A Comparison of the Central Place Hierarchy Pattern of Central Indiana to the Walter Christaller Model

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Abstract

Walter Christaller's theory on the hierarchy of central places was used as a model for the analysis of the distribution of agglomerated centers in central Indiana. The 132 study centers were analyzed for potential hierarchy breaks relating to the degree of centrality of the individual centers. The *t* test method was used to check whether or not significant differences existed between the spacing of Indiana centers and the theoretical Christaller pattern. Finally, the Near-Neighbor Analysis was used to test whether or not the distributional pattern of the study centers conforms to the maximum dispersal of the hexagonal framework. Conclusions drawn from the study affirm the hypotheses examined.

The purpose of this study was to empirically analyze the basic principles of the central place theory. The problem is focused on the interpretation of the spatial relationships which are found among the central places on the Tipton Till Plain of central Indiana—namely the size, spacing and distribution of central places within the study area.

The method of analysis was concerned with testing two primary hypotheses. The first being that certain ordering principles of settlement exist in nature; second, that there is a distinct relationship between the organization and distribution of agglomerated centers in central Indiana and the Walter Christaller pattern for southern Germany.

Delimitation of Study Area

The study area consists of the 52-county, 20,362 square mile central portion of Indiana. These counties reflect homogeneous unity in that they are all directly associated with the physiographic sub-province of Indiana known as the Tipton Till Plain. All counties either border on or lie within this physiographic unit.

The Tipton Till Plain is a nearly flat to gently rolling glaciated surface (6) with virtually featureless topographic expression (relief seldom greater than 50-100 feet). The monotony of the flat-lying landscape is evident throughout the central portion of the state with only the extreme southeastern section (the gradational boundary zone) reflecting any topography related to the underlying bedrock (8).

The Tipton Till Plain exemplifies a homogeneity of economic activity as well as topography. It is an agricultural region (4) containing three predominant types of farming: cash-grain in the west, grain-livestock in the central portion, and general farming in the east.

Some portions of the study area deviate from the normal pattern described in this section. These particular areas will be discussed in detail later in the study. The vast majority of central Indiana, however, is a flat-lying agricultural region.

This study is concerned with the distributional pattern of 132 agglomerated settlements within the study area. These settlements represent all centers within the region having populations of 1,000 or more. The cut-off limit was set at 1,000 due to the problem of acquiring comprehensive data for centers below this figure.

Evaluation of the Hierarchy Pattern for Indiana Centers

Population is a common measurement of the importance of place (3). It may, therefore, serve as a major criterion for determining the

