities or 'Sputnik' or 'new cities' were formed in distances of 35 km to 70 km far from metropolises (capitals) which had a key role in development of city networks (Rahim, 2011) [20]. The changing mobility triggered off a powerful centrifugal wave of migration from the city to the suburbs resulting in decentralization. The interaction of the centripetal and centrifugal forces of population and commodity movements produced and accumulated new form of huge number of settlements is called 'Metropolis'. This Metropolis further considered as functional region which has also been referred nodal or polarized region consisting of heterogeneous units with cities, towns and villages that are functionally interrelated (Chaudhuri, 2001) [6]. However, Klapka, Halas and Tonev (2013) [14] and Klapka and Halas (2016) [15] believe that the term "functional region" was initiated into geography, and in this manner other spatial sciences also introduced (Philbrick, 1957) [19], (Berry et al. 1958) [3], (Drobne, 2017) [7].
The functional region brings into focus the importance of different types of linkages or interconnections between places and areas for the functioning of those spatial units as human habitats. It can be called the functional spatial configurations wherein the interdependence between diverse formal areas or localities is ascertained for one or more selected phenomena of spatial flows and such interdependencies are usually so patterned as to form functionally

organized units in the spatial configuration, with varying centripetal intensities of spatial flows in each and such unit called functional regions (Chand, et al. 1983) [5]. Major centers of different functional regions in the spatial configuration can again be linked axially on the basis of macro-economic functional ties. Thereby concentration of capital, employment opportunities, economical activities, overall civic amenities inside the metropolises are caused concentration a large number of population from adjacent and fringe regions as well as hinterland to enter them for occupational and livelihood purpose. In France, Finland, Germany, Italy and United Kingdom, functional region serves up as a basis for recognize areas which qualify for assistance (Drobne, 2017) [7]. It recognizes as a continuous area in which aggregated supply and demand for various social and economic goods meet (Van D. L. et al. 2001; Farmer et al. 2011) [9, 25]. In addition to that functional region has been identified by a high frequency of intra-regional economic interaction, such as intra-regional trade in goods and services, labour commuting, an area of agglomeration of activities, transport infrastructure facilitating significant mobility of products, people and information (Karlsson et al. 2006) [12]. However, in a sequence manner increase of inhabitants and the number of new growing nearby towns and cities encircled the metropolises or any functional region through their exchange of services in inter linkage network frame. Moreover the group of connected areas, many social and economic interactions, flows of goods and services, interdependence of commuting flows, traffic flows, communication flows, financial flows etc, occurs (Vanhove et al. 1987) [26]. A versatile and extensive connection is being developed between metropolises and neighboring urban centers and the contiguous small and medium cities have various functional dependencies on metropolis. 'Metropolis' acts as a magnet and gradually becomes as complex network of functional region which is associated by horizontal cohesion in space in a form of spatial flows or interactions of several kinds such as goods, persons, material, information, energy etc among different parts of region (Ullman, 1980) [24]. Functional territories around a strong economic centre that attracts inhabitants of nearby and remotely big catchment areas is consider as central place of that functional region and its size depends on the scope and content of goods and services that offering to its inhabitants (Berry et al. 1958) [3]. Functional region is mostly behaved as areas of local and regional labour markets and as an analytic tool for creating planning, administrative and statistical region (Drobne, 2017) [7]. However, it is the most favorable unit for economic analysis and for interaction and discussion of social, political, and economic processes (Tomaney et al. 2000) [23]. Therefore 'metropolis' is encompassed by various small towns and cities which reflected on different levels of acceptance which are illuminated by shops, industries and organizations (Johnson, 1984, Rahim, 2011) [11, 20]. In metropolitan cities each function has benefited from the conditions which brought about the other functions and has found reasons for developing there itself where it is quoted that larger the city, the greater is the number and diversity of opportunity (Verma, 2006) [27]. There the powers of attraction make them bigger and bigger; and consequently enormity of their size increases their power of attraction. That has been also is happening in Siliguri which has developed tremendously during 1990 to 2020 due to its power of attraction through good number of diversity of modern civic amenities as well as employment opportunities.

