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AUTHOR Massam, Byran H.
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ABSTRACT

Designed to supplement undergraduate college geography courses, this paper discusses a particular type of territorial division--the administrative area within a state. The study of administrative patterns allows geographers to formulate and test hypotheses about man's organization of space, and also to assist in a very practical way by applying his knowledge to real world problems. All states, with the exception of only the very smallest, are divided for the purpose of internal administration into smaller units. With an increasing proportion of the world's population becoming concentrated in urban centers there is a pressing need to examine the spatial administrative structures which have been defined to delimit service areas of many public facilities, such as fire and police protection, education, health, and welfare. In many large metropolitan areas services are paid for by the residents of one municipality but these same services are enjoyed by people in neighboring municipalities. The problem becomes more complex when individual demands for services and daily movement patterns of consumers are considered. This paper examines the spatial aspects of administrative systems. The problems of how large the administrative area should be is examined and the contributions of disciplines related to geography are mentioned. The development of administrative structures over time is also discussed. (Author/RM)

FOREWORD

The Resource Papers have been developed as expository documents for the use of both the student and instructor. They are experimental in that they are designed to supplement existing texts and to fill a gap between significant research in geography and readily accessible materials. The papers are concerned with important concepts in modern geography and focus on three general themes. geography theory, policy implications, and contemporary social relevance. They are designed as supplements to a variety of undergraduate college geography courses at the introductory and advanced level. These Resource Papers are developed, printed, and distributed by the Commission on College Geography under the auspices of the Association of American Geographers with National Science Foundation support. The ideas presented in these papers do not necessarily imply endorsement by the AAG Single copies are mailed free of charge to all AAG members

[illegible] Lounsbury
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PART 1

INTRODUCTION

The division of the surface of the earth into territorial patterns is a dominant feature in the spatial organization of societies. The analysis of these patterns has attracted the attention of several disciplines and approaches. Attempts have been made to define the functions of territorial divisions and the relationship between spatial form and the function as it varies from place to place and over time. The decision-making process which gives rise to territorial divisions and the *sense of territoriality* which is pervasive in the explanation of man's spatial organization and behavior have also been examined (Resource Paper No. 8, *The Political Organization of Space.*)

In this paper we will focus upon a particular type of territorial division—*the administrative area within a state;* and while some of the ideas discussed may have broader implications and be applicable to many types of territorial divisions, these will not be developed here. It is widely recognized that all states, with the exception of only the very smallest, are divided for the purpose of internal administration into smaller units. Thus our immediate task is to examine the smaller spatial units and try to determine the precise reasons for their form and so add to our knowledge concerning man's organization of space. However, from a practical standpoint, to help in making decisions concerning the size, shape and number of administrative areas within a country we need to be able to define and measure efficiency of a particular arrangement and to compare this with alternative spatial arrangements. The advantages and disadvantages of all possible spatial patterns should be known in order to make a reasoned choice. Traditionally the decision-maker has relied heavily on his experience and on a trial-and-error basis for defining administrative areas. Clearly, geographers, among others, have a responsibility to help in the definition of areas by offering their knowledge on this subject to society to use as it deems most appropriate.

Administrative areas can be defined for many functions, and they are neither restricted to rural or urban areas nor to developed or developing nations Whether the problem is to define school districts in New York, health units in Botswana, milk marketing areas in Southern Ontario or voting districts in the U.K., it is imperative that the decision-maker have access to various plans so that he may select one objectively, rather than on a purely intuitive basis.

With an increasing proportion of the world's population becoming concentrated in urban centers there is a pressing need to examine the spatial administrative structures which have been defined to delimit service areas of many public facilities, such as, fire and police protection, education, health and welfare. In many large metropolitan areas we find that services are paid for by the residents of one municipality but these same services are enjoyed by people in neighboring municipalities. This is known as the *spill-over effect.* One way to equalize the payment for the service is to impose *user-charges* on the consumers irrespective of their residential location. This strategy is usually applied to transit systems. Another way to avoid spill-over effects is to amalgamate all the people using the service and tax everyone for services which are provided.

The problem becomes more complex when we consider individual demands for services and daily movement patterns of consumers. An individual may live in one community, work in another, do his shopping in another and have his children educated in a fourth Should we tax him according to this pattern of demands? How do we calculate the distribution of his tax dollar among communities if he changes his movement patterns frequently? This is almost an intractable problem, but we should note that attempts have been made by some metropolitan centers to amalgamate areas around the urban nucleus in the hope that a uniform taxation rate will equalize the quality of services throughout the area. Further, it is claimed that the burden of paying for the services is shared more evenly by the consumers.[1]

[1] A summary of Metropolitan Reforms in North America is provided in Resource Paper, No. 8, *The Political Organization of Space.*

It is clear that the study of administrative patterns is a fascinating field which allows the geographer to formulate and test hypotheses about man's organization of space, and also to assist in a very practical way by applying his knowledge to real-world problems. The geographer cannot stand alone in this field; he must cooperate with workers in other disciplines such as economics, operations research and business management. Also he must be prepared to use the tools of these subjects and so enrich his own discipline.

As geographers, we are interested to explain spatial patterns and thus the emphasis in this Resource Paper will be in this direction. Following the Introduction, Parts 2 and 3 will focus almost entirely on the spatial aspects of administrative systems. Part 4 will examine the problem of how large the administrative area should be, and here we will consider contributions from the related disciplines mentioned above. In Part 5 we will look at the development of administrative structures over time. Conclusions will be presented in Part 6.

The topic does not finish with the last line of Part 6. The future rests with the reader, either to concentrate on the construction and testing of hypotheses and the development of theory of human spatial organization or to tackle real-world problems of defining administrative areas. The two are not incompatible and both provide ample scope for imagination and skill.

PART 2
SPATIAL PATTERNS OF ADMINISTRATIVE AREAS

There is a growing body of literature in human geography which is devoted to the description of geometrical properties of the distribution patterns of man and his activities. From these geometrical properties we try to infer the processes which have caused the particular spatial distribution, and thus we relate form to process—a basic aim of science. In Part 2 we will follow this approach and start by describing the geometry of administrative areas. In later sections we will show how it may be used to evaluate the spatial efficiency of an administrative area, and to determine the best location of administrative boundaries and centers.

In most of the studies which derived measures of the geometry of areas it is assumed that the space under examination is Euclidean space and thus has the following properties: parallel lines never meet; the shortest distance between two points is a straight line; and that distances between points can be calculated from Pythagoras' theorem.[2]

The assumption that earth-space can be treated as Euclidean has been criticized by several workers. Their view is that earth-space is made of a surface of varying friction, and that the separation of points and the effort in moving from one to another is related to the frictional force of the intervening space. Points may be joined by a fast super-highway or a dirt track, and the straight-line distance does not reflect truly the time, effort or cost of moving between places. Rectangular road patterns, traffic congestion, mode of transportation all serve to produce earth-space of varying frictional qualities and sets of points of varying degrees of accessibility. Thus when we define space as having a certain shape, based upon Euclidean space assumptions, we should note the nature of the surfaces upon which the area is defined. Administrative areas have shapes on a map and the distortions from map to map may be due to the form of projection used. However, the same areas may take on different shapes if they were defined in time-space, cost-space or effort-space. These notions have not been fully explored in geography, yet they seem very pertinent when we consider the division of space into administrative units when the criterion may be to define units to minimize time, cost or effort in moving across the administrative unit

Shape Measures on Homogeneous Surfaces

Shape has been defined by Blair and Biss (1967) as

> "that quality of an object or form which depends on constant relations of position and distance from all the points composing its outline or its external surface. As such, under the concept of shape we understand a set of properties compactness, elongation, and others which are spatially related and combine together."

We should also note that the shape of something can be independent of the size; it is independent of scale as are most of the pattern measures used in spatial analysis.

Attempts to define and apply shape measures to administrative areas have been offered by William Bunge and Peter Haggett, among others. Bunge (1962) in his book *Theoretical Geography*, classified the shapes of Mexican communities using a series of measures of distances between vertices of polygons which were fitted over the shapes. The shapes of a set of ninety-seven communities were measured and shape types defined. They varied from elongated thin shapes, through compact square shapes, to elongated stars.

Haggett (1965) studied a sample of *municipios* in Brazil, and he counted the number of neighbors touching each

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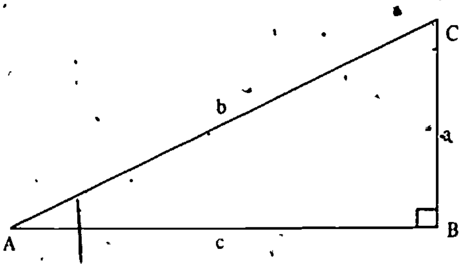
[2] Pythagoras' theorem states that for a right angle triangle ABC

$$b^2 = a^2 + c^2$$

$$\therefore b = \sqrt{a^2 + c^2}$$



unit. The number of contacts varied from two to fourteen, though approximately 30 out of the sample of 100 had six neighbors. The mean was 5.71. Pedersen (1967) extended Haggett's approach to administrative communes in Jutland and Fyn in Denmark. He examined 553 communes and found the mean number of contacts to be 5.83. However, Haggett and Chorley (1969) have pointed out in their text *Network Analysis in Geography* that,

> "... this number should not be interpreted to indicate the existence of a hexagonal net structure, for 'blurring' of basic triangular or quadratic nets could give very similar averages."

Michael Dacey, a geographer who is keenly interested in the mathematical properties of spatial patterns, has examined some of the theoretical bases of shape values and concludes that a value close to 6.0 is inevitable for a large number of patterns, including those generated according to random rules.

A more rigorous shape measure has recently been provided by Lee and Salee (1970) of the University of California at Davis. They used it to classify the shape of twenty-five villages in the Nile Valley in northern Sudan. The village shape was overlain by a circle drawn in such a way as to minimize the area of "non-fit" between the village and the circle. For each shape the area of the union of village and circle ($K \cup L$) was measured, as was the area where village and circle coincided ($K \cap L$). The areal measurements were fitted into the following formula to obtain an index number for the circles, T=1 – area [($K \cap L$)/area ($K \cup L$)], where K represents the unknown shape and L the standard (in this case a circle), and T the index number. Comparisons with circles, squares, equilateral triangles and rectangles (length = 3 x width) are shown in Table 1. The lower the values of T the closer the fit. For the sample of units examined it can be seen that the (3 x 1) rectangle has the best fit.

TABLE 1 INDEX VALUES FOR THE SHAPES OF TWENTY-FIVE SUDANESE VILLAGES COMPARED WITH FOUR STANDARDS

Village	*Circle*	*Square*	*Triangle*	*Rectangle*
1	0 585	0 580	0 492	0.471
2	.581	.695	.668	669
3	.568	555	.551	293
.				
.				
.				
23	0 636	0 600	0.570	0 381
24	381	415	427	.397
25	.564	647	.521	.331
Mean	0 511	0 527	0.501	0 428

Adapted from Lee and Sallee, 1970

Shape Measures on Non-homogeneous Surfaces

The index that we use to measure shapes on non-homogeneous surfaces is more complex because it has to take into account distributions within the areas. The indices discussed in the last section assume an even distribution of matter within each area. To deal with an area with varying density, the following index can be employed $S_v = \frac{A^2}{2\pi Ia}$, where S_v is a shape measure for a unit with varying density.

Derivation of Shape Measure S_v

We define $S_v = \frac{Ic}{Ia}$, where Ic is (1)

the moment of inertia of a disc around its center of gravity and Ia is the moment of inertia of an *administrative unit* around its center of gravity. Both the disc and the administrative unit are the same area A.

Given that $I_c = \frac{\pi r^4}{2}$ where r is the radius of (2)

the disc,

$$A = \pi r^2 \quad (3)$$

thus

$$r^2 = A/\pi$$

$$Ic = \frac{\pi}{2} \cdot \frac{A}{\pi} \cdot \frac{A}{\pi}$$

$$Ic = A^2/2\pi \quad (4)$$

Substituting (4) into (1) we have

$$Sv = \frac{A^2}{2\pi Ia}$$

Ia is a measure of the distribution around the center of gravity of the unit. It is calculated from the formula

$$Ia = \sum_{i=1}^{n} d_{ij}^2 m_i, \text{ where}$$

the unit is made up of n points, j is the center of gravity and d_{ij}^2 is the square of the distance between each point i and the center of gravity, m is a weight for each point. This measure Ia is called the *moment of inertia,* and it originated in the field of pure mechanics. For our purposes it serves as a useful measure of dispersion of matter around a point. The index S_V expresses the ratio of the Moment of Inertia of a circle of area A, around its center of gravity. S_V can vary from 1.0 for a perfectly compact area, to 0.0 for a long thin strip.

Massam and Goodchild (1971) have developed this index and used it to examine the shape of administrative areas in southern Ontario. They calculated S_V for the administrative areas at different points in time and examined the trend in the spatial organization of areas between 1948 and 1967; this study will be discussed in Part 5.

Spatial Efficiency Measures

Using the concept of Moment of Inertia we can define a measure of spatial efficiency of the location of an administrative center with respect to the distribution of consumers in an administrative area. Figure 1 shows an administrative system with a set of points representing the consumers and the location of the center. The boundaries are also shown.

For each area we can calculate the Moment of Inertia (M); the distances are straight-line distances.

