THE USE OF CENTRAL PLACE THEORY AND GRAVITY-FLOW ANALYSIS TO DELINEATE ECONOMIC AREAS

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INTRODUCTION

A growing awareness of the need for a comprehensive approach to regional and local planning for studying urban and rural areas as parts of an interrelated socio-economic system has stimulated interest in the problem of delineating economic regions, areas, and sub-areas. The Office of Business Economics, U. S. Department of Commerce, has designated 173 economic sub-areas in the U. S. for purposes of planning by federal agencies. State governments are also busy delineating planning areas for state and local agencies. Ten such planning areas were designated in South Carolina by executive order of the Governor in March 1969. Presumably, future public policies and programs in such fields as natural resource management, industrial development, housing, and highway construction, etc., will be designed and implemented on the basis of these spatial delineations.

Although economic geography has made major strides in recent years toward the development of analytical tools for the study of spatial economic phenomena, there is no definitive system for delineating economic areas. However, there are two basic concepts upon which such delineation may be postulated: (1) the "homogeneity concept," which views an area as being composed of spatial units which are of similar economic structure and character; (2) the development pole, or nodal development theory, which views an area as the hinterland of some central place [7, pp. 709-727]. Actually, areas defined on the basis of the development pole or nodal concept may be homogeneous to the extent that the residents of the surrounding hinterland interact in the same central place [2, p. 366]. Our objective is to employ a synthesis of the two concepts using tools developed by economic geographers and traffic planners for other purposes.

CENTRAL PLACE THEORY

The first written exposition of central place theory dates from the publication in 1933 of Walter Christaller's Die Zentralen Orte in Suddeutschland.[1] Briefly, Christaller noted that the spatial organization of economic activities was ordered around a hierarchy of urban places. At the top of the hierarchy are the cities which serve as the central place for a broad hinterland relative to very specialized services (such as higher education, regional government, the arts, etc.). At the bottom of the hierarchy are the hamlets and villages, which serve as the central place for a somewhat smaller hinterland relative to such everyday activities as food purchasing and local government. In the middle strata are wholesale centers, area shopping centers, etc., which serve intermediate-sized hinterlands[1, p. 107].

The role of the central place as the economic center of some spatial expanse may be demonstrated by observing traffic flows as manifested in shopping patterns, distribution systems or the journey-to-work of commuters. Ideally, all three measures should be used together, but data limitations often intervene to force a more restricted observation. In such cases, commuter patterns appear to be a useable index of the attraction of a central place over some hinterland. A particular pattern of commuting is built up because of the local geographic distribution of jobs [5, p. 125]. The number of jobs in any one location is proportional to the number of economic functions performed at that site. The larger the central place, the greater the number of functions it performs, the greater the employment requirements of each function, and the wider the hinterland over which it attracts workers to man its economic activities. It follows, therefore, that there is also a hierarchy of hinterlands (regions, areas, sub-areas) which corre-

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[1]Translated, literally, as Central Places in Southern Germany. An English translation of the same can be found in Christaller [4].

spond to the hierarchical ranking of their node or central place and that the boundaries of these hinterlands might be delineated on the basis of the prevailing or dominating direction of commuter patterns.

GRAVITY-FLOW ANALYSIS

For several years, traffic engineers have made use of a concept borrowed from Newtonian physics to quantify the potential flow of traffic from one point to another. Essentially, the concept of gravity is adapted to examine the attraction between two areas of human activity (e.g., two counties) and their potential for interaction. The basic premise is that the attracting force for interaction between two spatial units is proportional to the population mass of the two units. A friction against interaction is caused by the intervening space over which the interaction must take place. That is to say, interaction between two centers of activity varies directly with some function of the population size of the centers and inversely with some function of distance [8, p. 494; 3, p. 94]. Stated mathematically, the general gravity-flow model may be written:

$$I_{ij} = \frac{f(P_i, P_j)}{f(D_{ij})}$$

where

I_{ij} = a measure of the interaction between center i and center j;

P_i, P_j = the population of center i and j, respectively; and

D_{ij} = the distance between center i and center j.