At present it is considered as Siliguri Metropolitan Area (SMA) as well as functional region of North Bengal. According to geographers view SMA is a perfect functional region which has certain functional coherence, an interdependence of areas on the basis of certain functions, services (Chowdhury, 2001). With it almost 10 lac population, it comes into the importance of various kinds of interconnections with other towns and cities of North Bengal i.e Darjeeling, Jalpaiguri, Kochbihar, Balurghat and Malda, as well as other national and international urban centers (North Bihar, Sikkim of India, Bangladesh, Nepal and Bhutan) for servicing of education, goods flow, flow of perishable & non-perishable commodities, transport services, medical services, circulation of newspaper etc.

2. Objective

a. To identify the gravitational force limit of Siliguri Metropolitan Area (S.M.A) over different contiguous towns and cities of North Bengal.

3. Study area

The study area covers the region of North Bengal, comprising eight districts-Darjeeling, Kalimpong, Jalpaiguri, Alipurduar, Koch Bihar, Uttar Dinajpur, Dakshin Dinajpur, and Malda. Geographically the area is extended from $24^0 4' 2''$ N to $27^0 13'$ N latitude and from $87^0 59'$ E to $89^0 53'$ E longitude. The total area of the region is about 21859 sq. km with total population of about 17,211,010 as per the 2011 census comprising more than 20 big and small urban centers and where Siliguri (SMA) is the second largest city of West Bengal after Kolkata. Geographically the city is located at the latitude of $26^0 72' N$ and the longitude of $88^0 41' E$. Since, SMA is sited at the foot hill plains of the Himalaya Mountains, so it is easily connects the hill stations such as Gangtok of Sikkim, Darjeeling, Kalimpong, Kurseong and Mirik and North-East states (Assam, Meghalaya, Nagaland, Manipur, Mizoram) to the rest of India. It is the trade and commerce centre and now considered as the gate way to the North East India. It acts as a transit point for air, rail and road, connecting the neighboring countries like Nepal (lies in the west of the city 10 km towards Panitanki from Bagdogra), Bhutan (on the North East about 180 km) and Bangladesh (in the south of Fulbari about half km). The geo-strategic location of this city makes it a base for essential goods supplies to the above regions. Now, Siliguri is fastest growing city in West Bengal and most of services such as business services, higher education & research facilities, modern medical facilities, military service, Govt. and Non-Govt. regional head office, modern industries, good transport & communication, world class recreational services centers, tourism are concentrated in Siliguri Metropolitan Area (SMA).