Using $M = \sum_{i=1}^{n} d_{ij}^2 m_i$ as the general formula for calculating the Moment of Inertia, we can apply this to area B.

$$M_B = \sum_{i=1}^{6} d_{ij}^2 m_i$$

$$M_B = (1 \times 1^2) + (4 \times 3^2) + (5 \times 2^2) + (2 \times 3^2) + (6 \times 4^2) + (9 \times 2^2)$$

$$M_B = 207 \text{ units}$$

We now calculate the center of gravity of the distribution of points for area B on Figure 1. We locate the points within a coordinate system and measure the distances a,b,c,d,e and f. The x coordinate of the center of gravity is given by

$$X_{CG} = \frac{(4xa) + (2xb) + (5xc) + (1xd) + (6xe) + (9xf)}{4+2+5+1+6+9}$$

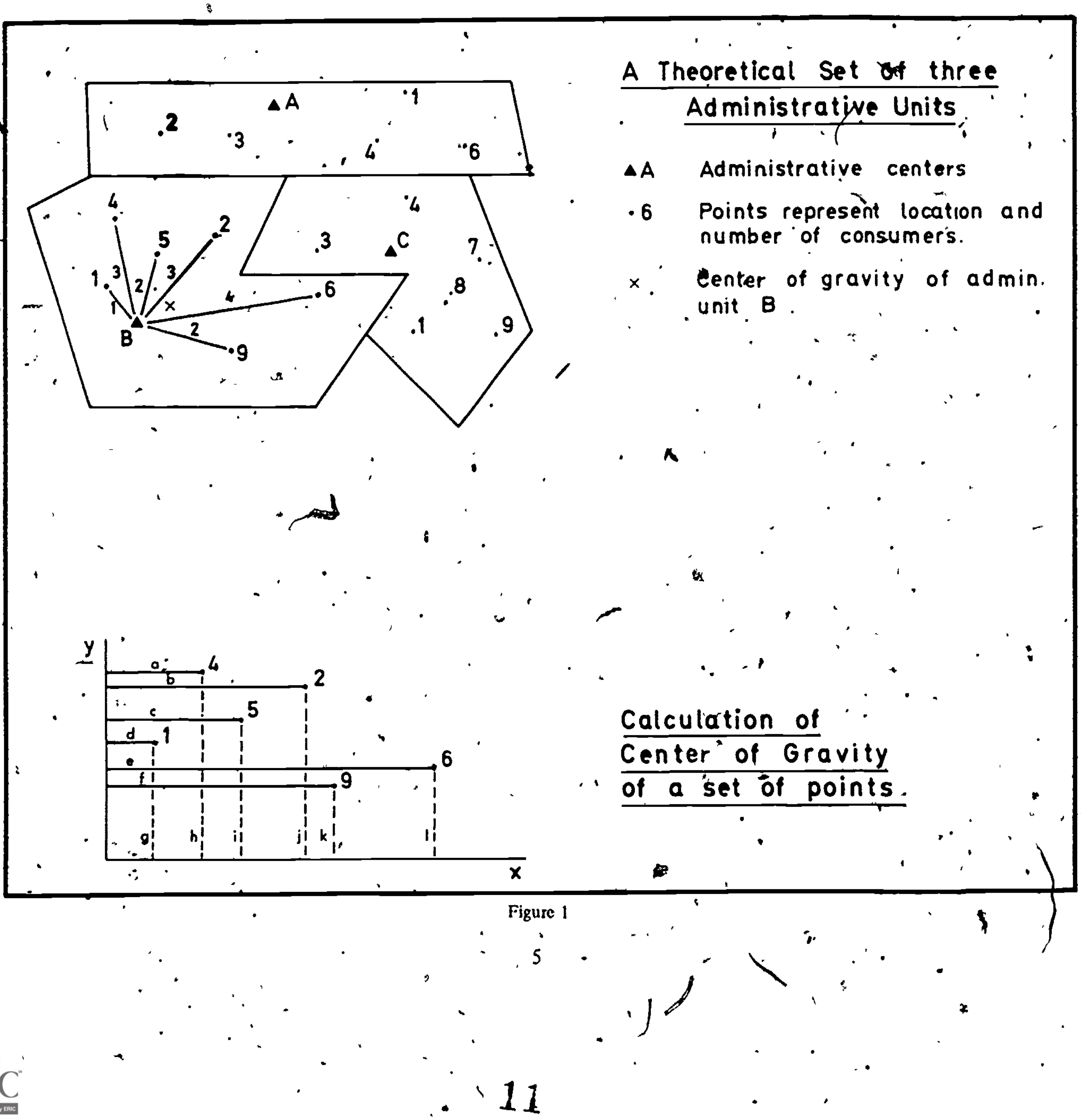


Figure 1

the y coordinate of the center of gravity is given by

$$Y_{CG} = \frac{(1 \times g) + (4 \times h) + (5 \times i) + (2 \times j) + (9 \times k) + (6 \times i)}{1 + 4 + 5 + 2 + 9 + 6}$$

The point (X_{CG}, Y_{CG}) is now marked on the original map of administrative areas. The next step is to calculate the Moment of Inertia of the points around the center of gravity (M_G). This is done using the same procedure as was used to calculate M_B.

It should be noted that when we calculate M_B or M_G we multiply the weight of the point by the *square of the distance*, therefore points which are twice as far from the center carry a weight of four times, and those three times as far carry a weight of nine times. We are biasing our measure by weighting very heavily those points which are furthest from the center. Recently a method has been found to calculate the point within the set of points which minimizes the linear distance to all points. This is the point of minimum aggregate travel (M.A.T.). The technique for determining this point is complex and until now most studies have used the location which minimizes the square of the distance (this is the center of gravity). This is easy to calculate and provides a unique answer, the point of M.A.T. is found on a trial and error basis and there need not be a unique position for it.

We now define an index of efficiency (E) as $E = \frac{M_G}{M_B}$

If this is equal to 1.0 then the actual administrative center is at the center of gravity. As the value of E becomes smaller than 1.0 the distance between the actual center and the theoretically located center at the center of gravity increases.

An empirical study of the spatial efficiency of eight administrative agencies in Ontario has been undertaken by Massam and Burghardt (1968) using the E index defined above. Each agency divides the total area into administrative units and each unit is served from a regional center. Table 2 summarizes the efficiency indices for each agency. The mean value of E for each agency is shown and it appears that the Ontario Hospital Services Commission has the highest level of spatial efficiency, and the Ontario Hydro-Electric Commission the lowest value. The E index provides a standard which can be used as a starting point for further analysis of the spatial structure of administration. If we examine the variation of E for each area and each agency we can evaluate the spatial efficiency which is lost due to choosing locations away from the center of gravity of the population distribution. In this way we can attach efficiency values to specific locations and for the Ontario agencies answer questions such as, what will be the loss in spatial efficiency due to locating centers away from the U.S.–Canada border, away from Ottawa, the Federal capital, near major route intersections, or in a small center such as Belleville? However, as mentioned earlier, the E index can only be used as a starting point. To understand spatial efficiency more completely we have to examine the exchange of the service from the centers to the consumers. Thus for the services which demand physical movement of people or goods, such as hospital facilities or hydroelectric repairs, the spatial form of the unit strongly influences the efficiency. However, where messages are transmitted by mail or telephone we are operating in spaces which cannot be measured in traditional ways, and the E index has no utility. For these services, for example the distribution of welfare checks, the primary concern is to delimit areas with respect to the number of checks to be distributed, so that efficiency can be maximized at the administrative center. Little attention needs to be focussed on the location of the recipients. The problem could be quite different if we are trying to locate welfare centers in cities where counselling is offered. In this case we must consider the location of clients, we are searching for locations that minimize their travelling efforts. This problem in its general form is the *Allocation-Location Problem*. In Part 3 we will examine it with respect to the location of administrative centers and boundaries.

TABLE 2. INDICES OF SPATIAL EFFICIENCY–MEAN E INDEX

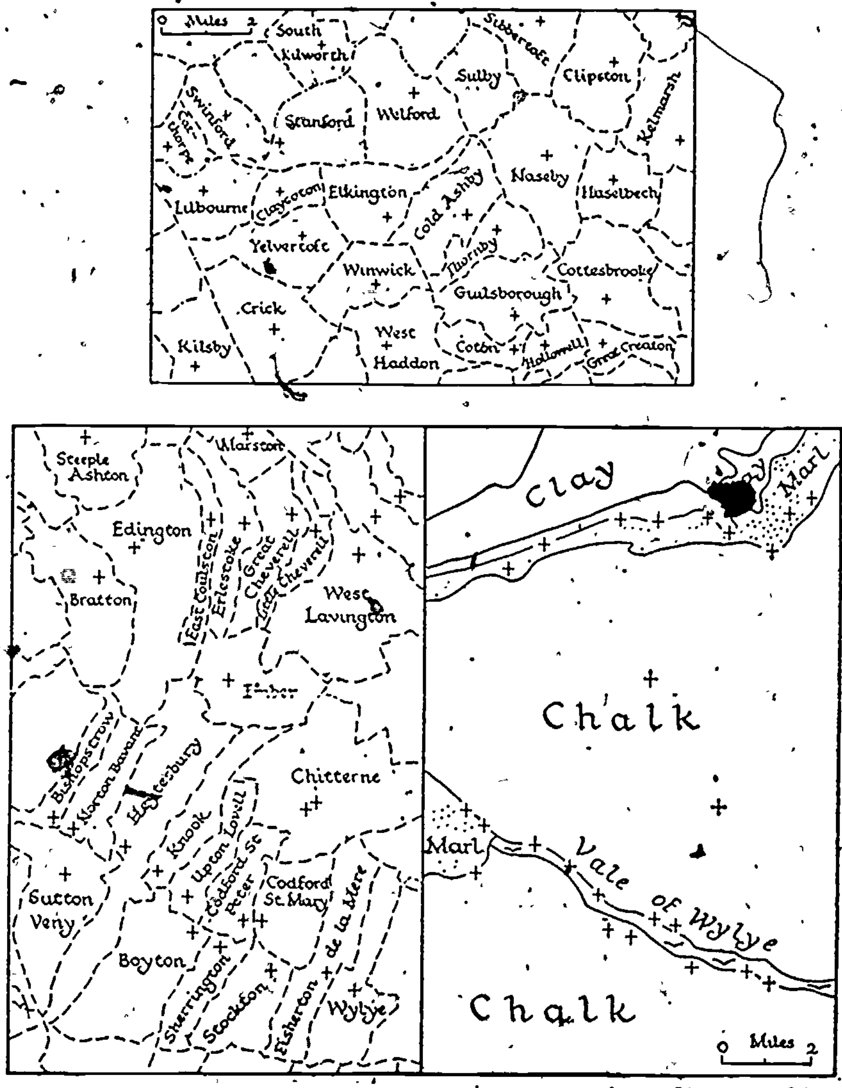
1	Department of Economics and Development	796
2.	Department of Education	.760
3	Department of Highways	.719
4	Ontario Hydro-Electric Commission	679
5.	Ontario Hospital Services Commission	860
6.	Ontario Provincial Police	.732
7.	Department of Public Welfare	717
8.	Department of Transport	776

Empirical Studies

Blair and Biss (1967) calculated a compactness index for parishes, the lowest units in the spatial political hierarchy in Britain. They found that in the county of Cheshire the parishes tend to be fairly regular and compact, whereas uncompact parishes due to elongation are best exemplified in Wiltshire and Lincolnshire. Dudley Stamp (1964) in his book *Man and the Land* provides further examples (Fig. 2). The shapes reflect the initial settlement process of the area. The precise link is clearly stated in the quotation from Mitchell's (1954) book *Historical Geography*.

> "The shapes as well as the sizes of the parishes are illuminating. Where there is little variation in soil the parishes tend to be approximately round or square more or less symmetrically disposed about the village. Most of the parishes of High Norfolk and Suffolk are

Parish Boundaries in Britain



from Stamp, 1964

Figure 2. In each case the cross marks the village church, usually at or near the village center. In homogeneous lowland where surface water is everywhere available, the church or village is centrally placed and parishes are of much the same size. In country of contrasted types the church or village site was dictated by the need for a good water supply and the parishes are long narrow strips, taking in land of varied character.

like this. But where the quality of the land is variable, the parishes boundaries tend to be arranged so that each village has a share of the different soils. Where the structure is a simple tilt or fold and different rocks outcrop in linear bands, the parishes are often a series of long narrow rectangles cutting across the outcrops. The parishes of Lincoln Edge show this arrangement, two great groups meet along the crest. Each parish of the eastern group runs from crest to fenland, including within its boundaries a stretch of downland for pasture, of arable along the dip slope and of fen for meadow in the valley of the Witham, each parish of the western group lies half upon the downland, half in the Trent valley. The villages of both series lie on the spring line halfway along the long axis of the parishes. The parishes of the chalklands of eastern Cambridgeshire show a similar arrangement. In narrow river valleys the parishes tend to be arranged transversely across the valleys, in the upper and narrower parts running right across the valley, in the lower and wider part in a double series each occupying one side of the valley, the river itself forming a common boundary along one of the short sides of the parish rectangle. This arrangement too gives an economic variety of land; upland pastures and water meadows with well-drained gentle slopes between for arable. In areas where one patch of soil is particularly desirable, the parish boundaries often make peculiar patterns so that each may have a share. On Cambridgeshire chalk five villages share an outlying patch of Fenland particularly valued no doubt for its hay meadows and summer pastures as well as its reeds and rushes, turf, fish and water fowl. Where villagers could not satisfy their needs in the immediate area, they sometimes acquired rights to pasture beasts, cut wood, evaporate salt, or mine iron, for example, in an outlying area. Sometimes several villages each some distance away parcelled out among them an area that possessed a valuable local resource. The existence until very lately of small areas detached from the rest of the parish mark these old right of common, in nearby, but not adjacent, areas."

