

ENTROPY ANALYSIS OF CHANGING URBAN PATTERN IN NORTH-EASTERN INDIA : 1901-1971

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ABSTRACT : An effort has been made to apply entropy method, developed from information theory and introduced by Medvedkov in settlement geography, to analyse the nature and spatial pattern of urban places in North-Eastern India. This method distributed urban places at a specific point in time. The greater the randomness the greater is the entropy leading to greater disorder and a more disorganised system. The hypothesis tested in this study is that uniformity of urban places tends to increase over time. The entropy parameters obtained for the eight points in time from 1901 to 1971 indicate a trend from randomness toward uniformity. The percentage of uniform component increases from 60 in 1901 to 84 in 1971. Thus, the distribution of urban places is tending toward a more uniform pattern over time and the hypothesis is confirmed.

The investigation into distributional aspects and spatial interrelationship of urban places has been receiving increasing attention of location theorists. The central theme in location theory is expressed in a question posed by Christaller (1933); "Are there laws which determine the number, size and distribution of towns?" Given an isotropic surface with uniform terrain and resource localization, uniform distribution of population and purchasing power, and equal transport facility in all directions, urban places would be uniformly spaced in a hexagonal pattern. Since the above isotropic conditions are seldom met we cannot expect to find perfect uniformity in urban place patterns. However, we can expect a tendency toward uniformity or organisation in the system. Recognising the possibility of such changes in urban place patterns, researchers have called for studies into the development of urban place systems. Such studies lead to a deeper understanding of the evolution of urban place system and "ultimately to the formulation of a much

needed dynamic central place theory" (Marshall, 1969).

Studies encompassing evolution of spatial patterns fall under two categories; first, studies concerned with the organisational features of urban places and second, the disorganisational features. System organisation is taken to indicate systems in which uniformity tends to increase through time. Skinner (1964) has treated the market as the most important central place institution in rural China and has suggested that the pattern of market location before 1949 revealed uniformity. The notion of organisation is also implied in Semple and Golledge's (1970) study of the distribution of settlements in the Canadian Prairies. They attempted to measure whether the urban places tended towards a more uniform pattern between 1911 and 1961. The significance of the analysis lies in the tendency of the distribution to move towards an ideal pattern. With this increasing uniformity, the system as a whole appears to be more efficiently organised and

more predictable in later periods than in earlier periods.

The development of urban clustering leading to disorganisation in urban system was also seen in many parts of the world. Morrill (1962) indicated a development of disorganization in the urban system of Sweden which helped to account for observed symmetry in central place patterns and for the inconsistency in the existing theory. This contention is also implicit in the Welsh city system, where industrial sub-system has acted as a constraint in the organisational goal of the system (Carter, 1969) Dziewoniski 1972, 1973 indicates that one of the important trends of the Polish Urban system is a constantly increasing clustering to disorganisation. The development of disorganization in urban system was not unique to Europe; studies concerning Africa, Asia and Latin America have suggested a similar process. In the last hundred years Nigerian urban system has been leading towards spatial disorganization under the improved transport technology and economic characteristics (Mabogunje, 1968). Similarly, urban settlements in Malayasia did not move to uniformity from 1911 to 1957, instead the pattern was associated with increasing sectoral concentration (Wang, 1970). Recently, Haynes and Enders (1975) found that the settlement pattern has not exhibited a trend towards uniformity in central Argentina between 1914 and 1960.

The above studies, in large, demonstrate a tendency towards disorganization inconsistent with Christaller's hypothesis. In other words, the relative location of urban places was not equidistant from each other. Yet there remains a common belief that urban systems move toward an organized state in which the distribution of urban places is relatively uniform. In this study the hypothesis to be confirmed is that uniformity tends to increase over time.

The Study Area.