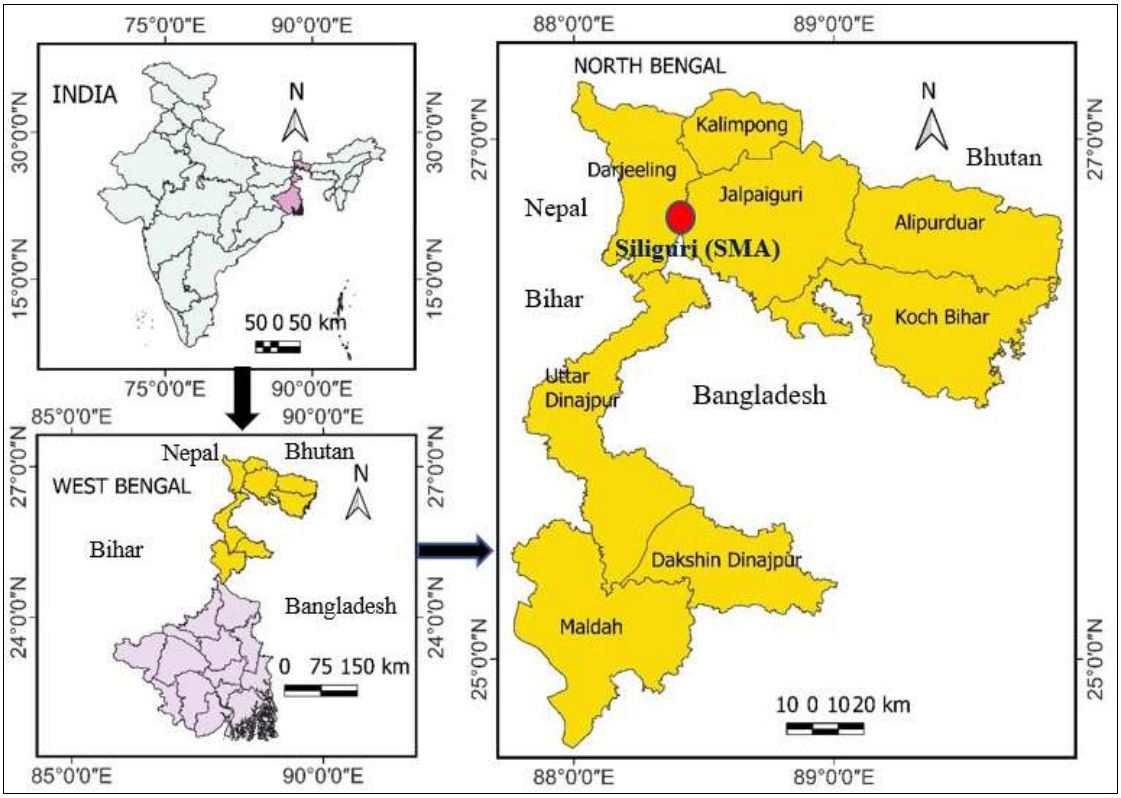

Fig 1: Site map of North Bengal, prepared by author

4. Data source

The above mentioned hypothesis is analyzed based on secondary data & information through the application of Gravity Model concept (breaking point analysis). The relevant related data and information have been gathered from India Census reports, District wise Census Handbooks records (Census of India, 2011, West Bengal-Series 20-Part XII B-District Census Handbook), source of internet and online journals for population and distance related data of towns and cities of North Bengal. Some necessary calculations have also been computed by the author based on 'Breaking point analysis' formula of W. Reilly's and P.D Converse.

5. Methods for determination of Gravitational Influence Zone:

Some important methodologies for delineation of functional regions may be analyzed on three main approaches: (i). the local labour market on a way commuter flows, (ii). Commuting zone approach on counted reciprocal dependence between cities and (iii). Accessibility way (Karlsson & Olsson, 2006) [12]. But one of the significant methods deployed for determination of influence of functional region is the method of determination of 'Gravitational force' through Breaking point analysis. Here the W. J. Reilly's breaking point analysis has been applied to delineate Gravitational force and linkages of Siliguri Metropolitan Area (S.M.A) throughout its contiguous towns and cities. Similarly, a modified Breaking Point formula (Reilly's) of P.D Converse (1949) has also been determined to delineate Gravitational force and influence region of S.M.A and its adjacent towns and cities which is subsequently popular as 'New Law of Retail Gravitation' of the breaking-point. Subsequently, two different influence zone map of S.M.A has been prepared based on these concepts accordingly.

6. Results and Discussions

6.1 The Gravity model analysis

Academicians from different disciplines have found gravitational models useful in predicting migration patterns, commodity flows and urban travel (Mayo, et al. 1988). In social science 'Gravitational analysis' describes with forces of attraction by providing service between the service centers. This concept of social physics developed by G.K Zipf, W. Reilly, Stouffer and others where analysis is developed on the probability of human interaction through services flow generating from concept of 'Newtonian physics'. The logical basis of Gravity model is that two cities or place interact with each other in proportion to their product of size or masses and inversely proportional to the friction of distances which is defined as follows.

$$Tij = k\left[\frac{PiPj}{d^2ij}\right]$$

Where,
Tij represents the gravitational force between the centers 'i' and 'j'
Pi & Pj are the masses of the centers 'i' and 'j', and
dij is the distance between them and
k is a constant.

Here the mass has been represented by different variables i.e population, workers, income, expenditure; whole sale and retail turnover between two centers where distance has been represented in surface length, in terms of times and prices.

6.2 Application of W.J. Reilly's Law

'Gravity model' has developed on the basis of 'Newton's Gravitational law' for determining the service limit of urban centers as well as urban region relations (Rahim, 2011) [20].

This concept has been initiated by 'W. J. Reilly' and according to him 'urban centre' is considered similar to 'Gravitational field' of attraction for its variable services to the hinterlands (Azimi, 2002) [2]. Reilly's classical application was to apply this concept in the study of 'retail trade' between two centres. As a result, he created 'Law of Retail Gravitation' which is a particular form of the general Gravitational law and states that "the force 'F' of attraction, or scale of spending in a village with purchasing power 'm' is proportional to the number of retailers 'N' in a town 'V', and inversely proportional to a certain power of the distance 'd' separating the town 'V' from the village, i.e. 'F= k (N/d$^{\alpha}$) m' (Chand, et al. 1983) [5]. The boundary of attraction between two towns 1 and 2 is therefore, describe by the formula:

$$\frac{N1}{N2} = \left[\frac{d1}{d2}\right]\alpha$$

Subsequently, the concept has been simplified and explained that the dimension of people to the city has its inverse relation with distance although it has a direct relation with its own population (mass). Consumers are always willing to travel long distance from the smaller city to higher attraction of big retail business city. So, in order to prove the above hypothesis, it is disclosed a point conversant as 'breaking point' (Last limit) between two cities based on two variables, i.e. distance and mass (Population). If, there is same population size and area (mass) in between two cities, so due to its same Gravitational attraction of force, breaking point would be in the middle position between the cities. But, if the cities have different size of population and area (mass), then big city would have more power of service (Gravitational attraction) to attract the customers than the small city. In that way, the breaking point of big city would get away towards small city and would approach in proportion to the dimension of mass of the big city. So, it explains that the Gravitation force of attraction of services for consumers of any big city will be always higher than smaller cities although little more chance of power of smaller cities has through attracting customers beyond its nearby developed cities. So, it is emphasis by Ingene and Lusch (1981) that traditional retail norm separates spatial locations from most of the other functional areas of marketing (Friske, et al. 2013) [10]

To get the distance of breaking point between two cities, 'W.J. Reilly' has expressed the following formula:

Distance (km/mile) of Breaking point to 'A' city

$$D_{BP} = \frac{DAB}{1+\sqrt{\frac{PB}{PA}}}$$

Where

D_{BP} denotes distance of Breaking point of city 'A' (larger city) to 'B' city (smaller city)', D_{AB} means Distance between city 'A' & 'B',

P_A indicates Population size of the A city & P_B indicates Population size of B city.

This formula applies to search surrounding breaking point of Siliguri Metropolitan Area (SMA). In eastern, southern and western regions of Siliguri Metropolitan Area, the breaking point is favored toward Siliguri Metropolitan Area (S.M.A) because of good transport & communication network (such as National Highway 33, Asian Highway 2, Bagdogra Airport, Railway lines etc) and also providing various good access of vehicle services for passengers & goods which leads Siliguri city more influential through its gravitational power. But Northern, North-eastern, North - western regions from SMA, namely the Siliguri-Darjeeling road (N.H 55), Siliguri-Malbazar-Alipurduar (NH31C) and Siliguri-Sikkim (NH31A) is less influential by gravitational power of SMA because of mountain and ruggedness surface and absence of good communication services i.e broad gauge train service, airway service, big bus services etc. The details calculated breaking points distances in respect of SMA are shown in the table 1 worksheet.

Table 1: Worksheet table for breaking point analysis based on 'W.J. Reilly' law

Name of Cities	Population (2011 census)	Distance from Siliguri Metropolitan Area (by road) (D_{AB})	Distance on map in cm (Scale 1 cm to 25 km)	Breaking Point (D_{BP})	Distance on map in cm (Scale 1 cm to 25 km)	Remarks
Siliguri	513264	-	-	-	-	$D_{BP} = \frac{DAB}{1+\sqrt{\frac{PB}{PA}}}$
Maldah	205521	250.5 km	10.02	153.68 km	6.14	
Raiganj	183612	176.7 km	7.07	110.71 km	4.42	
Balurghat	151416	280.6 km	11.22	182.20 km	7.28	
Darjeeling	118805	63 km	2.52	42.56 km	1.70	
Jalpaiguri	107341	48.3 km	1.92	33.31 km	1.33	
Kochbihar	77935	163 km	6.52	117.27 km	4.69	
Alipurduar	65232	174.8 km	6.99	128.53 km	5.14	
Gangarampur	56217	243.6 km	9.74	183.16 km	7.32	
Islampur	54340	70.9 km	2.84	53.31 km	2.13	
Kaliaganj	53530	200.6 km	8.02	151.96 km	6.07	
Kalimpong	49403	66.8 km	2.67	50.99 km	2.03	
Dhupguri	44719	80.4 km	3.22	62.33 km	2.49	
Kurseong	42446	33.00 km	1.32	25.58 km	1.02	
Dalkhola	36930	132.7 km	5.31	104.48 km	4.17	
Dinhata	36124	170.8 km	6.83	134.48 km	5.37	
Mal	25218	55.7 km	2.22	45.66 km	1.82	
Mathabhanga	23890	116.3 km	4.65	95.33 km	3.81	
Tufanganj	20998	167.8 km	6.71	139.83 km	5.59	