A similar spatial arrangement of territorial units has been identified by Harold Brookfield (1963) in his work on the Chimbu of the New Guinea Highlands. Clan territories lie at right angles to the series of land classes thus ensuring that each clan has a similar distribution of terrain types. A further example is provided by the seigneurial system of land tenure along the St. Lawrence. Colebrook Harris (1966) in his classic study *The Seigneurial System in Early Canada*, suggests five reasons why the elongated rectangle with its long axis at right angles to the river and with a width-to-length ratio of approximately 1·10 was adopted as the basic territorial unit.

1) The strip pattern gave frontage to the major transportation artery (St. Lawrence) and this served as the colony's main street.
2) The elongated shape allowed families to live on their own farms and be close to their neighbors.
3) The rectangular shape permitted rapid and cheap surveying by the seigneur.
4) The strip pattern permitted maximum access to the river for fishing, an important source of food.
5) The strips often included a variety of soil types and vegetation associations.

Finally, Harris notes that it is arguable that strip farms in contemporary Canada are inefficient anachronisms, but in early Canada probably no other shape would have provided so much *net* advantage.

PART 3
THE LOCATION OF ADMINISTRATIVE BOUNDARIES AND CENTERS

We have treated the problem of describing the geometry of administrative units, we have introduced the idea of spatial efficiency and we have noted some relationships between the shape of areas, terrain features and social organization. Now we will turn to the problem of defining administrative boundaries and locating facilities to achieve specific objectives. Abler, Adams and Gould (1971) in their book *Spatial Organization* define this general Allocation-Location problem thus. "How shall we allocate one set of facilities to serve a second set of people?" This is shown diagrammatically on Figure 3. This problem is very common when we realize that "Hospitals must be located in geographic space to serve the people with complete medical care, and we must build schools close to the children who have to learn. Fire stations must be located to give rapid access to potential conflagrations, and voting booths must be placed so that people can cast their ballots without expending unreasonable amounts of time, effort or money to reach the polling stations." (Abler *et al*) .

Because we cannot solve this problem in its most general form we have to limit it to specific sorts of problems. In the next section we will look at some particular solutions to specific problems. However before we do this let us digress for a moment and develop the argument for trying to solve an Allocation-Location problem. There are two reasons other than the intellectual satisfaction which stems from the solution of difficult problems. The first is to determine the location for facilities in our everyday world such that

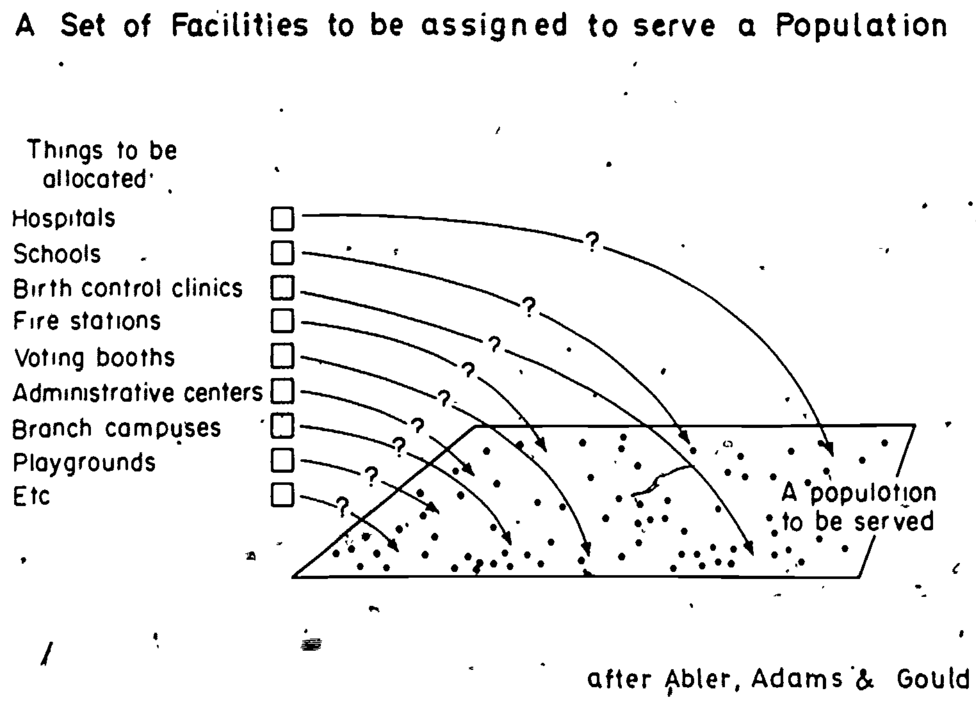


Figure 3

they operate as efficiently as possible and that the influence of space on efficiency is fully accounted for. This may mean for example, for schools, that we want to locate schools so that the average distance travelled by pupils is as small as possible. In most practical cases we try to find locations to minimize travel time, cost or effort in moving to or from a set of facilities. If we can determine ideal or normative locations then we are in a position to examine the differences between these normative locations and actual locations, and thus we can evaluate costs which will be incurred in extra travelling effort to facilities which are not ideally located. This is the second reason for tackling the Allocation-Location problem, and it stems directly from the first. We touched on these reasons briefly in Part 2 when we constructed the E index, which refers to the location of the administrative center with respect to a set of customers. In this part we will examine boundary *and* center locations. To recap, the larger the distance between the actual administrative center and the normative location for the center, the lower is the spatial efficiency of the system. We can turn the problem around by starting with a set of administrative centers and then defining the location of the boundaries so that all people travel to their nearest center. This will give us a highly efficient spatial pattern of administrative areas, but we take no account of the number of people served by each center and hence the work load of each area. This is shown on Figure 4 where the consumers are represented by crosses (x) and the three administrative centers by initials A, B and C.

To define areas for which all consumers travel to their nearest center we follow a few simple geometrical steps.

Step 1 – Draw the lines joining the centers

Step 2 – Draw the perpendicular bisectors of these lines.

Step 3 – Join the perpendicular bisectors at their points of intersection.

The shapes which are produced are called Theissen polygons and they have the property that any point within is closer to the center contained by the polygon than to any other center. Though the condition of distance minimization as stated at the beginning has been satisfied, we find that there is considerable variation between the number of customers served in each area, A serves 7, B serves 16 and C serves only 3. If we want to modify this situation and produce a set of areas such that an average of the distance between the centers and the customers is minimum *and* that each center serves a specific number of customers, then we must use a technique which has been developed in operations research. The tool is linear programming and the particular problem we are dealing with is the *transportation problem* (T.P.)

The problem is set up in the form of a matrix (Figure 5). On one axis we list the alternate centers, in this case A, B and C, and on the second axis we list the set of points which represent the customers' locations which we will call I, II, III and IV. In column R_1 we list the number of customers at each location, the total is 45. In row R_2 we list the number of customers that will be serviced by each center. If we wish each center to service the same number we assign 15 to each. The box at the bottom right-hand corner tells us that all customers have been assigned to a center. By examining all possible allocations from I, II, III and IV to A, B and C so that in each case $R_1=R_2$, and

Construction of Theissen Polygons

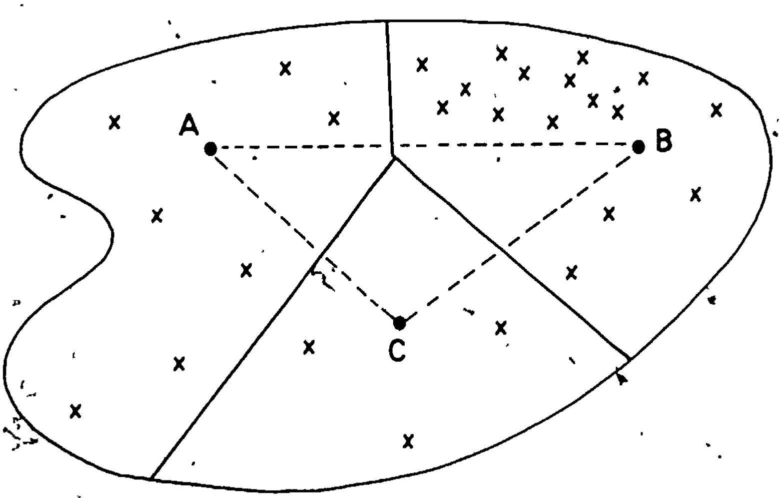


Figure 4

TRANSPORTATION PROBLEM MATRIX

CENTERS

CUSTOMERS' LOCATIONS		A	B	C	R_1
	I				5
	II				10
	III				10
	IV				20
	R_2	15	15	15	45

$(R_1 = R_2)$

Figure 5

knowing the cost of moving people to the centers we can select the allocation which gives us the lowest total transport cost. This is the optimal allocation pattern, and we now know which customers should go to each center. On this basis we can draw the administrative boundaries. A typical result is shown on Figure 6 where each customer is defined by a number which refers to the center he should use. Each center services fifteen customers.

Goodchild and Massam (1969) have used some of these ideas to produce a set of models of administrative boundaries for southern Ontario. They started with a set of 504 points to represent the consumers in the area, equivalent to I, II etc. on Figure 5. Each point was weighted according to the population it represented. Eight administrative centers were used, (the ABC's on Figure 5) and a series of models of administrative areas under different sets of conditions were produced. The maps are shown on Figure 7. Table 3 describes the conditions for each model. In the language of linear programming the conditions are called *constraints.*

On the maps the actual center is marked, and also the point of minimum aggregate travel (M.A.T.). In some cases these are quite close and suggest that these areas have a high level of spatial efficiency. The three maps (ii), (iii) and (iv) on Figure 7 show the sequential solution to the problem of defining the best location of administrative centers *and* boundaries. The procedure for producing these maps is given below as a series of steps.

1. Start with *actual* centers and solve T.P.
2. Draw boundaries of area.
3. Within these areas locate M.A.T.
4. Use M.A.T. from step 3 and solve T.P. as in step 1.
5. Draw new boundaries for each area.
6. Within these new areas locate M.A.T.
7. Continue this sequence until the M.A.T. and the centers from the previous time are at the same location.

Map of Assignment of Points to Three Centers

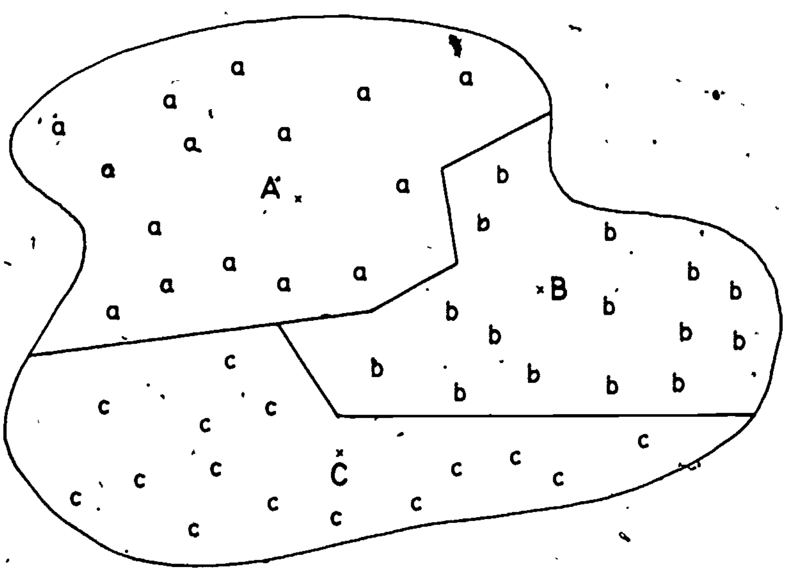
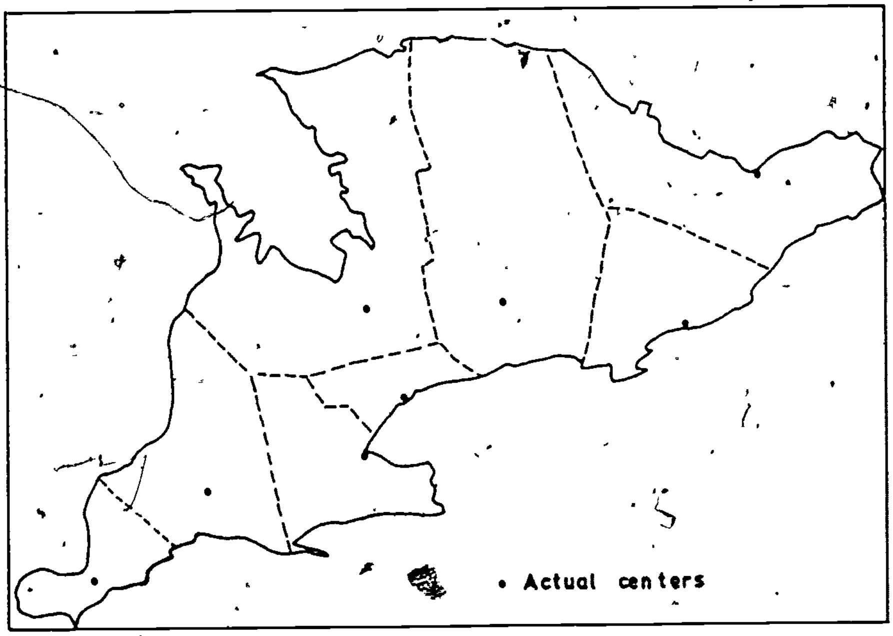