The model can be modified to examine commuter patterns by specifying the population variables as the resident labor force of some county and distance as the road mileage between county seats (or some alternative central location in the county).

A step-by-step development of the gravity-flow model in explicit terms has been worked out by Walter Isard and David Bramhall, and the following paragraphs draw heavily from their work [8, pp. 495-499].

The probability that any one worker will commute within a given spatial expanse, such as a state, can be expressed as the ratio:

$$K = \frac{T}{P}$$

where

K = the probability that any one worker within the state will commute;

T = the actual total number of commuters who made trips within the specified time period; and

P = the total labor force of the state.

Similarly, the probability that the commuter's destination will be county j is the ratio:

$$PJ = \frac{P_j}{P}$$

where

PJ = the probability that the destination is county j;

P_j = the labor force of county j; and

P = term defined previously.

Thus, the probability that the worker will commute and will commute to county j is the product (K) (PJ).

Now, if there are P_i workers residing in county i, it is possible to estimate the number of commuters from county i to county j by:

$$T_{ij} = (P_i)(K)(PJ)$$

where

T_{ij} = the total expected number of commuters from county i to county j; and

P_i,K,PJ = terms defined previously.

There are two very strict assumptions associated with the gravity-flow model as developed above. First, it is assumed that all counties in the state are homogeneous with respect to the average propensity to commute. That is, the probability that a worker will commute to an out-of-county job is the same for every county in the state. Second, the coefficient of friction associated with the distance between counties i and j is zero. This latter assumption can be relaxed somewhat by obtaining an estimate of the friction of distance by using regression techniques. One procedure which shows promise is to regress the logarithm of the ratio of actual to expected commuters on the logarithm of the distance between the two counties, such that:

$$\log \left(\frac{I_{ij}}{T_{ij}}\right) = a + b \log D_{ij}$$

where

I_{ij} = the total number of actual commuters from county i to county j;

a,b = parameters estimated by regression techniques; and

T_{ij}, D_{ij} = terms defined previously.

The estimate of b can be taken as an approximation of the friction coefficient associated with distance. The coefficient of determination (r^2) for the fitting of this function is a measure of the validity of the homogeneity assumption relative to the propensity to commute: a high r^2 would indicate a high degree of homogeneity; a low r^2, a low degree.

The distance coefficient can be entered into the gravity-flow model by converting to standard notation so that:

$$\frac{I_{ij}}{T_{ij}} = \frac{c}{(D_{ij})^b}$$

or

$$I_{ij} = \frac{c\,T_{ij}}{(D_{ij})^b}$$

where

c = the antilog of a; and

$I_{ij}, T_{ij}, D_{ij}, b$ = terms defined previously.

Then, since

$$T_{ij} = K\left(\frac{P_i P_j}{P}\right)$$

notation can be simplified by letting

$$G = \frac{cK}{P}$$

so that

$$I_{ij} = G\left[\frac{P_i P_j}{(D_{ij})^b}\right]$$

whioh is a restatement in explicit terms of the generalized gravity-flow model presented above.

A MODEL FOR APPLICATION

To accomplish the objective of this study, the gravity-flow model outlined above was used to place boundaries on commuter hinterlands for a hierarchy of central places in South Carolina.

There are forty-six counties in South Carolina. These counties were used as the basic spatial unit for delineating economic areas. For any given South Carolina county, there are forty-five possible in-state-destinations for commuters who leave their county of residence. Likewise, for any given county, there are forty-five possible in-state counties which may serve as origins for commuter trips. Thus, a 46 x 46 matrix was constructed of the I_{ij} variable (expressed on a per thousand basis) calculated according to the procedure outlined above. Unpublished data on the "Journey to Work" from the 1960 Census constituted the basic input. This matrix showed the potential (per thousand resident workers) of any given county in the state to contribute its residents as workers to any other county.