Haldibari	14404	71.1 km	2.84	60.77 km	2.43	
Gangtok (Sikkim)	100286	112.1 km	4.48	77.84 km	3.11	
Thakurganj (Bihar)	18348	54.5 km	2.18	45.79 km	1.83	
Kisanganj (Bihar)	105782	102.8 km	4.11	70.89 km	2.83	
Kakrabhita (Nepal)	21366	28.2 km	1.12	23.50 km	0.94	
Phuentsholing (Bhutan)	42254	153.8 km	6.15	119.22 km	4.76	

Source: Prepared by Author, based on 'W.J. Reilly's law.

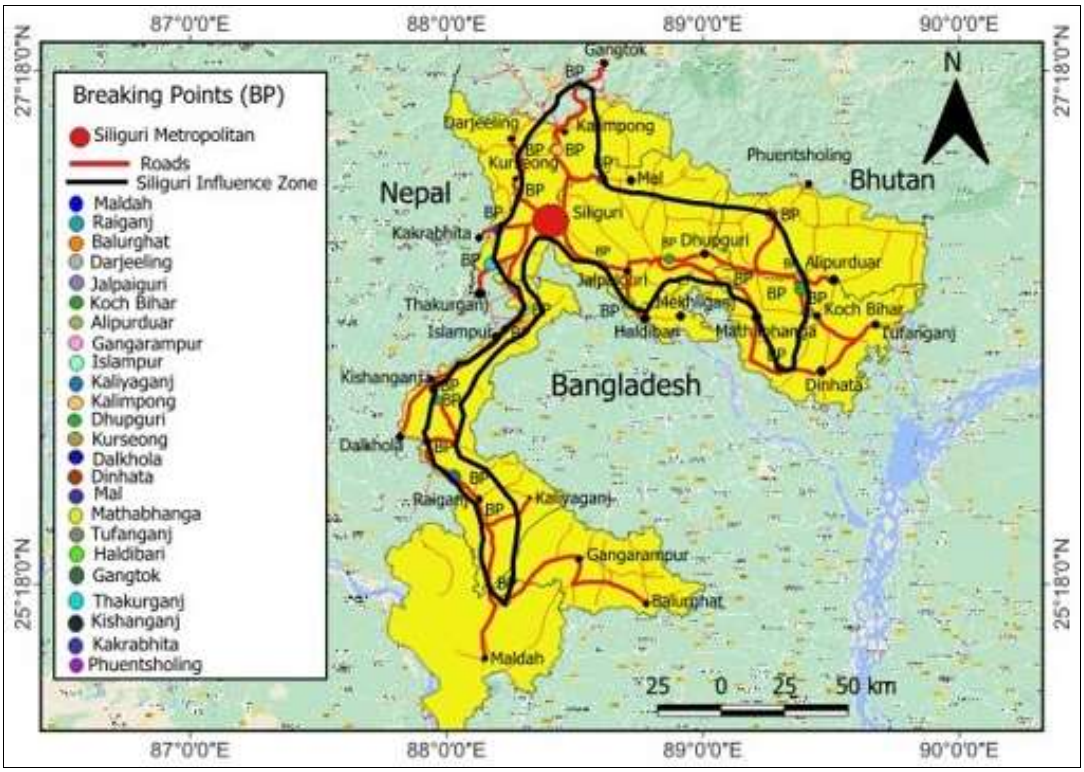

Fig 2: Functional region of S.M.A, based on W.J. Reilly's law, prepared by author

6.3 Application of P.D Converse Law

Similarly, in order to measure the distance of breaking point between two cities, P.D Converse has tried to express a new formula. In 1949, P.D Converse modified 'Reilly's Gravitation law' and prepared 'New Law of Retail Gravitation' of the breaking-point and expanded its new formula as follows.