Figure 6

Models of Administrative Areas
S. Ontario

PROXIMAL REGIONS

(i)



OPTIMAL REGIONS - equal population

(ii)

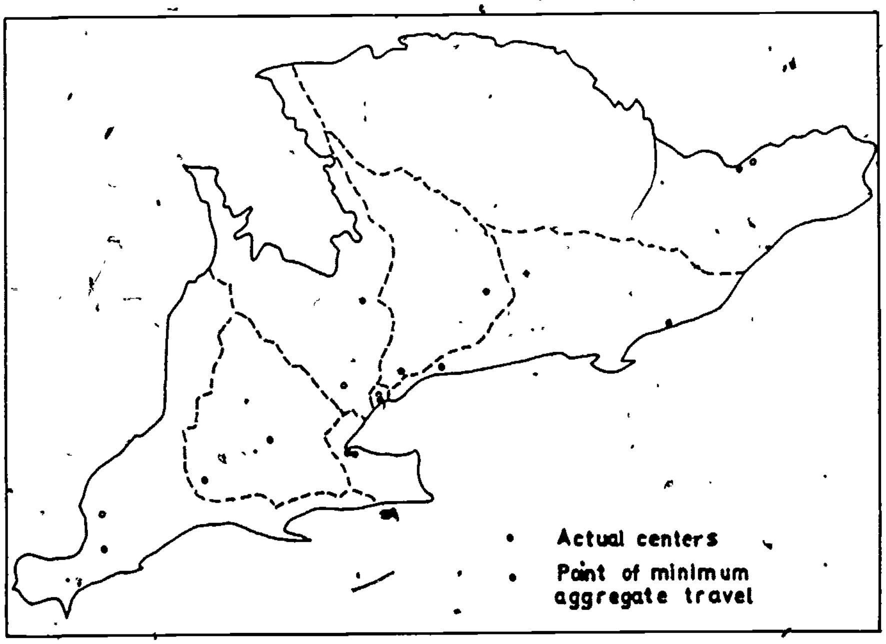
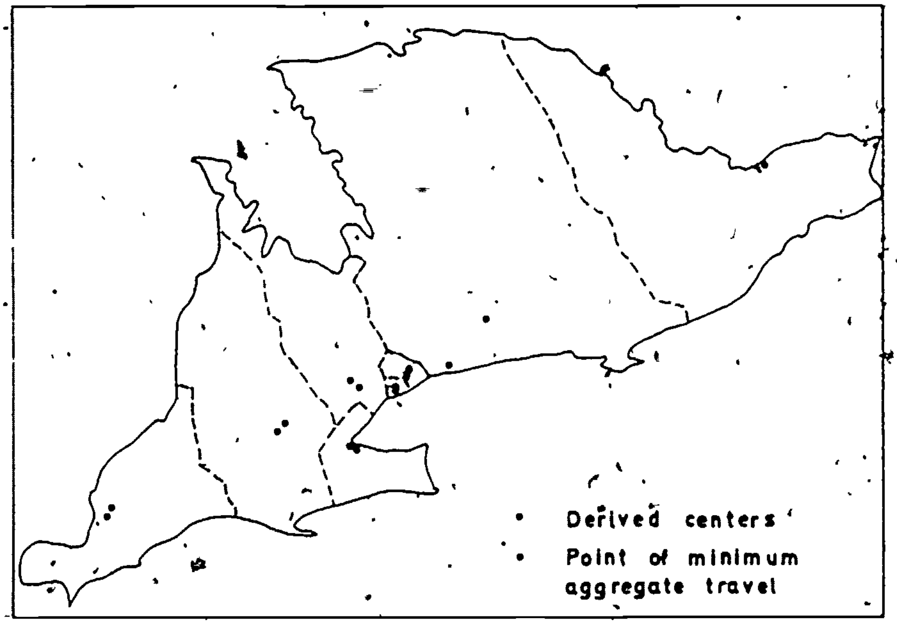


Figure 7 (Boundaries adjusted to township lines)

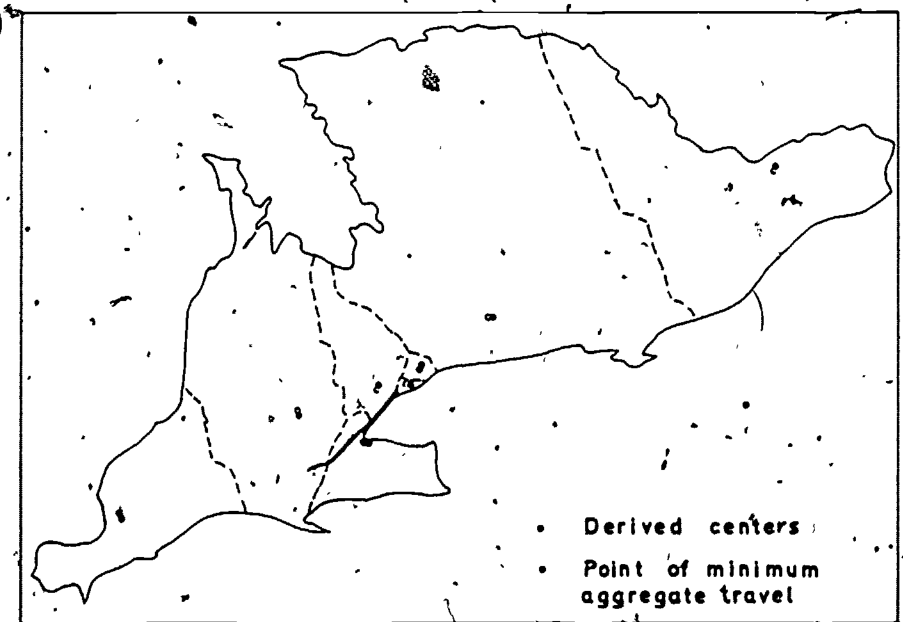
OPTIMAL REGIONS - equal population

(iii)



OPTIMAL REGIONS - equal population

(iv)



from Goodchild & Massam 1969

Figure 7

TABLE 3. MODELS OF ADMINISTRATIVE AREAS. SOUTHERN ONTARIO

Model	Constraints
(i) Proximal	Customers are served by their nearest center, no account is taken of the number of people served by each center.
(ii) Optimal Regions	Each center serves the same number of customers
(iii) (iv)	Boundaries and centers are located in sequence, until the best locations are found

This gives the best location of both centers and boundaries. We should note that each center serves the same number of customers, therefore in the densely populated part of Ontario near Toronto, the administrative unit is small. The map shown on Figure 8 was produced under the constraint that the proportion of customers served by each center was not equal. In fact the proportion served by each center in the model is the same as the proportion served in reality. The proportions are shown on Table 4. Only one map is presented and it represents the end-point of a sequence of three maps which were produced following the steps outlined below. The final positions of centers and boundaries as well as the penultimate location of centers are shown. The numbers shown in each area refer to figures given in Table 4. In this model the administrative units are approximately the same size. The final location of centers and boundaries may be different if we start with a different set of actual locations, and we cannot say if we have found the overall best solution. This we call the *global solution.* However, if the final locations are always in the same place when we start with different sets of actual centers we can be fairly confident that we have identified the global solution.

For each set of administrative areas we have created we can calculate the following indices.

1) Percentage of population served by the nearest center. The higher this value the more spatially efficient is the arrangement of centers and boundaries.
2) The mean distance between customers and their administrative centers. The lower this value the greater the spatial efficiency.

The models of administrative areas described above are

OPTIMAL REGIONS

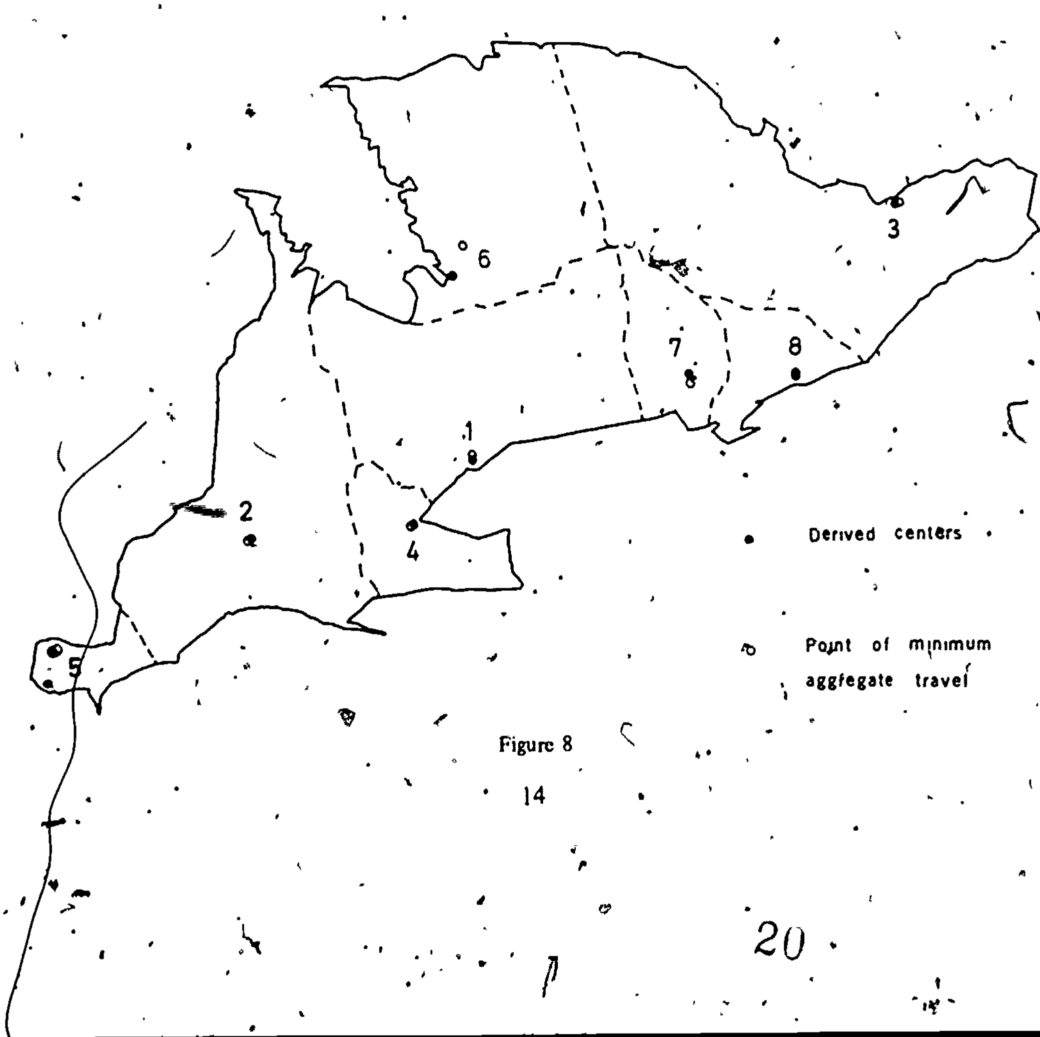


Figure 8

TABLE 4 PROPORTION OF POPULATION IN SOUTHERN ONTARIO SERVED BY A SET OF EIGHT CENTERS

Area	*% of Population of Southern Ontario*
1	50
2	15
3	12
4	12
5	5
6	2
7	2
8	2

based upon specific assumptions. For example, all people in southern Ontario are treated as a set of weighted points, all distances are straight-line distances and it is argued that the most efficient locations of centers are based upon the assumption that the *airline distance* between the points and the centers is minimum. In reality, we have to modify the assumptions upon which we build our models, but at this time we use the strategy of starting with a relatively simple model that we can make operational and then successively modify it to suit our purposes.

Gould and Leinbach (1966) have tackled a similar problem, that of determining the best location of hospitals in western Guatemala. They used linear programming to examine the costs of moving people to a set of possible hospital locations given existing routes. They had to choose the three best locations from a set of five.

First, they assumed that each of the three hospitals had the same capacity. This allowed the problem to be structured as a transportation problem and the optimal flows of patients to hospitals to be calculated. The problem was run ten times to allow all combinations of the five possible locations to be examined three at a time. The set of three locations which gave the lowest transport costs was accepted. The next step was to modify hospital capacities and transportation facilities by examining the map of flows given by the computer By working with the computer and a set of maps, new assignments of patients to hospitals were examined until the lowest cost pattern was determined. The authors stress the importance of this type of objective approach to locating facilities when planning decisions relate to transportation links, hospital capacities and the desire to provide good health services as economically as possible.

The Swedish geographer Godlund (1961) has tackled a similar problem in his country. His task, as a government adviser, was to select eight towns to receive large regional hospitals and to divide Sweden into referral regions around these hospitals. The predicted population distribution for 1975 was used and the problem narrowed down to the selection of two centers from five large towns, Linkoping, Jonkoping, Karlstad, Örebro and Sundsvall. The other six centers were selected on the basis of medical facilities currently available. Travelling times and costs for all possible ways of assigning the two centers were calculated. The two towns which gave the lowest average travel times were Örebro and Linköping, and these two were chosen by the government to receive investments of approximately $40 million. The cost of the research was $2,000. Clearly we have a good example of the way in which a geographer makes a positive contribution to practical planning.