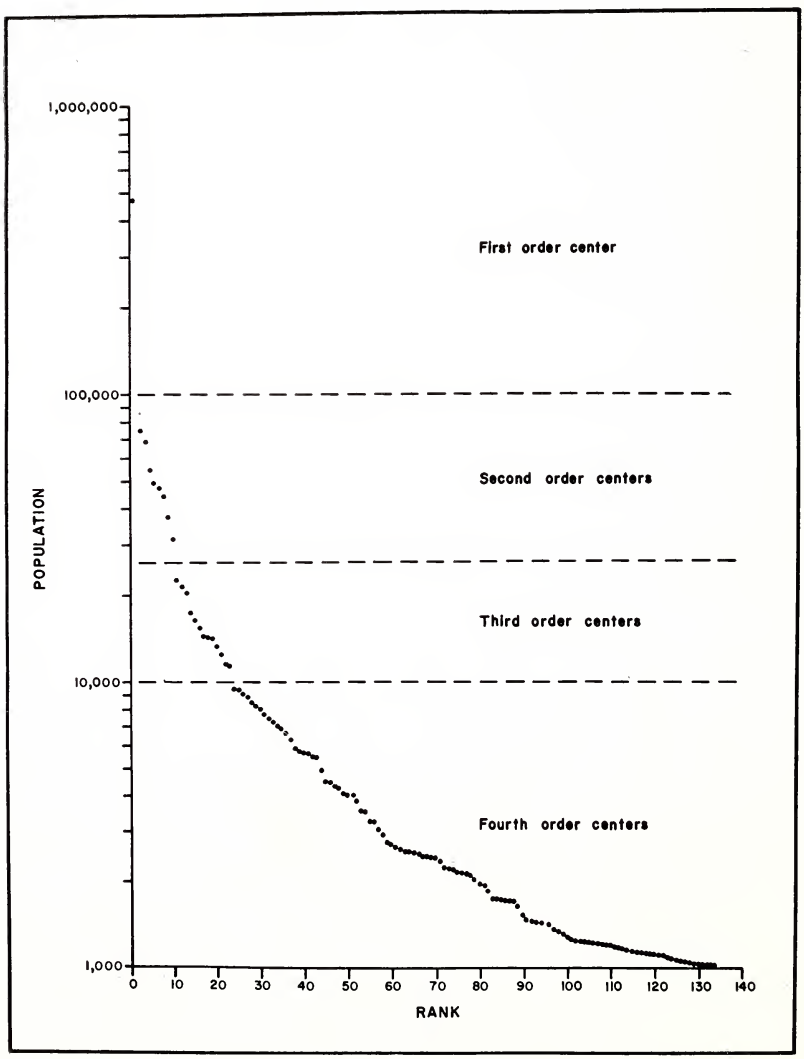

FIGURE 1. *Rank-size relationship of urban centers in Central Indiana.*

functional grade of trade centers. Population gaps in the progression from small to large centers would reflect major distinctions in the size groups (1). Theoretically, a hierarchy of centers would develop relating to the degree of centrality of the groupings.

By plotting the 132 centers on a semi-logarithmic graph according to their rank-size value, distinct groupings within the series are observed (Fig. 1). The progression from largest to smallest is geometrically constant from 80,000 to 30,000; 23,000 to 11,000; and 9,600 to 1,000. Distinct gaps in the trend line are evident between 400,000 to 80,000; 30,000 to 23,000; and 11,000 to 9,600. This pattern would imply four well developed hierarchy groupings for the central places distributed within the study area.

The first order or primary group descends to approximately the 100,000 level. This would include only one center, that of Indianapolis. The secondary grouping ranges from 80,000 to 30,000. This grouping contains 8 cities. There are 13 tertiary centers ranging from 23,000 to 11,000; and 110 centers of quaternary level with a population of 9,000 to 1,000.

Description of Areas Excluded from Study

There are two factors which tend to upset the normal pattern of homogeneity within the study area. Both have had a noticeable effect on the development and distribution of central urbanized centers within the region.

In the south-central portion of the study area, there is a hilly, unglaciated surface located within the Norman Upland physiographic region (5). This is a rugged area with the greatest local relief in the state. The natural agglomerating principles on which this study is based are restricted to a great extent in topographic regions as complex as this upland section. Second, in the late 19th century, natural gas was discovered in the Muncie-Anderson area (7). The locations within this region never developed in such a way that they can be classified trade centers within the criteria set forth in this study. These centers developed as a result of proximity to a natural resource rather than in the context of having a functional service location. Since these two elements are not suitable to space and distance calculations, they will henceforth be segregated from the rest of the study area by suitable boundaries of their own.

Model Pattern for Indiana Centers

Having once established a distinct hierarchy pattern for the study area, the next step is to analyze the spacing of the centers in light of the various groupings.

Christaller ordered the pattern of development in the form of hexagons. Six centers within each net are located at equal distances from one another as well as from their focal place. Each center within

the group represents the same magnitude of centrality. The distance between centers of each successive group increases by the $\sqrt{3}$.

The model from the Tipton Till Plain region is composed of 46 type cast centers from the 4 hierarchy groupings. The centers were selected on the basis of the best-fit rule. The theoretical distribution based on the Christaller scheme portrays the centers symmetrically placed about the landscape.

The primary (first order) city is Indianapolis. It is the most centralized of the major cities in the state. Indianapolis was designated the state capitol in 1825 largely because of the central location and easy accessibility. It continues to function as the major focus of all administrative and consumer activity within the study area.

There are six secondary centers (excluding those in the industrialized area) fairly evenly spaced around Indianapolis. These are Terre Haute-West Terre Haute, Bloomington, Lafayette-West Lafayette, Marion, Richmond and Columbus-East Columbus. Each occupies a focal point on an apex of the hexagon.

Between the primary city and the six secondary centers are grouped six tertiary centers: Crawfordsville, Frankfort, New Castle, Shelbyville, Franklin and Greencastle. Although Greencastle and Franklin were previously classified fourth order centers, their strategic location with respect to serviceability warrants a third order trade distinction.

Around each of the first, second and third order centers are quaternary centers in clusters of 6 (33 centers in all). These centers range in population from 1,000 to a little over 10,000. Although centers such as Bedford were previously ranked as third order places, their true trade status is more comparable to the quaternary level. Therefore, a few such centers have been adjusted to fit the model more correctly.

Comparison of Spacing Patterns

In actuality the centers are distributed about the landscape in a more random fashion than the model prescribes. However, a statistical analysis concerning the spacing of the trade centers gives impressive support to the hexagonal theorem.