Fourteen central places in South Carolina were identified on the basis of the concentration of economic activity. This concentration was measured by the percentage of total state wholesale, service, and retail activity in a particular county. Data indicated that each of these economic activities was more specialized in nature than its successor. A hierarchy of three orders, or levels, of the central places was established on the basis of these criteria [6, Ch. 1]. The hierarchy was used to rank these central places in a descending order from those central places with the most areally concentrated activities to those central places with the least areally concentrated activities. The third order included the three metropolitan counties of Charleston, Richland (Columbia), and Greenville. The second order included the three third order places plus Anderson, Spartanburg, and York counties, a total of six places. Fourteen places were classified as first order places, including all the second-order places plus eight additional counties: Aiken, Cherokee (Gaffney), Florence, Georgetown, Greenwood, Orangeburg, Sumter, and Union. These counties, or central places, were considered destination, or "j" counties; that is, they were the nodes around which three orders of economic areas were delineated.

Each of the three orders of economic areas was delineated independently of each other. A county was assigned to the hinterland of one of the central places in a particular order if that central place attracted a greater number of potential commuters (per thousand resident labor force) than any alternative central place of the same order. That is, in the third order of the hierarchy, a county was assigned to the central place of Charleston, Richland, or Greenville, depending on which of these counties had the highest potential as a destination for the commuting workers of the county. Table 1 is a presentation of the gravity-model calculations for each of these 14 central

TABLE 1. VALUES OF COMMUTER POTENTIAL PER 1,000 LABORERS TO 14 SELECTED CENTRAL PLACES.