Breaking points, distance from B city = $\frac{Distance\ between\ city\ 'A'\ and\ 'B'}{1+\sqrt{\frac{Population\ of\ city\ A}{Population\ of\ city\ B}}}$

Where, A = larger city, B = smaller city
Or, it can be explained by

$$Db = \frac{D}{1+\sqrt{\frac{P_A}{P_B}}}$$

Where, Db = Distance from the small settlement in km/ mile
D = Distance between the two settlements (A & B)
P_A = Population size of the large settlement (city A)
P_B = Population size of the small settlement (city B)

'P.D Converse' identifies his new concept in the following manner "a trading center and a town in or neighboring its trade field split the trade of the town nearly in direct ratio to the population of the two towns and inversely as the squares of the distance factors, using as the distance factor of the home town". The distances of breaking points of influence zone of SMA functional region have been prepared through 'Converse' formula in the table 2 worksheet.

Executing above these two formulas, the breaking point and gravitational force dominance of SMA were identified and all calculated distances were marked according to convenience scale (1 cm represent 25 km) onto the map with different index of breaking points for better understanding and description of influence zone (Fig.2 & Fig. 3). Firstly, the distances between all contiguous small cities and SMA were calculated where population of 2011 census was considered as base population of every adjacent cities and SMA. Then, both the formulas were applied in the Excel software accordingly to compute the distances. Hence, different range distances were came out according to the respective distance and size of population of adjoining towns & cities of SMA which later were applied, measured and marked on 'Google earth' map according to the corresponding scale through QGIS software, so that boundary of breaking points of SMA was furnished and thereafter, two different map were made that how the breaking point of SMA functional region varies of influence zone in the variation of distance and population size for these different formulas.

Table 2: Worksheet table for breaking point analysis based on 'P.D Converse' law

Name of Cities	Population (2011census)	Distance from Siliguri Metropolitan Area (by road) (D)	Distance in cm (Scale 1 cm to 25 km)	Breaking Point (D_b)	Distance in cm (Scale 1 cm to 25 km)	Remarks
Siliguri	513264	-	-	-	-	$D_b = \frac{D}{1+\sqrt{\frac{Pa}{Pb}}}$
Maldah	205521	250.5 km	10.02	97.09 km	3.88	
Raiganj	183612	176.7 km	7.07	66.18 km	2.64	
Balurghat	151416	280.6 km	11.22	98.80 km	3.95	
Darjeeling	118805	63 km	2.52	20.52 km	0.82	
Jalpaiguri	107341	48.3 km	1.92	15.14 km	0.60	
Kochbihar	77935	163 km	6.52	45.66 km	1.82	
Alipurduar	65232	174.8 km	6.99	46.00 km	1.84	
Gangarampur	56217	243.6 km	9.74	60.59 km	2.42	
Islampur	54340	70.9 km	2.84	17.42 km	0.69	
Kaliaganj	53530	200.6 km	8.02	49.04 km	1.96	
Kalimpong	49403	66.80 km	2.67	15.83 km	0.63	
Dhupguri	44719	80.40 km	3.22	18.31 km	0.73	
Kurseong	42446	33.00 km	1.32	7.37 km	0.29	
Dalkhola	36930	132.7 km	5.31	28.05 km	1.12	
Dinhata	36124	170.8 km	6.83	35.81 km	1.43	
Mal	25218	55.70 km	2.22	10.11 km	0.40	
Mathabhanga	23890	116.3 km	4.65	20.62 km	0.82	
Tufanganj	20998	167.8 km	6.71	28.25 km	1.13	
Haldibari	14404	71.1 km	2.84	10.22 km	0.40	
Gangtok (Sikkim)	100286	112.1 km	4.48	34.39 km	1.37	
Thakurganj (Bihar)	18348	54.5 km	2.18	8.66 km	0.34	
Kisanganj (Bihar)	105782	102.8 km	4.11	32.13 km	1.28	
Kakrabhita (Nepal)	21366	28.2 km	1.12	4.77 km	0.19	
Phuentsholing (Bhutan)	42254	153.8 km	6.15	34.25 km	1.37	