A further empirical example is provided by the work by Yeates (1963). He showed how school districts could be redefined in Grant County, Wisconsin to reduce the average distance travelled by pupils, without altering the capacities of the schools. A saving of $3,000 to $4,000 per year for travelling expenses would result if the new boundaries were used. Busing times and travel fatigue for the pupils would also decrease.

Let us now turn to an administrative unit which has a different function but whose configuration strongly influences the efficiency with which it operates. We are referring to voting districts, electoral units or wards. These spatial units delimit constituencies and groups of voters. There are two distinct ways in which the spatial pattern of the voting unit can influence the choice or significance of the representative. First, if the voting units do not all have the same number of voters then a basic democratic principle, that the total number of representatives should be divided equally among the population, will not be satisfied. In 1962 the Supreme Court of the United States ruled that;

> "The apportionment of seats and districting of states must be so arranged that the number of inhabitants per legislator in one district is substantially equal to the number of inhabitants per legislator in any other district in the same state."

This followed a complaint from a group in Tennessee who noted that one vote in Moore county was equivalent to nineteen votes in Hamilton county, the latter had nineteen times more voters than the former. Silva (1965) has noted some of the most obvious inequalities and she claims that following the initial court case cited above,

> "The arrangements for legislative representation in many states were soon demonstrated to be a wonderland of alleged inequities. The prize went to the state of Vermont, where it was found that the most populous district had 987 times more people than the least populous district."

Second, areas may be defined to include or exclude certain groups of voters, and thus to influence directly the choice of representative. For example, according to Silva

Gerrymandering

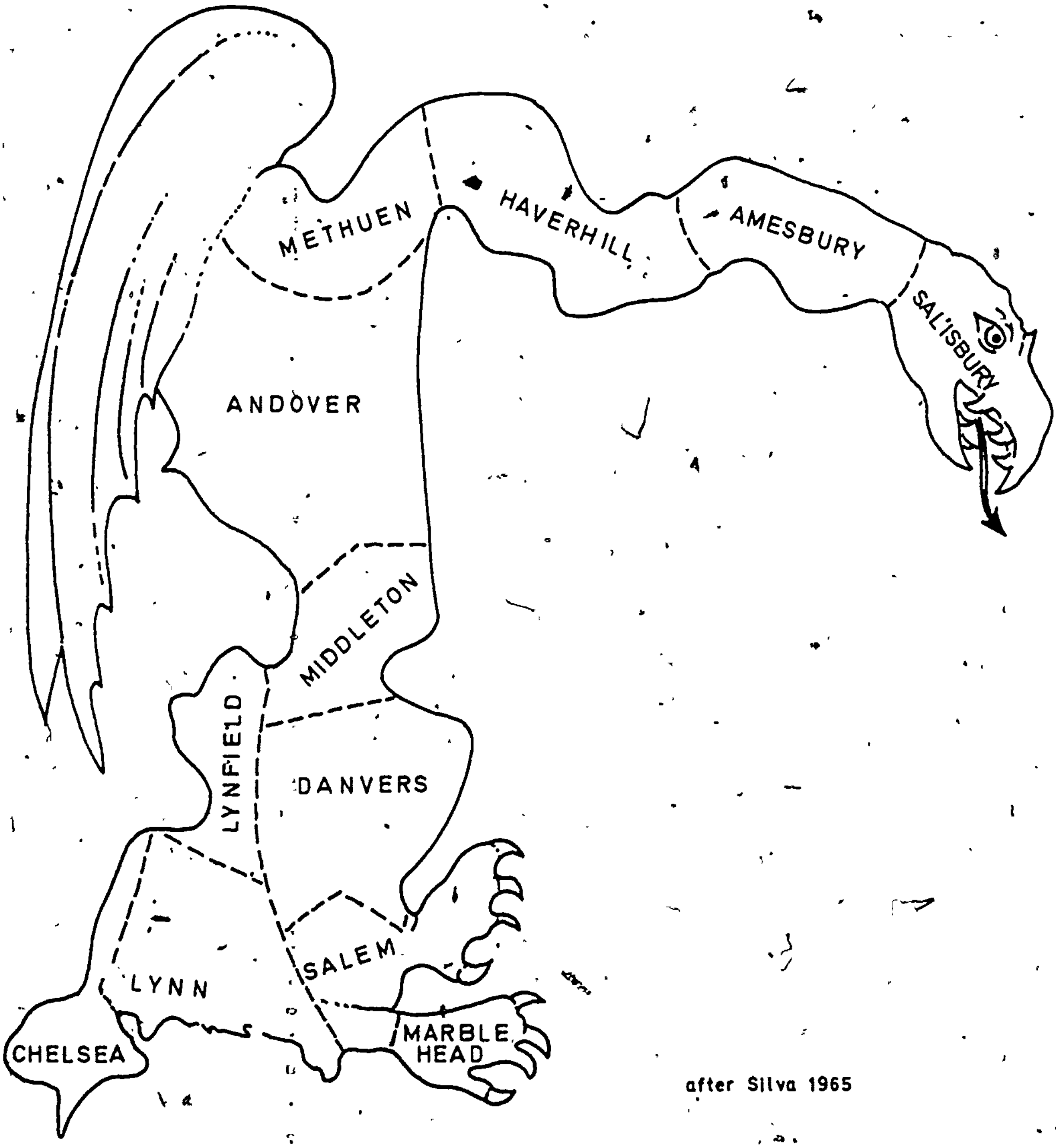


Figure 9. ORIGINAL GERRYMANDER was depicted in the *Boston Gazette* of March 26, 1812 The district, produced by an anti Federalist law setting up the senatorial districts in Massachusetts in such a way as to concentrate the Federalist vote in a few districts, was at first likened to a salamander but later came to be known as a gerrymander after Governor Elbridge Gerry, who signed the districting law

(1965), in South Dakota, (two Congressmen), dividing the state by a north-south line would result in the election of two Republicans, and division of the state into northern and southern halves would probably allow a Democrat and a Republican to be elected. A further example is provided for New York when it was divided into electoral districts by the Republicans. They distributed their vote to gain advantage over the Democrats, in fact the 1962 state senate election was won by the Republicans (33 to 25) though they polled a minority. They won in their districts by an average margin of 20,963 whereas the Democrats won their seats by an average of 27,883 votes.

The manipulation of boundaries of voting districts so as to secure disproportionate influence at election time for a party or social group is called *gerrymandering* (Figure 9).

To produce voting districts which are fair the following criteria should be satisfied.

1) Equal number of voters in each district.
2) Districts should be continuous and not divided by another district.
3) Districts should be as homogeneous as possible with respect to social, political and economic interests. This is probably best achieved by making districts as compact as possible.

While we might all agree that these are worthy objectives, until recently we have lacked a precise method for achieving them. However, with the aid of a computer and a modified version of the transportation problem we discussed earlier we can tackle the problem. Let us state the procedure as a series of steps and assume we are given the number of areas to be created (n) and a map of the basic population units, for example, census tracts. We have to combine population units to satisfy the criteria as closely as possible:

Step 1 Choose an arbitrary set of locations for the centers (n).

Step 2 Solve the transportation problem; this gives us the assignment of population from each population unit to each of the n centers.

Step 3 Combine the population units which have been split, to maintain contiguity of voting districts.

Step 4 Compute a new set of centers for the districts at the center of gravity of each district.

Step 5 If the location of the centers produced in step 4 differs from the old centers go back to step 2, otherwise the procedure has given us a set of voting districts which almost completely satisfies the set of criteria.

This sequence may give us voting districts with slight population variation because the population units have been combined to maintain contiguity.

A practical application of the method has been conducted by Mills (1967). He constructed wards for Bristol County Boroughs in the United Kingdom, for 1954 and 1965. Table 5 compares his set of wards with those actually used. The advantage of the computed schemes is to produce compact contiguous areas with approximately the same number of voters in each district. With the increased use of computers it should be possible to redefine voting districts at frequent intervals to ensure that the shape of the voting district does not unfairly influence the procedure of electing representatives of the people.

TABLE 5. WARD POPULATIONS, BRISTOL COUNTY BOROUGHS 1954 AND 1965

	Actual Ward Boundaries		*Computed Schemes*	
	1954	1965	1954	1965
Average No. of Voters per Ward	11,722	10,600	11,722	10,600
Maximum	14,053	16,234	12,987	12,275
Minimum	4,647	5,687	10,466	9,216

Adapted from Mills, 1967

PART 4
THE SIZE OF ADMINISTRATIVE SYSTEMS

So far we have emphasized the role of space as it relates to administration, and though we have sophisticated methods for evaluating alternate patterns of administrative areas we have avoided problems relating to the size of the administrative unit, the ideal number of customers serviced by a center, the size of the central facility and the number of administrators. Also we have not considered the quality of the service as this is influenced by the accessibility of clients to centers. The interplay between these aspects of administrative systems and the purely spatial elements determine the overall efficiency of a particular system. Now we will examine three aspects of the system which complement the spatial ones treated earlier. Their specific relationship to the spatial form of administrative areas will be outlined. The three aspects are economies of scale, interaction between clients and administrative personnel, and size of organization.

Economies of Scale

Economic theory suggests that there is a relationship between cost-per-unit output of an organization and the quantity of the commodity that the organization produces This relationship is defined by the average cost curve, and in the short-run—that is with no changes in the fixed costs[3] or the size of the production unit—the curve has a U-shape as shown by the short-run average cost curve (SAC) on Figure 10.

In the long-run—that is with changes in the fixed costs, the variable costs[4] and the size of the organization—the average cost curve is the envelope curve of the series of short-run curves. This is the long-run average cost curve (LAC) on Figure 10. The U-shape of the LAC is dependent upon the assumption that as the quantity of output of an organization increases, economies of scale begin to operate and thus manifests itself as a saving in

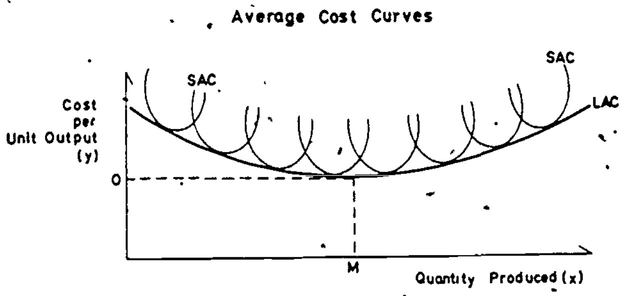


Figure 10

cost-per-unit output. However, after a certain point (M on Figure 10), diseconomies of scale result and cost-per-unit output increases. The optimum point of production is at M and the cost-per-unit will be 0. With respect to services provided for public consumption, if we can determine the cost curve and if this has a U-shape as suggested by the theory, we should be able to determine the best size for the area supplying the service. Best in this case is defined as that area in which the service is provided as cheaply as possible. It is often suggested that administrative areas such as school districts or police districts should be enlarged so as to take advantage of scale economies. In reality, however, there are not many empirical studies of administrative systems which provide us with a clear picture of the shape of the cost curves, and thus it is very difficult to state explicitly exactly how large an area should be to take full advantage of scale economies. The economist Hirsch has set a fine example in these types of studies and Table 6, modified from his work on the supply of public services, summarizes the variety of cost curves found empirically.

The shape of the cost curve can be determined empirically using data for a series of administrative areas at different points in time. (Time-series data). Data for different sized areas at the same point in time may also be used. These we call cross-sectional data. There are practical problems relating to the definition and measurement of output and cost-per-unit, and we should be aware of these before an empirical study is undertaken. Hirsch (1968)

[3] These costs are incurred even if the organization produces nothing, e.g., rents, taxes, depreciation on equipment, interest on capital.

[4] The inputs are paid for by the variable costs and they increase as the output increases.

TABLE 6. COST CURVE STUDIES OF SCALE ECONOMIES

Name and Year	*Service*	*Data*	*Result*
Lomax 1951	Gas	S	AUC declining
Isard-Coughlin 1957	Sewage plants	S	AUC declining
Hirsch 1959	Primary & secondary education	S	AUC approx. horizontal
Hirsch 1959	Fire protection	S	AUC is U-shaped with trough at about 110,000 population
Hirsch 1959	School administration	S	AUC is U-shaped with trough at about 44,000 pupils
Hirsch 1960	Police protection	S & Q	AUC is approx. horizontal
Schmandt-Stevens 1960	Police protection	S & Q	AUC is approx. horizontal
Johnston 1960	Electricity	S	AUC is declining
Nerlove 1961	Electricity	S	AUC is declining
Hirsch 1965	Refuse collection	S	AUC is approx. horizontal
Will 1965	Fire protection	E	AUC is declining–major economies reached at about 300,000 population
Kiesling 1966	Primary and secondary education	S	AUC is approx. horizontal
Riew 1966	Secondary education	S	AUC is U-shaped with trough at about 1,700 pupils
Dawson 1969	Secondary education	S	AUC approx horizontal
Maud Commission 1966-69	Local government	S	AUC inverted U-shape max. value about 60,000 population

Abbreviations S - Statistical data, Q - Questionnaire data, E - Engineering data, AUC - Average unit cost (average cost curve)

Adapted from Hirsch 1968.

deals with these in detail. If time series data are used we must adjust for price differences at the various times using standard prices. Also, when measuring output we must take account of quality differences because absolute numbers, (for example, children reaching grade ten, patient-days in hospital or burglaries-per-month) tend to distort the total picture of output of schools, hospitals and police facilities respectively.