Central Place / County	Aiken	Anderson	Charleston	Gaffney (Cherokee County)	Florence	Georgetown	Greenville	Greenwood	Orangeburg	Columbia (Richland County)	Spartanburg	Sumter	Union	Rock Hill (York County)
Abbeville	1.57	21.92	.27	.37	.13	.02	9.63	79.90	.33	2.16	2.62	.24	.60	.46
Aiken	- - -	.89	.82	.16	.23	.05	1.38	1.90	2.66	7.68	1.03	.51	.30	.33
Allendale	3.41	.28	2.06	.07	.24	.08	.47	.31	4.72	3.34	.36	.49	.10	.20
Anderson	.62	- - -	.19	.46	.08	.02	45.70	3.97	.18	1.02	4.79	.14	.50	.37
Bamberg	4.49	.30	2.93	.08	.42	.12	.59	.36	59.58	7.68	.43	1.09	.13	.30
Barnwell	10.07	.38	1.58	.09	.29	.08	.64	.49	8.96	6.67	.48	.63	.15	.28
Beaufort	.42	.11	4.25	.03	.16	.09	.20	.09	.73	.84	.15	.30	.04	.09
Berkeley	.44	.12	34.75	.05	1.08	1.33	.28	.11	2.18	.50	.22	1.54	.06	.17
Calhoun	2.52	.30	2.74	.13	.88	.17	.78	3.41	101.15	35.41	.67	4.29	.23	.53
Charleston	.30	.10	- - -	.03	.42	.76	.21	.08	1.03	1.13	.17	.61	.04	.11
Cherokee	.36	1.45	.21	- - -	.20	.02	10.71	.81	.20	1.76	101.03	.25	7.41	5.56
Chester	.51	.84	.37	1.98	.48	.05	3.24	.81	.52	8.07	9.23	.80	6.14	48.01
Chesterfield	.24	.19	.42	.19	3.46	.11	.55	.13	.33	2.80	.75	1.54	.22	1.84
Clarendon	.58	.16	3.14	.08	4.31	.73	.44	.16	3.91	5.55	.39	48.03	.11	.45
Colleton	.86	.16	11.42	.05	.37	.20	.30	.14	3.68	2.23	.24	.91	.07	.16
Darlington	.26	.14	.94	.11	297.52	.33	.37	.12	.50	3.10	.47	6.30	.13	.81
Dillon	.14	.09	.70	.06	12.34	.30	.24	.07	.28	1.18	.27	1.36	.07	.36
Dorchester	1.17	.18	10.25	.06	.65	.24	.37	.17	10.57	3.72	.31	2.08	.08	.21
Edgefield	35.83	1.79	.53	.22	.23	.04	2.57	7.68	1.15	7.32	1.47	.50	.45	.44
Fairfield	.92	.66	.60	.61	.71	.06	1.70	.88	7.66	51.11	2.93	1.67	1.91	4.64
Florence	.24	.13	1.19	.09	- - -	.46	.33	.11	.57	2.80	.39	7.24	.10	.61
Georgetown	.16	.08	6.22	.03	1.34	- - - -	.19	.06	.41	.89	.15	.98	.04	.15
Greenville	.46	21.99	.19	.64	.11	.02	- - -	2.11	.18	1.54	30.56	.19	1.02	.68
Greenwood	2.92	8.75	.33	.57	.17	.03	9.64	- - -	.47	3.59	4.20	.33	1.06	.68
Hampton	1.78	.22	3.26	.05	.21	.10	.37	.22	3.30	2.46	.28	.43	.08	.17
Horry	.11	.07	1.67	.04	2.68	2.86	.41	.06	.24	.82	.16	.86	.04	.18
Jasper	.60	.13	3.51	.04	.17	.08	.24	.12	.93	1.00	.18	.32	.05	.10
Kershaw	.81	.31	.86	.25	2.68	.14	1.22	.31	1.52	35.46	1.14	13.82	.41	2.28
Lancaster	.42	.42	.41	.77	1.16	.08	1.38	.33	.51	7.68	2.53	1.48	1.01	32.75
Laurens	1.26	8.20	.29	1.72	.18	.03	29.96	14.72	.40	4.01	17.46	.35	5.14	1.25
Lee	.44	.21	1.00	.16	10.47	.25	.51	.19	1.07	8.48	.67	28.55	.21	1.39
Lexington	4.77	.73	.96	.32	.65	.08	1.62	1.37	4.43	416.72	1.56	2.39	.74	.92
McCormick	4.08	4.63	.34	.27	.16	.03	3.73	20.59	.48	3.33	1.82	.31	.42	.38
Marion	.16	.10	1.08	.06	34.58	.62	.24	.08	.35	1.46	.27	2.08	.07	.35
Marlboro	.17	.13	.53	.10	7.76	.62	.35	.08	.29	1.62	.43	1.48	.11	.70
Newberry	2.65	1.93	.48	.96	.33	.18	5.52	5.61	.83	19.27	6.36	.83	4.36	1.76
Oconee	.27	14.40	.12	.28	.06	.01	14.21	.76	.10	.55	2.54	.09	.20	.23
Orangeburg	3.23	.31	3.38	.11	.67	.16	.62	.37	- - - -	18.00	.56	2.17	.18	.42
Pickens	.35	21.95	.15	.66	.08	.02	138.50	1.20	.13	.94	7.82	.13	.45	.40
Richland	2.78	.53	2.00	.29	.97	.11	1.65	.84	5.35	- - -	1.51	4.83	.65	1.44
Saluda	10.92	2.01	.56	.40	.29	.05	3.61	9.98	1.25	14.00	2.94	.71	1.06	.79
Spartanburg	.47	3.14	.21	21.01	.17	.02	41.68	1.25	.21	1.92	- - -	.24	8.16	1.98
Sumter	.57	.22	1.82	.12	7.73	.36	.62	.24	1.98	14.85	.57	- - -	.17	.76
Union	7.38	17.92	.30	8.39	.25	.03	7.54	1.72	.37	4.52	44.48	.39	- - -	4.92
Williamsburg	.32	.12	3.78	.06	7.73	2.16	.33	.11	1.24	2.71	.29	7.24	.08	.34
York	.32	.51	.29	2.44	.56	.05	1.96	.43	.34	3.86	4.20	.67	1.91	- - -