The area selected for empirical analysis includes five states (Assam, Meghalaya,

Tripura, Manipur and Nagaland) and two union territories (Mizoram and Arunachal Pradesh) in Northeastern India. It has a total geographical area of a little over 2.5 lakh square kms. inhabited by about 20 million persons. Thus the region accounts for 8% of the country's total geographical area and only 3.5% of the total population. The region is partly marked by homogeneous fertile plain and partly by diverse complex topography. The fertile plain of Assam falling in the Brahmaputra valley is an extension of the Indo-Gangetic trough; while the region is also covered by ranges of Extra-Peninsular mountains along Assam-Burma border and with an outlier of the Peninsula in the Shillong plateau. The region has a humid monsoonal climate with extensive forest cover on the uplands, while the valley parts are composed of fertile alluvial soils. Cultural features and population density also vary greatly. The mountainous and forested tracks are inhabited by a large number of tribes but the plains have a mixed composition. North-Eastern India is an industrially backward area. Road and rail systems are relatively incomplete and unevenly distributed. About 9.4 per cent of the total population lives in 101 urban centres. Gauhati (146026) is the largest city and commercial capital of the region. The urban place system is centred at Gauhati.

Data Sources

The data used for the purpose of hypothesis testing is basically locational and includes the number of urban places for the period 1901, 1911, 1921, 1931, 1941, 1951, 1961 and 1971. However, Census identification of urban places has been the source of considerable confusion because no definite criteria were fixed by the authorities. The matter was entirely left with the Census Superintendent to apply his discretion in reporting the number of urban places. For example, in 1901 and 1911 administrative function was a primary consideration while size of population was

a secondary one. In 1921, 1931 and 1941 apart from administrative function, the Census Superintendents were given some discretionary powers. These were concerned with the character of the population, the relative density of the dwellings, the importance of the place as a centre of trade and its historic associations. In 1951 emphasis was given to infrastructural urban characteristics but there was no specified list of urban characteristics with the Census Superintendents. Therefore, an element of arbitrariness prevailed in the definition of urban places guided by the direction of the Census authorities. A standard and rigorous definition of urban place was ultimately laid down in the Census of 1961 and 1971 when it was specified that an urban place must have 5000 inhabitants, a density of not less than 1000 per square mile, over 75 per cent of its working population must be engaged in work other than agriculture and it must possess a few pronounced urban characteristics and amenities. Thus it seems that there has been some difference from one Census to another but such difference is minimal particularly between 1961 and 1971 time period. Therefore, the Census classification of urban places is accepted because of its availability on a consistent basis in the Census records. With this basic information, dot maps showing the location of urban places were prepared and entropy method applied to measure the changing urban pattern.

Entropy Method

Shannon (1948) developed the concept of entropy in his classic paper and proposed a discipline of communication theory which focussed on the study of information theory and entropy. This theory makes use of a basic mathematical notion related to thermodynamics. The second law of thermodynamics states that thermodynamic degradation is unalterable over time, e. g., a burnt log cannot be unburnt and lukewarm water cannot be separated distinctly into hot water and cold water. Originally, the hot water and cold water were separate which

showed order and discrimination but after mixing, this element of order was lost. These changes constitute a passing of the system from ordered arrangement into more chaotic or random distribution. The disorder disorganization or randomness of organization of a system is known as its entropy (Miller, 1969). So, entropy is a measure of disorder and negentropy or information is a measure of order of a system. Since the system changes to a less organised state from a highly organized state and to more probable states from less probable states, entropy is maximized and the magnitude of entropy is described by a set of probabilities.

This theory has been extended and applied to a variety of practical problems in different fields including physical, biological and social sciences (Fast, 1970; Wyatt, 1967; Morowitz, 1970; Kultback, 1959; Quastler, 1953 and 1955; Buckley, 1968; Theil, 1967 and 1972; Chapman, 1977; Medvedkov, 1967 and Thakur, 1972 and 1979). Contemporary science has accepted it as one of the foundation stones for empirical research. Thus increasingly, there is a growing interest among the social scientists about the understanding, significance and the application of the concept of entropy.