Once we have plotted a scatter diagram of the two variables, quantity and cost-per-unit output, the next task is to search for the best-fit line. This is the line which is closest to as many points as possible.

If our theory is true then this line should be of the same shape as the curve in Figure 10. The equation of this line is of the general form

$$Y = a - b_1 x + b_2 x^2$$

Variations from this line may be due to the following reasons:

1) Economies of scale do not exist, therefore the LAC is a horizontal line—Figure 11
2) Economies of scale operate at low levels or high levels of output—Figure 12
3) Random variation from the U-shaped curve—Figure 13.

If we derive cost curves of the forms shown in Figures

Horizontal Cost Curve

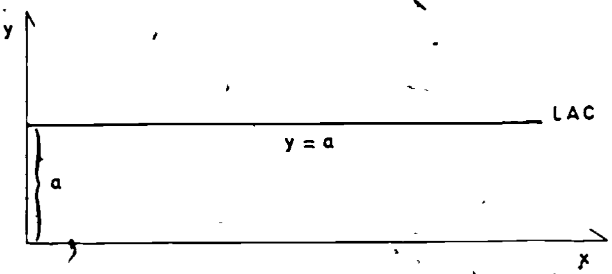


Figure 11

Inverted Cost Curve

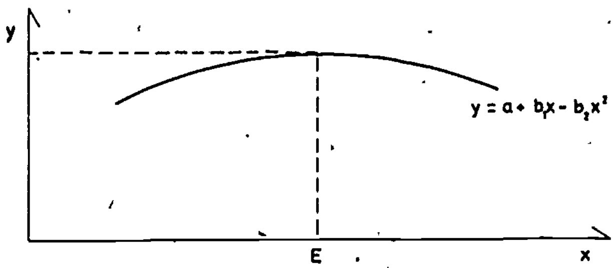


Figure 12. E represents the most expensive scale of production. Any move from this point will cause the cost-per-unit to decrease.

U-shaped Cost Curve

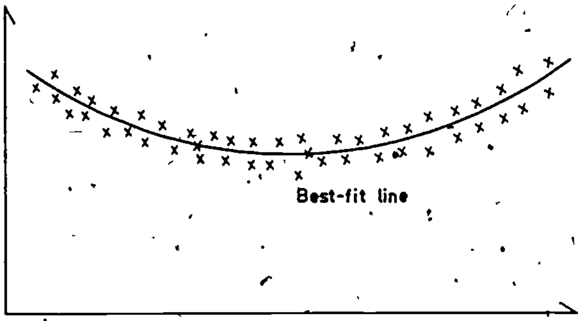


Figure 13

11 and 12, then before drawing the conclusions suggested above we should consider the following question. Do the separate service units operate at the lowest point on their individual cost curves? If not, why not? Can we suggest that variation in managerial skill or administrative ability is causing some service units to operate more efficiently than others? This situation is illustrated in Figure 14. Here we have a set of eight separate service areas (A to H). Each is operating at a different scale and at a different point on its respective short-run average cost curve. In total it seems that we have a relationship as suggested in Figure 12, but closer examination reveals that units A and H are operating near the lowest points on their curves, while D, E and F are operating at much higher points; units B, C and G are operating at intermediate points. Clearly, the next task is to examine the administrative skill in the units and possibly we will find that the more efficient administrators are in units A and H, and the less efficient in the other units. To substantiate this hypothesis we should examine the situation over a period of time and so be aware of seasonal changes and random errors.

Inverted LAC : U-shaped SAC

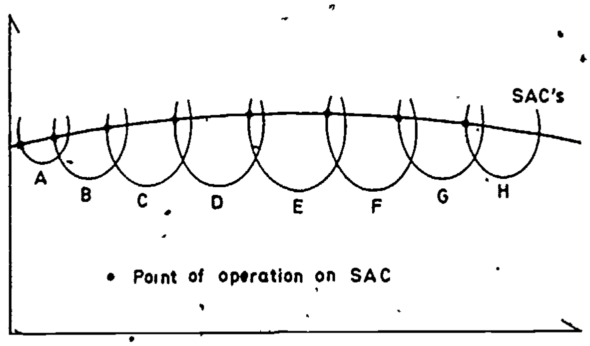


Figure 14

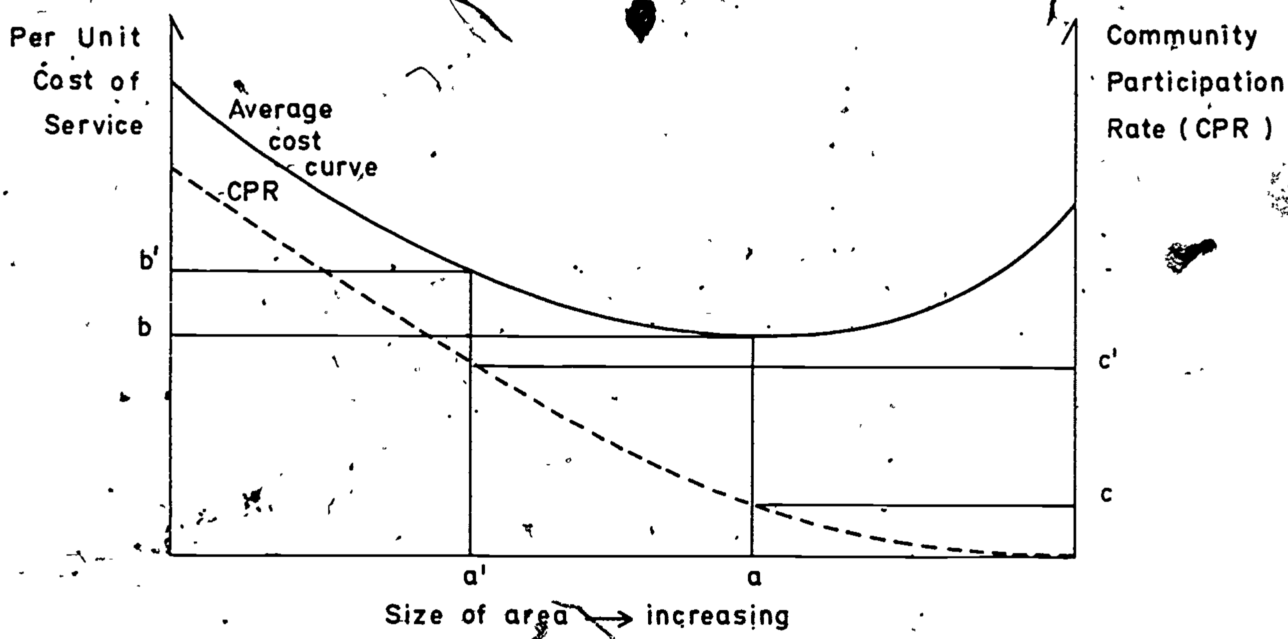
As we increase the size of a service area or an administrative unit we may gain some economies of scale due to specialization of jobs and the use of mass production. However, as we increase the size of the area we increase the demand by adding people and in most cases we have to increase the stock of the commodity which the consumer may require. Let us consider a library facility. We assume that libraries need larger supplies of books to meet the requirements of a more populous area, as the number of libraries is reduced in an area. However, there is a proposition of inventory theory (the square-root theorem) which indicates that for a given level of service the number of volumes need not rise in direct proportion to the number of users of library facilities. The number of volumes should increase in proportion to the square root of the number of users. In fact, it becomes less expensive per capita to provide readers with a wide selection of books as the number of users increases. Now we find ourselves in the position that any savings due to increases in size of area and restriction in the number of libraries must be weighed against the increases in time and effort of the users in travelling to the libraries. This situation is shown graphically on Figure 15. The planner has to balance the two sides, costs of service against quality of service.

Let us now consider the quality of the service provided. Wilbur Thompson, an economist who has done much to advance urban economic theory, stresses that consideration of the quality of a service must play a much more dominant role in economic theory. He suggests that,

> "It is very hard to believe that the consumer-taxpayer will opt for utilitarian public goods (services) to substitute for or complement his high-style private goods."

In an affluent society, communities may opt for local provision of expensive services rather than join with their neighboring community and have a standard service at a lower cost.

With reference to local political jurisdictions, every jurisdiction has a range of services and activities which it has the option to provide for itself within its boundaries. This can be called the option *to make*. The jurisdiction can obtain the service from an outside source; this is the option *to buy*. Assuming the decision is rational, it will be related to a comparison of the costs and benefits of each option. Such costs and benefits are often difficult to determine, for though they can primarily be expressed in dollars and cents, as soon as they reach the decision-making arena they often gain parameters less readily definable. Mowitz (1965) has drawn a distinction between *efficiency values* and *boundary values*. The former he associates with an economic analysis of the comparative costs involved in the *make* or *buy* alternatives. The latter are determined by answering the



At area size a, the least-cost-per-unit level is achieved (b) and the participation rate is at c. If area is changed to size a', then cost-per-unit increases to b' and the participation rate to c'. The decision-maker must choose between alternate sizes, given cost data and participation rates.

Adapted from Isard 1960

Figure 15. Cost versus Quality of Service

question. do the efficiency values warrent giving up the political decision-making discretion associated with retaining the total operation within the boundary of a single jurisdiction? The boundary values, therefore, are those associated with the doctrine of local autonomy. If it is determined to be worth more to make within one's own jurisdiction regardless of the economies of buying outside, boundary values are greater than efficiency values. Metropolitan complexes and contiguous jurisdictions, together with economies of scale that accrue to larger-scale organizations, have encouraged make-or-buy decisions to become a common feature of contemporary urban politics. Wheaton (1964) has noted that despite the apparent chaotic pattern of political communities in American metropolitan areas, and given the lack of substantive evidence on scale economies, coordinated efforts between political communities are not uncommon. He offers a set of propositions explaining inter- and intra-community cooperation, in terms of networks of influence. Such networks develop from convergence of interests within and across political boundaries. Morando (1968) has examined inter-municipal cooperation in the Detroit Metropolitan Area, and his study shows that though communities cooperate, and services are transferred across municipal boundaries, this has not led to loss of political autonomy within each municipal area. The communities he examined appear to enjoy the best of both the political and economic worlds. Williams (1965) has reviewed inter-municipal cooperation in the Philadelphia area for a variety of functions and he suggests that the "higher" socio-economic communities try to maintain control of the provision of their services, and communities with similar socio-economic status tend to cooperate.

It appears that in many cases within the North American context, boundary values are considerably stronger than efficiency values, and this applies particularly to services which evoke personal sentiments, such as education and police protection. The provision of water and sewage systems tends to be weighted more towards efficiency values. However, before explicit recommendations can be made about amalgamation of municipalities much more information is needed on the shape of the cost curves for public utilities.

Interaction between Clients and Administrative Personnel

When a client arrives at an administrative center to receive a service, the speed with which the service is provided strongly influences his impression of the efficiency of the system. In this section we will examine this point in some detail; and while it is true that the time a client waits for a service is not directly related to any spatial variable. it may influence the quality of the service as a whole, and hence the efficiency of the administrative system. Further, the length of time a client has to wait probably influences the decision whether to come to the center. These considerations should be clearly understood when service areas are defined and centers are staffed. For example, if we wish to locate welfare centers or health clinics in an urban area, then to help us determine how large the centers must be and how many centers are to be located we need to know the frequency with which clients are likely to visit a center. Insufficient attention has thus far been focussed on this aspect of the spatial structure of administrative areas.

The interaction between clients and administrative personnel can be conceptualized into four stages as shown on Figure 16. In general, customers arrive at varying time intervals, and as the time to serve a client tends to vary, in consequence the time spent waiting varies and a queue may be generated. The size of the queue should determine the size of the waiting facilities and will probably influence the customer's decision to wait. Further, if there are no clients waiting then the server at the center will be idle, i.e. not serving clients. We can describe the basic stages of the process in subjective terms, but for a more rigorous treatment we must turn to a branch of operations research and to the field of queuing theory.

Suppose that customers arrive at intervals of 4, 5, 9, 3, 2, 6, 10, 9, 1, 3 (minutes). From this we can calculate the *average interarrival interval.* This is 5.2 minutes. Using a similar procedure we can calculate the *average service time* (average time taken to provide a customer with a service). Let us assume this is 4.6 minutes. We are now in a position to calculate the *traffic intensity*, ζ. This is defined as

$$\zeta = \frac{\text{average service time}}{\text{average interarrival interval}}$$

and for our problem

$$\zeta = \frac{4.6}{5.2} = 0.88$$

In a simple administrative system with a single service point, such as a doctor's office with only one doctor on duty, a value of ζ less than 1.0 indicates an absence of a queue *if the service times and arrival times are constant.* However, in most cases these times fluctuate and if we know the distribution of arrival times and service times, we can calculate the *average waiting time* (this includes the time being served). A typical curve of an arrival distribution is given on Figure 17. Using empirical data we can determine the shape of the distribution. On the graph we can see that the shortest interarrival time is 0.5 minutes (point A) and all other interarrival times are equal to or greater than this. Point C indicates the largest interarrival time. This is seven minutes and there are two customers which fit into this category.