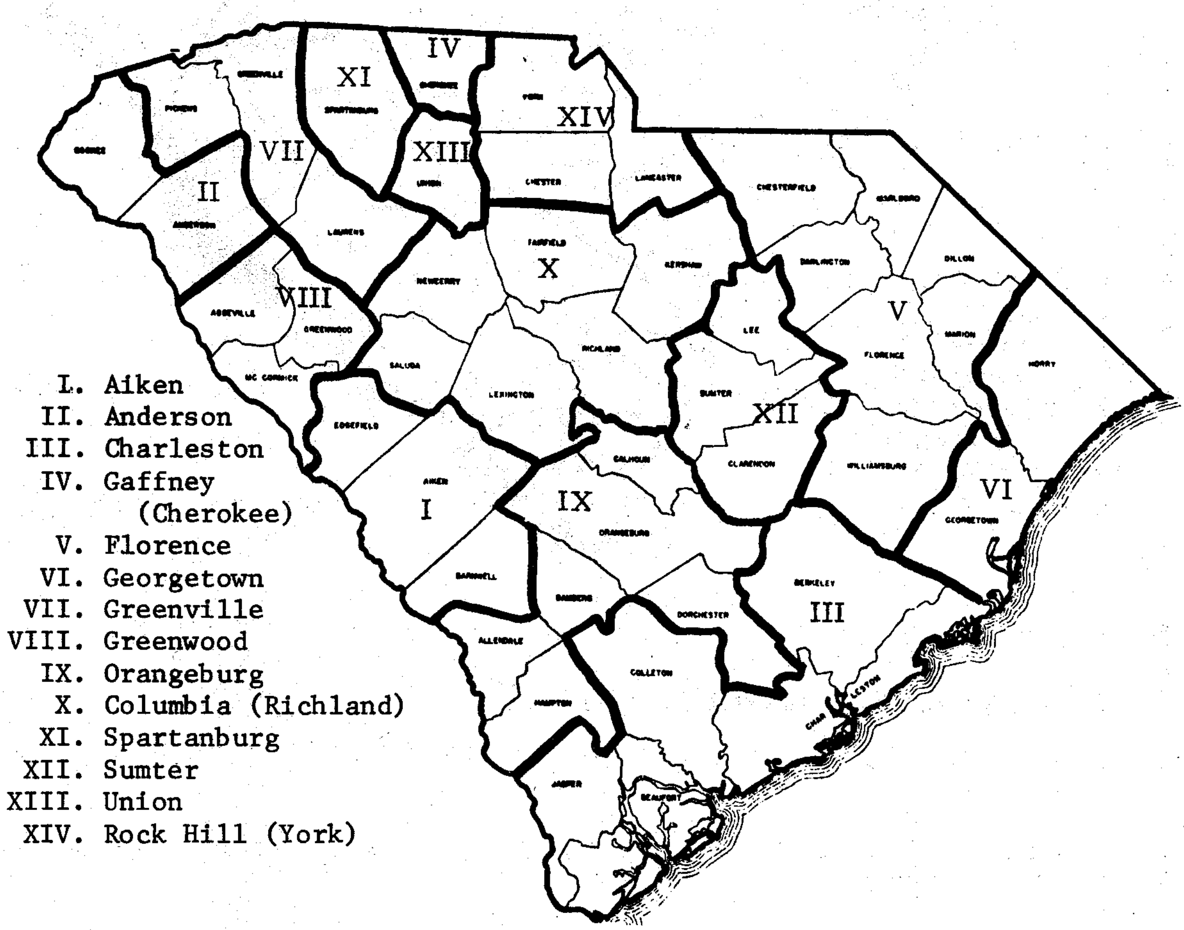
places. The three orders of economic classes delineated by this method are shown in Maps 1–3.