The theory states that the mean distance between centers within the four groupings is directly proportional with the distance to functional groups of the next higher order. The mean distance between secondary centers is 38.6 miles, while the mean distance to the primary city is 58.0 miles. The tertiary cities have a mean distance of 35.5 miles; the distance to the secondary cities averages 35.1 miles. A mean distance of 20.7 miles separates quaternary centers with the nearest places of higher order approximately 20.9 miles away.

Christaller further projected that each successive hexagonal net would increase by the radical of three. This would postulate that by

ascribing a theoretical value to the secondary centers, the lower groupings would approximate the $\sqrt{3}$ rule in descending order.

Based on the mean distance figure, the distance between secondary centers is ordered at 58.3 miles. This places the tertiary centers at a model distance of 33.7 miles; the actual computed distance is 35.1 miles. Quaternary centers should average a distance of 20.4 miles; in reality they are 20.9 miles.

When observed distances and theoretical distances are analyzed quantitatively, the results reflect a minimal aberration among the units tested. The average variation is computed to be 3.18% with a correlation coefficient of 0.9984 (Table 1).

TABLE 1. *Comparison of spacing patterns.*

Hierarchy Groupings	Mean Measured Distance (Miles)*	Theoretical Distance (Miles—Based on $\sqrt{3}$)	Variation from Theoretical (Percentage)
2nd to 1st	58.0	58.3	—.52 (.0032)
2nd to 2nd	58.6	58.3	+.51
3rd to 2nd	35.1	33.7	+4.15
3rd to 3rd	35.5	33.7	+5.34
4th to 3rd	22.6	20.4	+10.78
4th to 2nd	20.5	20.4	+.49
(nearest) 4th to 1st	19.6	20.4	—3.92
(around 3rd) 4th to 4th	20.7	20.4	+1.47
(around 2nd) 4th to 4th	20.7	20.4	+1.47

* The distance measurements were taken from a 1968 Indiana Chamber of Commerce road map. Calculations were based on straight line distances. It was found that straight line distances between centers averaged from 7%-19% less than road distances. Therefore a mean correction factor of 13% should be applied to the straight line distances to obtain the approximate read distances between centers.

Therefore one may conclude that the centers of this region tend to lie in a uniform pattern about the landscape, evenly spaced within their own unique groupings as well as externally between groupings. The distance between the various hierarchies conforms directly with Christaller's observed tendency toward $\sqrt{3}$ as the set norm of increase.

Analysis of Deviations from Theoretical Locations

The theoretical hexagon system was rotated to a position of best fit with reference to the observed location of the model centers (Fig. 2). Best fit was determined by calculating the position which warranted the lowest sum departure of the observed secondary centers from their theoretical locations. After the theoretical pattern had once been fixed

in position, departures were calculated for each of the model centers. These figures were then analyzed to determine to what degree each hierarchy grouping correlated with the Christaller framework.

A "t" test was used to test the significance of the difference between the observed and the theoretical distances to adjacent centers. The test was computed for each of the three groups in an attempt to determine the amount of uniformity within units. The result from the "t" test showed that in all 3 groupings the observed distances and the theoretical distances were not significantly different at the 0.05 level.