As an alternative to conventional nearest neighbour technique Medvedkov (1966) has related this notion to the problem of settlement pattern analysis. He has suggested that any settlement pattern has a uniform component and a random component. These components can be measured by the method used for detecting signals in the presence of noise in information theory. Signal is analogous to the uniform component and noise to the random component. Entropy has been used as a measure of noise in information theory and as a measure of disorder in spatial distributions. Medvedkov suggests that a settlement pattern is a composite of two super-imposed sub-patterns, one random and the other uniform. Each of these sub-patterns will have its own mean density of points, and the two

densities added together will be equal to the mean density of the composite pattern. Likewise each sub-pattern has its own entropy value, and these summed will be equal to the entropy value of the composite pattern. However, the entropy value of a uniform pattern is zero, therefore, the entropy value of the random component will be equal to that of the total pattern. If the pattern is not perfectly uniform the entropy function is density dependent and there is no upper limit to the value of the entropy. Entropies for different patterns can be compared precisely only when the cell count data is obtained using the same grid in the same position on the map. Therefore, for comparative studies in time or space, the size and form of the grid must not be altered.

In this kind of entropy analysis there arises the problem of quadrat size. For the present investigation, several studies concerning this matter were consulted (Getis, 1964, Harvey, 1966). While theory demands that certain requirements be met it does not reveal the exact size to be used. Trials were carried out with grid squares of 180, 200 and 220 kilometres; and a judgement was made that squares of 200 kilometres on a side were most useful. Grid overlay was placed on a map and the number of points in each grid was counted. The cell counts were recorded for each map and used in the calculations described below.

The sequence of calculations is as follows:

1 The map of urban places is reduced to a field of points and partitioned into Q equal quadrats. The side of each quadrat should be greater than the mean spacing of the points.

2 By counting the number of points in each quadrat, n levels of D_i ($i=1,2 \dots n$) are obtained.

3 The frequency of each density level is noted and is designated as M_i . By means of the formula $M_i = \frac{P_i}{M_i}$ the frequencies P_i

can be calculated.----- (1)

4 The entropy H_s or the uncertainty for the system follows Shannon's formula:

$$H_s = - \sum p_i \log_2 p_i \text{-----} (2)$$

Where p_i is the frequency of occurrence of events. This introduces entropy H_s or the information concept of uncertainty into the analysis. The value of p_i in formula (1) is used to calculate entropy. In practice ready-made tables giving the values of $p_i \log_2 p_i$ are used for this purpose. In order to evaluate a particular H_s it is useful to calculate the uncertainty contained in specified lattices.

(a) Regular lattice (R): This lattice is the one postulated by Christaller and Losch for ideal settlement patterns. In this pattern it is clear $H_R=0$, since $n=1$, $D_i=K$ (a constant) and $M_i=Q$. The amount of uncertainty generated by the pattern is zero.

(b) The opposite of the regular lattice is the random lattice (P) or the poisson generated field of points. The H_p be approximated as:

$$H_p = 1.952 + 1.461 \log a + 0.193(\log a)^2 \text{-----} (3)$$

The next step involves the breakdown of the actual pattern into a completely random and a completely regular component (P and R). If the map of existing pattern is treated as the superimposition of two maps consisting of regular and random components respectively, its entropy can be expressed as:

$$H = H_R + H_p \text{-----} (4)$$

but $H_R=0$, hence $H=H_p$. Similarly, the mean density of the existing pattern as also equals the sum mean density of the two respective original maps, i. e.,

$$aS = aR + aP \text{-----} (5)$$

By using equation (3) the mean density of points per quadrat for the random system can be obtained. Since aP is known, aR is found substituting in equation (5). Then aR is compared to aP and the ratio of uniformity to randomly spaced urban places is obtained. From this ratio the actual number of uniformly and randomly spaced urban places can be calculated. This does not,

however, mean that the particular points belonging to the various components can be identified.

6 This procedure is repeated for each of the time periods chosen. Thus the importance of this technique lies not in the derivation of specific percentage or number for each of the components, but in its ability to identify trends in the overall pattern by a comparison of the components over time.