EVALUATION

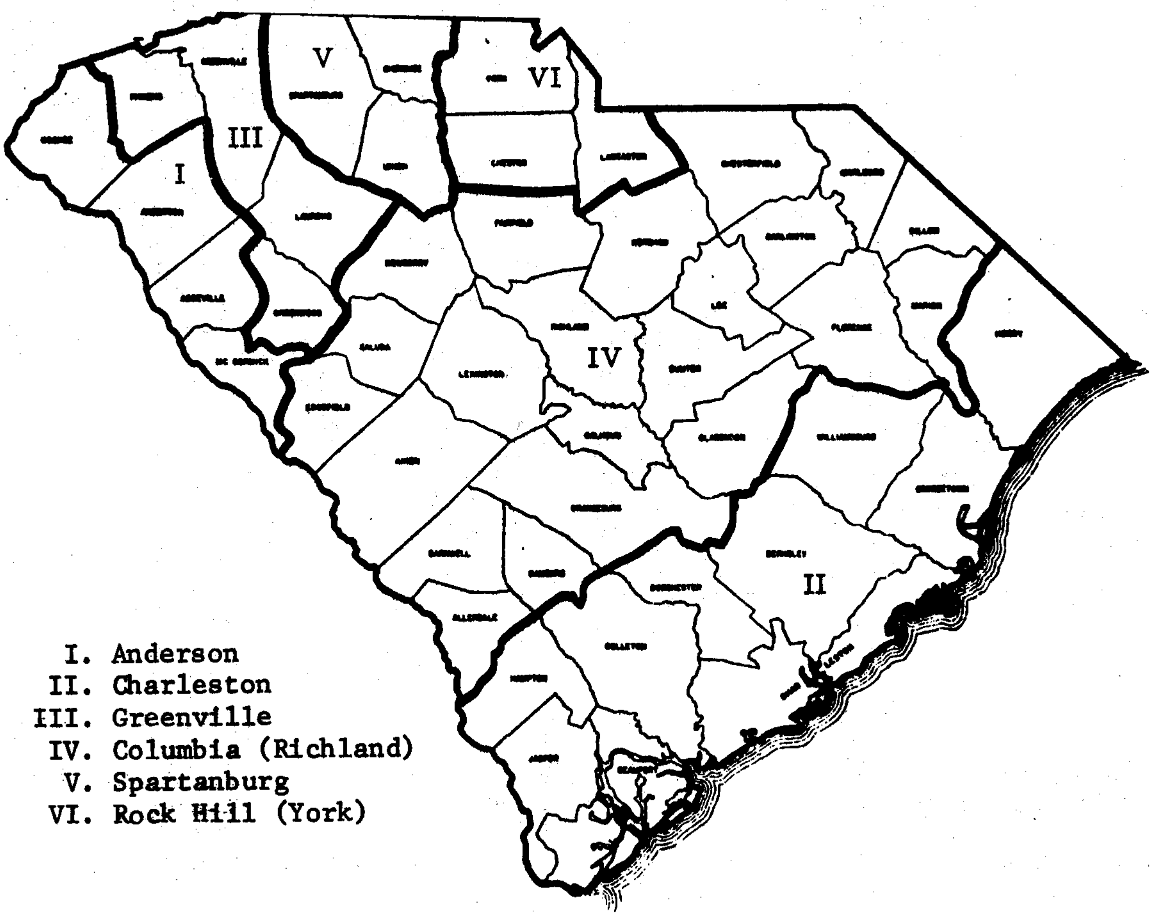
There is no generally accepted system for evaluating particular methods of delineating economic areas or for comparing one method of delineation to another. Consequently, any evaluation of the use of central place theory and gravity-flow analysis to delineate areas in this manner must be somewhat subjective.

There are two positive observations, however, relative to the system of delineation reported above: (1) Central place theory is a widely accepted theory of economic geography which has been empirically tested in several parts of the world. Thus, there appears to be a plausible rationale for both a hierarchy of economic areas, as opposite to only one set (as delineated by OBE) and for the number of areas delineated in each order of the hierarchy. (2) The gravity-flow model provides an objective basis for classifying a county (or any other spatial unit) as to its proper area. This latter point is valid even if some index of spatial interaction other than commuting patterns is used.