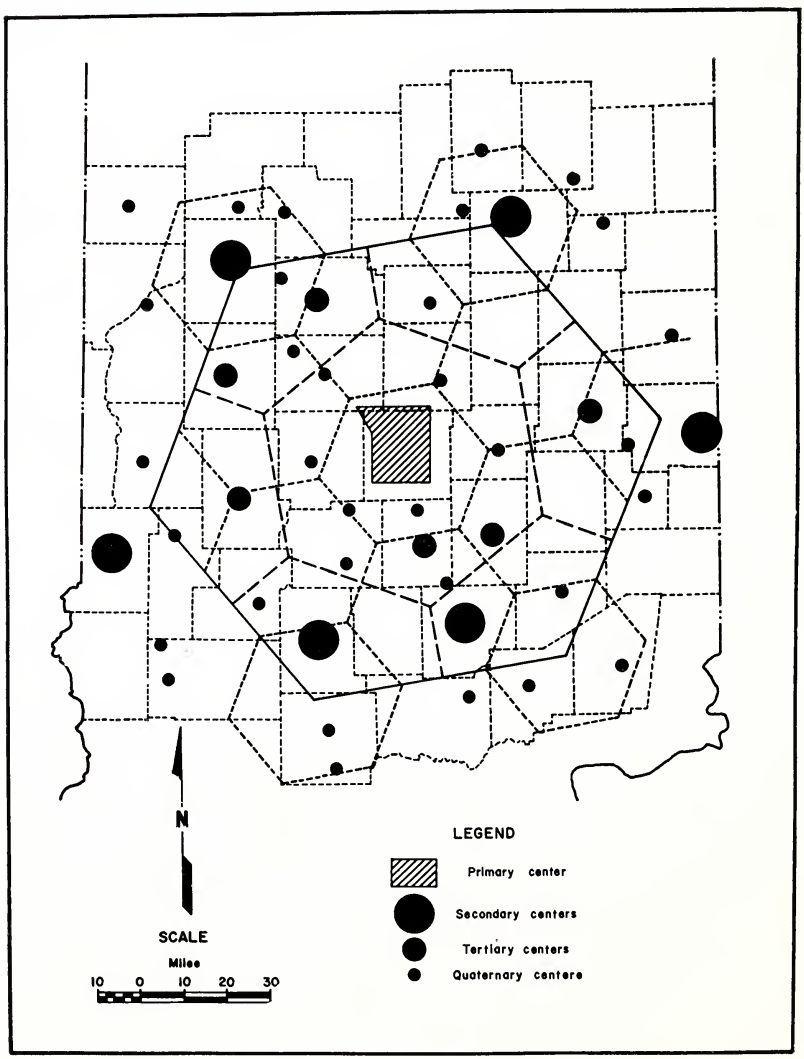

FIGURE 2. *Comparison of theoretical pattern and model centers.*

Therefore, one may conclude that even though the centers do deviate to a certain degree from their theoretical location, the spatial patterns are similar enough to be considered statistically related.

Near-Neighbor Analysis

To test if the centers were located in a pattern of maximum dispersal (which is in essence what the hexagonal theorem prescribes), the spacing of each unit with respect to its adjacent settlements must be analyzed.

Examination of this pattern can be accomplished by the use of the Near-Neighbor Analysis. This technique indicates the degree to which any observed distribution of points deviates from what might be expected if the points were distributed in a random manner within the same area (2). The theory states that there are three distinct patterns of settlement: Aggregate (clustering), Random and Uniform.

The mathematical test for the Near-Neighbor pattern assigns an "R" value for the observed density of points in the area under consideration. An "R" value of less than 1.00 represents a tendency toward clustering (0.00 equals a perfect aggregate pattern). An "R" value of greater than 1.00 reflects a tendency toward uniform spacing (2.15 equals maximum dispersal or the perfect hexagonal pattern).

The following results were obtained by use of Near-Neighbor analysis. The "R" for the second order grouping is 2.011. Deviation is 0.139 (6.4%) from the perfect hexagonal framework. The tertiary centers have an "R" of 2.126. This pattern's deviation is less than 2% (0.024) from the maximum hexagonal dispersal. The "R" for the fourth order centers is 2.060 with a departure from uniformity of only 0.090 (4.1%).

Therefore, one may conclude on the basis of the aforementioned data, that there is a distinct distributional pattern of settlement for this region. The model centers do in effect reflect a near perfect relationship with the uniform spacing (2.15) tendency of the Near-Neighbor equation.

Conclusion

The results of this study clearly support the two hypotheses tested. Nature dictates a certain degree of order to the development of central places. The central places of central Indiana have a tendency to conform to such an ordering principle; and the pattern for this area is very much similar to the K-3 network of Walter Christaller.

Literature Cited

1. BERRY, B. J. L., and W. L. GARRISON. 1958. Functional bases of the central place hierarchy. Econ. Geogr. 34:145-154.

2. BERRY, B. J. L., and D. F. MARBLE. 1968. Spatial Analysis: A Reader in Statistical Geography. Prentice-Hall, Inc., Englewood Cliffs, N.J. 512 p.

3. BRUSH, J. E. 1953. The hierarchy of central places in southwestern Wisconsin. Geogr. Rev. **43**:380-402.

4. HART, J. F. 1968. Field patterns in Indiana. Geogr. Rev. **63**:450-471.

5. KINGSBURY, R. C. 1966. An Atlas of Southern Indiana. Occasional Pub. No. 3. Dept. of Geogr. Indiana Univ., Bloomington. 60 p.

6. SCHNEIDER, A. F. 1966. Physiography, p. 40-56. *In* A. A. Lindsey [ed.] Natural Features of Indiana. Indiana Acad. Sci. Sesquicentennial Volume. Indianapolis. 600 p.

7. VISHER, S. S. 1923. Economic Geography of Indiana. D. Appleton and Co., N.Y. 511 p.

8. WAYNE, W. J. 1956. Thickness of drift and bedrock physiography of Indiana north of the Wisconsin glacial boundary. Progress Rep. No. 7. Indiana Geol. Surv., Bloomington, Ind.