Entropy Analysis Results

Table I presents results of entropy analysis obtained for the eight points in time from 1901 to 1971. It is seen that the percentage of uniform component increases from 60 in 1901 to 84 in 1971 but indicates intermediate decline to 40 in 1921 and 1931 and 44 in 1941. In 1901 only 9 of the 16 urban places, in 1911, 11 of the 18, in 1912, 10 of the 26, in 1931, 10 of the 26, in 1941, 16 of the 28, in 1951, 24 of the 30, in 1961, 54 of the 70 and in 1971, 85 of the 101 urban places were uniformly spaced. By comparing the changes in the number and percentage of urban places uniformly and randomly distributed.

a pattern significantly from random with a tendency toward uniformity can be detected. Thus, the distribution of urban places is tending towards a more uniform pattern over time. The results tend to confirm the hypothesis that uniformity tends to increase over time and also appear correspond to the hypotheses developed by Christaller and Losch.

In another study the author (1979) has identified a centre-periphery dichotomy in evolution of urban pattern in Eastern India. The study consisted of five natural regions: Bihar plain, Chotanagpur plateau Lower Ganga plain, Orissa highland region and Utkal coastal plain, for which Lower Ganga plain was considered as the Central region and the others as peripheral regions. In the central region the urban places have shown a trend toward randomness while in the peripheral regions they have grown towards a more uniform pattern over time.

The present study area is also a peripheral region of large and complex Calcutta urban system which covers the whole of Eastern India. The results obtained for this area are quite similar to other peripheral regions of Eastern India. Therefore, the results of this study have further corroborated the postulates of centre-periphery dichotomy in the evolution of urban pattern as well as in the development of regional urban system and a sweeping generalisation may be proclaimed about the behaviour of Indian urban system,

Conclusion

This study has aimed to examine the spatial patterns of urban systems with the specific purpose of deriving notions concerning the spacing of urban places. The hypothesis that uniformity of urban places tends to increase over time, has been tested using Northeastern India as a case study. The study area does not approximate the Christallerian isotropic conditions, still, it has several advantages for the present study. The area offers a rigorous test because it departs radically from most of the ideal spatial characteristics of Christaller uniformity assumptions. Urban places adopted for each time period ranging from 1901 to 1971 have been mapped as points on map and entropy method has been used mapped as quantitative measure of uniform and random components of point patterns. This method seems to be effective in separating the random and uniform components of urban pattern and as such is a useful device for comparing the respective components of different patterns. The entropy parameters obtained during the period 1901 to 1971 have exhibited a trend towards greater uniformity consistent with the postulates of Christaller and Losch and the hypothesis has been confirmed. With this increasing uniformity, the urban system as a whole appears to be more organized and predictable. It may be concluded that organization tendencies revealed by urban places on a non-uniform geographical setting-

identify a system moving toward dynamic equilibrium or steady state.

The only drawback at present seems to be the problem of quadrat size, but this problem is also present in many of the

alternative techniques available' e.g., quadrat sampling and self-organizing system analysis. However, entropy method is a workable technique for the settlement pattern problem.

Table - I
Entropy Changes in Urban Place Evolution In
Northeastern India : 1901 - 1971

Entropy Parameters	1901	1911	1921	1931	1941	1951	1961	1971
B	16	18	26	26	28	30	70	101
Q	6	6	6	6	6	6	6	6
Hs	2.2516	2.2516	2.5848	2.5848	2.5848	2.2516	2.5848	2.5848
as	2.6666	3.0000	4.3333	4.3333	4.6666	5.0000	11.6666	16.8333
ap	1.049	1.049	2.581	2.581	2.581	1.049	1.581	2.581
au	1.6176	1.9510	1.7523	1.7523	2.0856	3.9510	9.0826	14.2523
%R	40	35	60	60	56	21	23	16
%U	60	65	40	40	44	79	77	84
R	7	7	16	16	16	16	16	16
U	9	11	10	10	12	24	64	15

B = Total number of urban places,

Q = Quadrats,

Hs = Entropy of the pattern,

as = Average cell density

ap = Average cell density for random component,

au = Average cell density for uniform component,

%R = Percentage of urban places in random component,

%U = Percentage of urban places in uniform component,

R = Number of urban places in uniform random component,

U = Number of urban places in uniform component.

Source : Calculated by the author

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