On the scatter diagram a smooth curve has been drawn and this closely approximates the distribution. The equation of this line is $y = e^{-at}$ where y is the cumulative relative frequency, t is the interarrival time, e is a constant (2.7182) and a is a coefficient which gives a particular form to the curve. This type of distribution is known as the *negative exponential* and it is quite common in queuing situations to find an equation of this form that describes the arrival time characteristics of consumers, and also the variation in service times. Turning to the hypothetical example and assuming negative exponential arrival and service characteristics and a single service point, we can calculate the customer's average waiting time, A. This is given by the equation

$$A = \frac{1}{1 - \zeta} \times (\text{average service time})$$

Using the empirical data

$$A = \frac{1}{1 - 0.88} \times 4.6 \text{ (minutes)}$$

$$= 38.33 \text{ minutes}$$

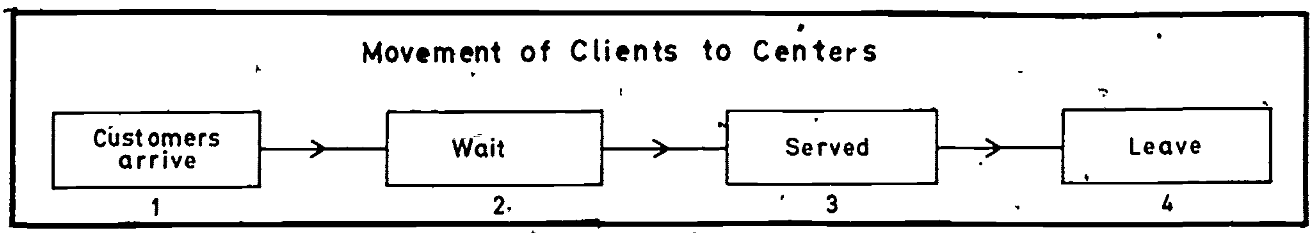


Figure 16

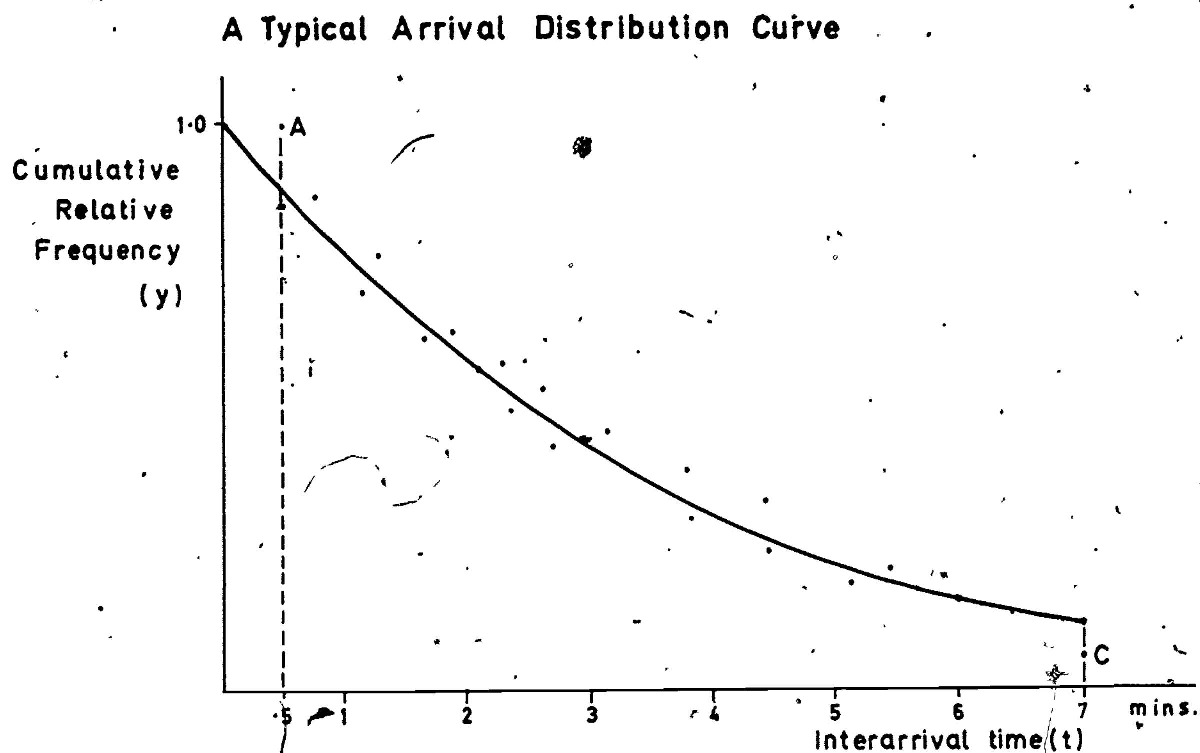


Figure 17

In practice A should be calculated over a long period of time, not with only a sample of ten values. With a traffic intensity of 0.88 a slight increase in the average service time has the effect of sharply increasing the average waiting time. In the case of an average service time of 5.0 minutes rather than 4.6 minutes, the average waiting time increases by four minutes, and if the service time increases to six minutes, this moves A to over fifty minutes. The general relationship between traffic intensity and mean waiting time (average waiting time divided by average service time) is show on Figure 18. Note the waiting time here *excludes* the time spent receiving the service. In general, as the traffic intensity approaches 0.7 the sensitivity of the mean waiting time rapidly increases. Clearly, information on the waiting time and traffic intensity of a variety of administrative structures is needed before we can select the one which provides a predetermined level of service to clients.

Size of Organization

The purpose of defining administrative boundaries is to delimit a group of clients and thus to define a demand area with a certain work load. The interaction between clients and centers has been examined in the last section with respect to the arrival characteristics of clients. In this section we examine the problem of determining how many administrative personnel are needed to handle a specific work load, irrespective of whether there is physical movement of people to or from centers. If we can measure the efficiency with which different sized work loads are handled, then we can determine an optimum size work load This we can use to determine the size of administrative areas. As with the last section, this aspect of the spatial structure of administrative systems has been barely touched on by geographers.

Let us divide administrators into two classes, supervisors and non-supervisors. The first group includes those who make the major decisions, and the second group includes the clerical and ancillary staff. Pondy (1969) has tackled the problem of analyzing the administrative efficiency of organizations and he suggests that,

> "A theory of organization structure ought to explain why the relative size of the administrative component [supervisors] varies so widely across organizations – and should have something to say about the optimum administrative intensity [the number of supervisors] for a given industry or organization, i.e. optimum in terms of maximum efficiency or profit for a given level of operation."

Pondy examines the relationship between size and complexity of an organization and administrative intensity. He defines administrative intensity as the number of managers, professionals and clerical workers divided by the number of craftsmen, operatives and laborers employed by

Relationship between Traffic Intensity and Mean Waiting Time

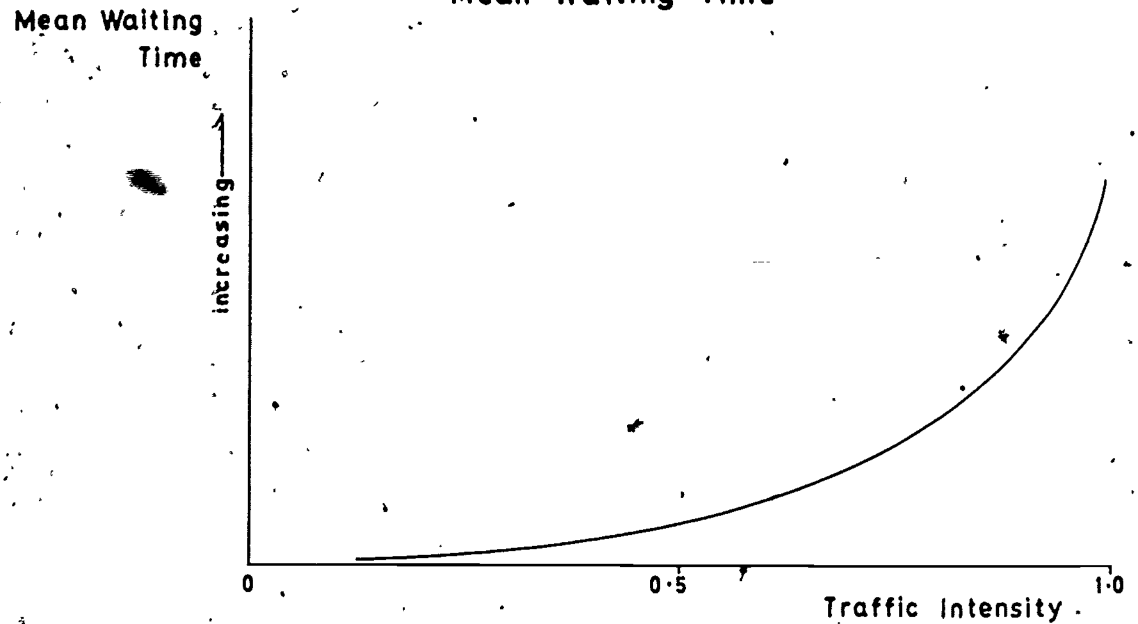
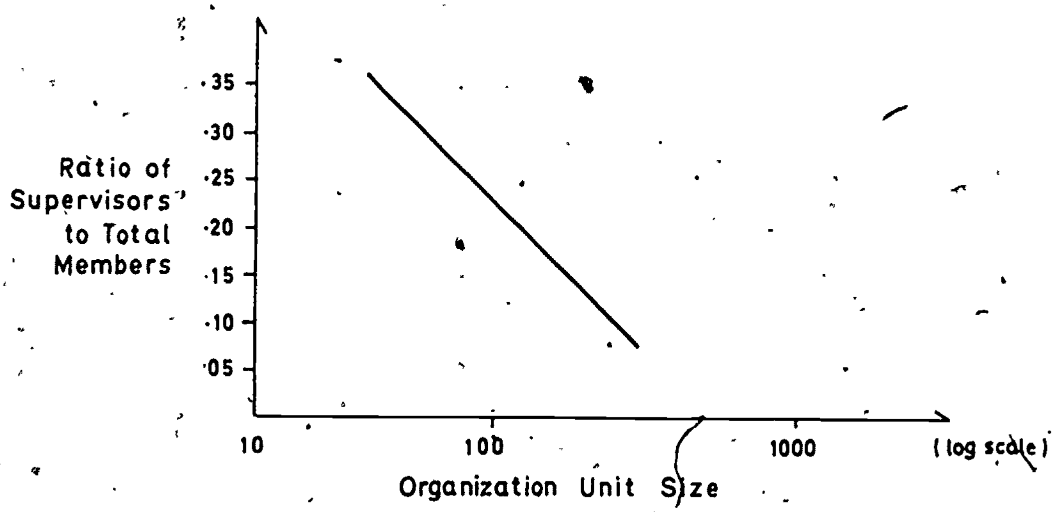


Figure 18

Relationship between Organizational Size & Supervision Ratio



Source: adapted from Indik

Figure 19

the organization. We could replace this by the number of supervisors divided by the number of clerical and ancillary staff. Supervisors, administrative personnel in Pondy's paper, are considered as a factor of production, together with the traditional inputs of labor and capital. This can be stated in the form of the functional relationship,

$$Q = f(K,L,A) \text{ where}$$

Q is the total output, L is the number of production personnel, K is the capital and A is the number of supervisors, f tells us that the value of Q is related to the values of K,L and A. Following the rigorous formulation of a model of a production process which included K, L and A and maximized Q, the output, Pondy tested his formulation against empirical data for forty-five organizations in America. He concluded that, ". . .administrative intensity is found to decrease with organization size . . . ." This finding agrees with that of the psychologist Indik (1964). He studied five sets of organizations and found that the relationship between organizational unit size and supervision ratio is logarithmic in form and negative in slope. Figure 19 illustrates the empirical relationship Supervision ratio was defined as the ratio of supervisors to total employees, and organizational unit size was measured by the number of employees,

The findings of a third empirical study, by Terrein and Mills (1955) contrasts with the two cited above. They conclude from an analysis of the organization of school districts in California, that as the size of the school district increases, the ratio of administrative personnel to total members increases.

In conclusion we can suggest that much work lies ahead of us before we can state clearly the optimum number of supervisors and non-supervisors necessary to achieve maximum efficiency at the administrative center. A start has been made. In order to plan new administrative areas, to recommend amalgamation of areas or the decentralization of facilities, more information is required, if we are to make plans based upon objective reasoning rather than on pure subjectivity. The field is peripheral to traditional geography but command of it is essential if we are to examine thoroughly the structure of administrative systems

PART 5
THE EVOLUTION OF ADMINISTRATIVE SYSTEMS

The evolution of administrative systems can be examined from two main standpoints. The first refers specifically to the spatial pattern of areas and the second considers temporal changes in the control and organization of the system. We will place greater emphasis on the first, but we should recognize that changes in the spatial pattern over time are often strongly related to the style of organization of the system and the control mechanism. For example, a powerful individual at the head of a government agency may feel that school boards should be amalgamated and made large, thus during his period of office we note this trend in the evolution of the spatial form. At another time local citizen groups and parents' associations may be able to marshall support for a plan to maintain local control of small school boards, therefore during this period we note the persistence of many small school boards. In reality the competition is often between several groups, not just citizens against one government official. This competitive framework underlies most decision-making, and it is felt by social scientists that it is so important that if we are to understand and explain how decisions are reached we must frame the decision-making process into a type of competition or game. An example of the game theory approach to decision-making and administration will be given later in Part 5.