Source: Prepared by Author, based on 'P.D Converse' law

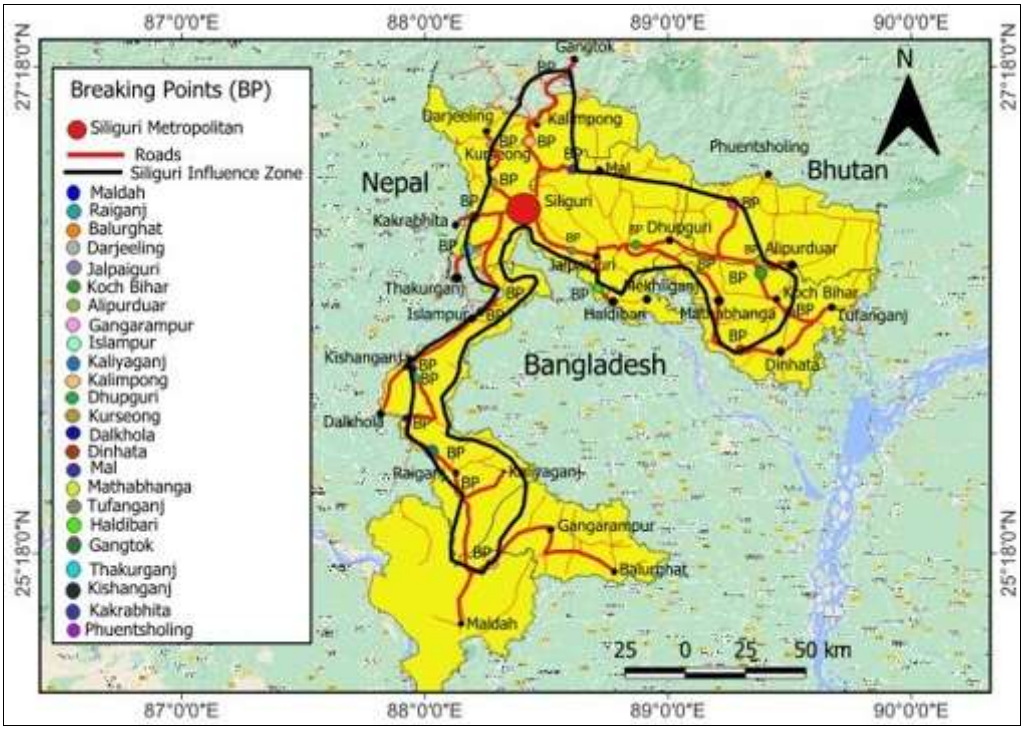

Fig 3: Functional region of SMA, based on P.D Converses law, prepared by author

From the above discussion it has been explained that both the concepts were applied to delineate the last limit of functional region through flow of trade influence of cities and how the influence area should be distributed among different trading centers with the main trading centre. Reilly's & Converse's law establish on the following two concepts i. always two stand against cities are equally accessible from the major road, ii. Population is a good exponent of the dissimilation in the goods and services obtainable in different cities (Anderson, el al. 2010) [1]. However in this discussion, two different functional regions are demarcated for SMA where it has been observed that the extension of functional region and influence based on 'Reilly's Law' is comparatively less than 'Converse

Breaking-Point' law. Though, both concepts emphasizes that larger cities have larger influence zone and smaller influence zone for smaller centers which may have necessarily acceptable for further data analysis. But, in present decades decentralization of urban trading centers, establishment of new retail business concepts and mobility enhancement in rural areas through better connectivity and accessibility network may reduce gravitational forces of large cities and trade area dominance on small size urban or service centers. However, in this 21 century, E-commerce changes the nature of business concepts, consumer shopping patterns etc. (Anderson, et al. 2010) [1].

7. Conclusion

The study conducted to delineate influence zone of functional region of SMA through the 'Reilly's Law of Retail Gravitation' and the 'P.D Converse Breaking-Point' analysis and its impact on adjoining cities. The influence zone of SMA is quite more in southern, eastern and south-western side than those in north and north-eastern side due to its well connectivity and accessibility with urban centers. The SMA in southern, eastern and south-western side has extensive connections with neighboring cities via Asian highway, National highways and railways which helps to enhance influence of gravity of SMA, while the northern and north-western side are not only cast-off of railway, but also are developed its transport & communication on landslide hazardous area, where roads are narrow turns even its sinuosity and slanting in nature of surface. So, the connectivity of SMA with northern and north-western side is not uniform to that of southern, eastern and south-western sides. On the basis of breaking point analysis, it has been decided that maximum gravitational attraction as well as influence zone of SMA functional region is being extended towards eastern, southern and south-western direction comparatively than northern, north-western side although that foothill and mountainous regions depends on SMA for livelihood needs. Therefore, connectivity network development should be started by applying the future framework of smart project as well as on the basis of further analyses and research work on that region.

8. Data Availability Statement

All the data has been collected by the author from Census of India reports, Books and different online articles of journals. It also confirms that the data presented in this study are available on kind request from the corresponding authors.

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