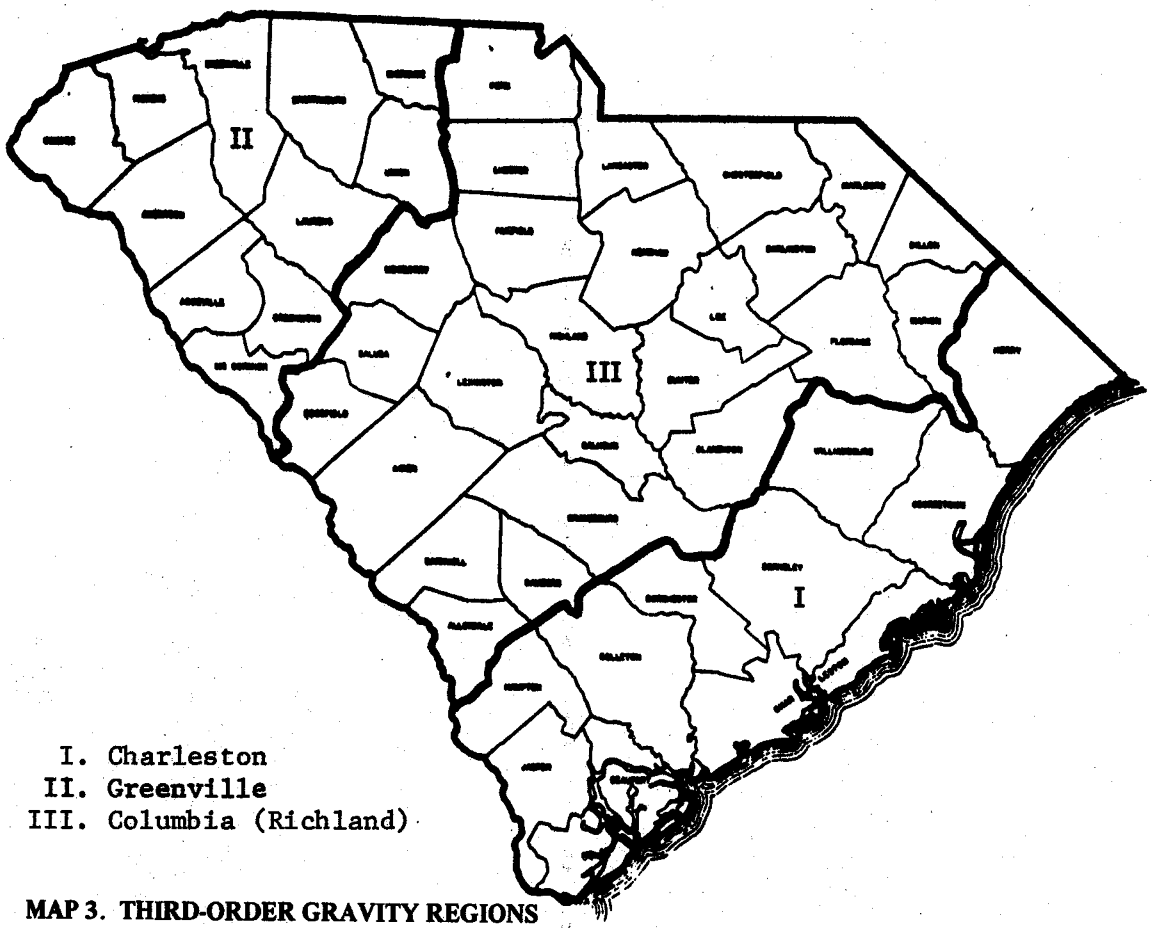
The principal weakness of the central place gravity-flow method, as applied in this study, is its reliance on one measure (in this case, commuter patterns) of interaction as the criterion for delineation. Undoubtedly, there are many other measures of interaction which should also be introduced into the delineation scheme. One promising technique for doing so involves the use of multiple factor analysis. Data limitations, however, preclude empirical attempts to apply this technique without expensive field surveys of shopping patterns, patronage of the arts, etc.



MAP 1. FIRST-ORDER GRAVITY REGIONS



MAP 2. SECOND-ORDER GRAVITY REGIONS



MAP 3. THIRD-ORDER GRAVITY REGIONS

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