We will start by examining some of the purely spatial aspects of administration. The shape and size of administrative areas tend to vary over time. For example, in Brazil, there were 1,761 municipalities in 1950 and by 1960 the number had *increased* to about 3,000. An example of a *decrease* in the number of units over time is provided by the amalgamation of school boards in Ontario. In 1945 there were 5,649 separate public and secondary school boards in the province, but by September 1967 there were 1,446 operating school boards. A similar example is provided by the independent school districts in America where consolidations have reduced the number of independent districts by about 75% since 1942.

Because the restricted length of this Resource Paper does not allow a full examination of a variety of different types of administrative systems, we will concentrate on some general principles and basic ideas. The application of these generalities to a selection of empirical studies will be made to clarify the main points. The process of spatial evolution of an administrative system can be divided into a series of stages. These are summarized below.

A CONCEPTUAL FRAMEWORK FOR THE SPATIAL EVOLUTION OF ADMINISTRATIVE SYSTEMS

Time	*State of the Area*	*Stage of Administrative System*
t_1	Unknown and unsettled	No spatial units
t_2	Explored, but unsettled	Some boundaries may be shown on maps to claim sovereignty of area.
t_3	Settled in part	The settled part may be subdivided into distinct units.
t_4	a) Expansion of settlement	New areas defined
	b) Density of settlement increases	Subdivision of existing areas to maintain small units.
t_5	a) Density of settlement increases	Amalgamation of small units to take advantage of economies of scale.
	b) Communication systems improve with transportation innovations	Centralization and standardization in the quality of the administrative service.
t_6	Modification of demand and supply as values change, population density changes and distribution mechanisms change	Areas may be modified to amalgamate different functions. Areas may be kept at a level which *explicity* does not take advantage of economies of scale, but provides local standards of service. Affluence of communities may encourage quality to dominate quantity–cost considerations of pure economic reasoning.

The stages outlined in the conceptual framework can be considered as a sequence of results in a competition between a completely centralized administrative system with a single administrative center and no local subdivisions, and complete decentralization, whereby each individual provides all the goods and services he requires.

Let us now tackle the problem of trying to identify and explain specific trends in the spatial organization of an actual system. We are given a set of maps for a series of points in time, for example, a twenty-year period, and we know that once a year decision-makers have the option to redefine the administrative units. Areas may be amalgamated, new areas may be created or administrative centers may be relocated. For each year, and for each administrative area, we have data on the number of clients, the demand for the service, the location of the center, and the boundary locations.

Figure 20 shows maps of a system in 1948 and in 1967. It is clear that between these two dates the number of areas has decreased, and the average size has increased. This general trend is typical of many spatial administrative systems. The earlier phase, showing an increase in the number of areas as noted in the early stages of the conceptual framework, is embedded in this gross trend The maps on Figure 21 illustrate this process in Santa Catarina state, Brazil, between 1872 and 1960. They illustrate that as the population density increases the number of areas increases. If we were able to examine all the maps in the period between 1948 and 1967 (Figure 20) then some interesting facts would emerge. However, Figure 22 shows the trend in the number of areas over this twenty-year period. Comparing this to the conceptual framework, 1948 can be taken to represent stage t_3, and 1953 stage t_4; from 1953 to the present we see stage t_5 and the beginning of t_6.

The next step is to measure the shape and the spatial efficiency of each area for each point in time and then

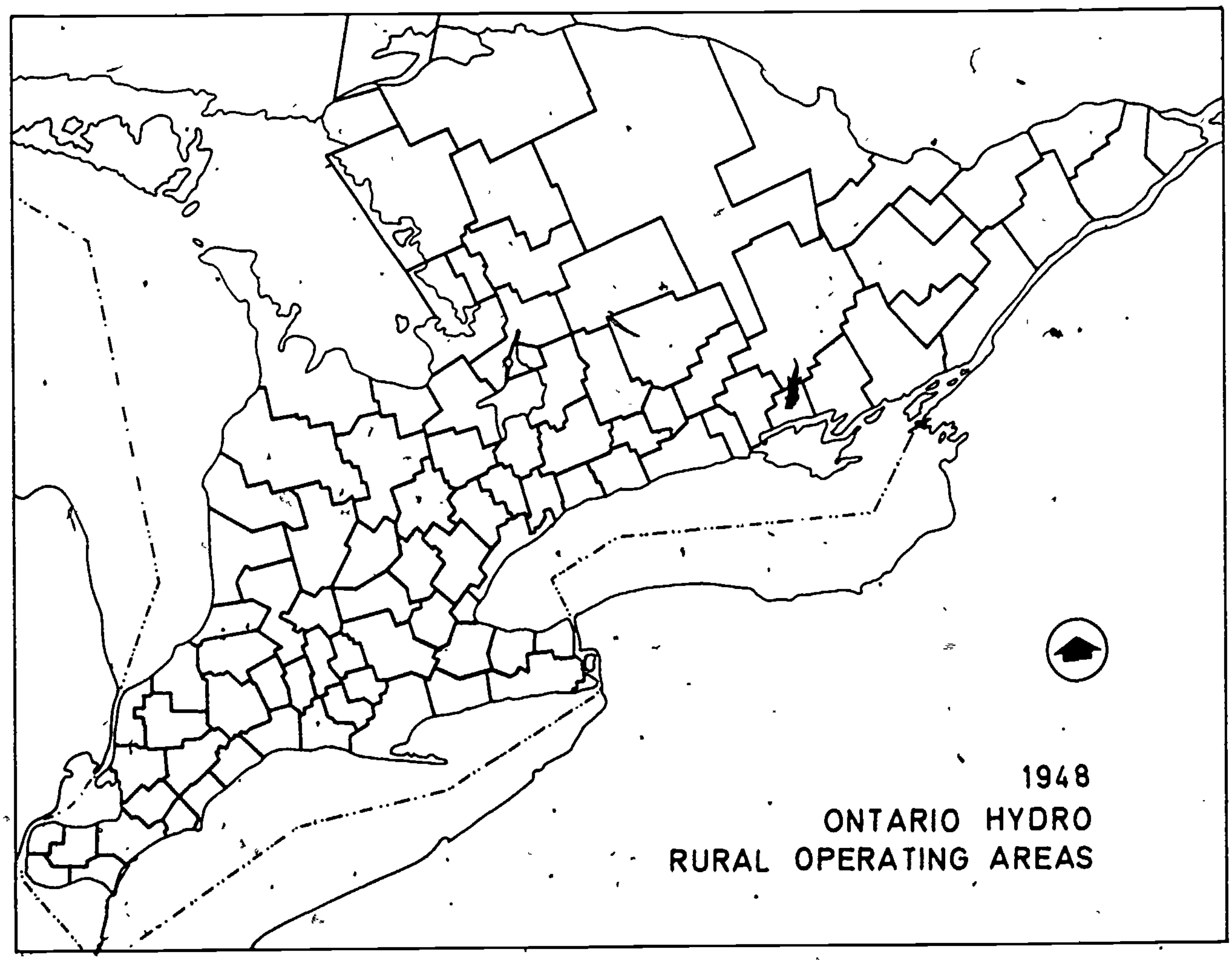


Figure 20

search for trends. The shape measures, $S = \frac{A^2}{2\pi Ia}$ and the efficiency index, $E = \frac{M_G}{M_B}$ can be used. They were discussed in Part 2.

The values for all areas at each point in time are calculated and the average value taken to represent the *state* of the administrative system at that time. Figure 23 shows the trend of S and E between 1948 and 1967. To test if the trends are significant we must use an objective method, and because we have no reason to expect a straight-line trend (linear trend), we should *not* compare actual trend to a straight line using linear regression. However, we can determine if the trend is monotonic, that is, consistently *increasing* or *decreasing* using the Spearman Rank Correlation test. Here we rank the value for E and S. We actually obtain and compare these to a rank of 1 to 20. The latter refers to a ranking of the years 1948 to 1967. If the two *ranks* are identical then the Spearman Rank Correlation Coefficient, r_s, is 1.0. This indicates that the trend is monotonically *increasing*. If a value of -1.0 is calculated, we know that the trend is monotonically *decreasing*. When we calculate r_s we have to test if this value could have occurred by chance. If so, the trend is not significant. For the example considered here we assign a significance level of 0.05 to r_s. If the r_s we calculate is greater than r_s at 0.05, we conclude that the actual trend is significant and has a low probability of occurring purely by chance. In Figure 23 we note that the trend of E is significant, and over time the aggregate spatial efficiency of the system is increasing. If we look more closely at the trend for E we note that an increase in efficiency between 1948 and 1955 was followed by a sudden drop and then a further increase. A second sudden drop occurred between 1962 and 1963, and an

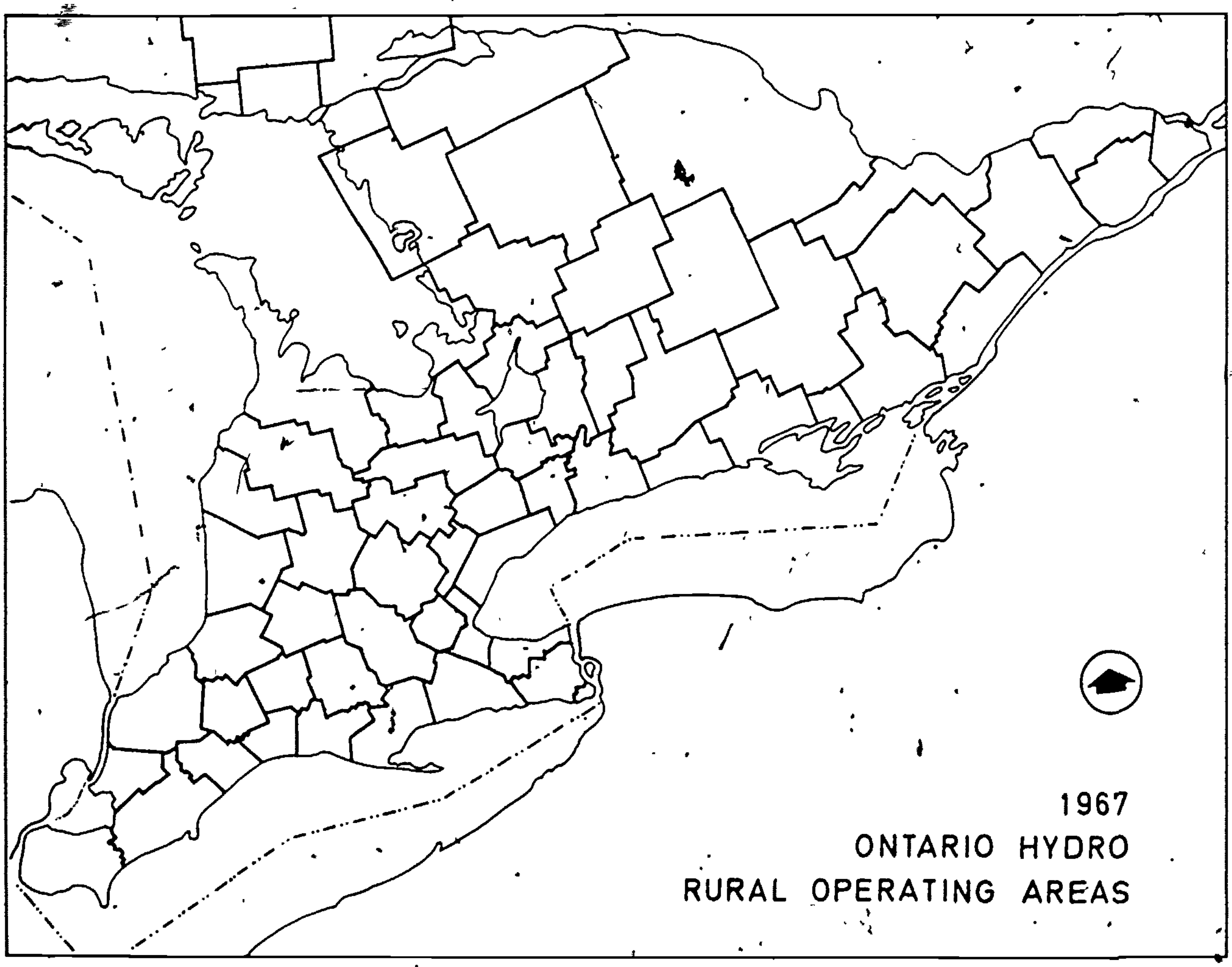
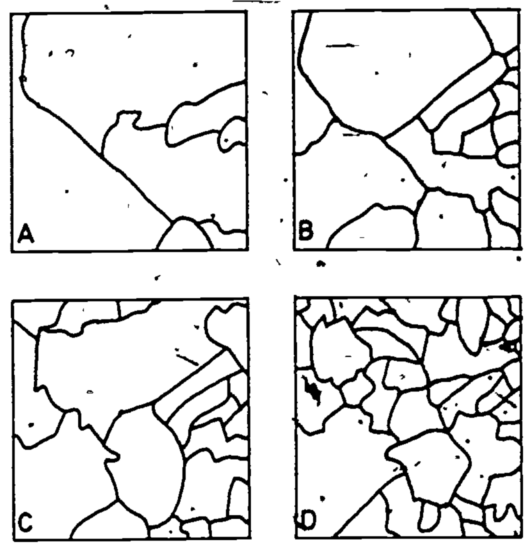


Figure 20



Progressive territorial subdivisions of sample quadrat
Santa Catarina state, Brazil.
A - 1872 B - 1907 C - 1930 D - 1960

Adapted from Haggett 1965

Figure 21

Trend in the Number of Administrative Areas, 1948 - 67

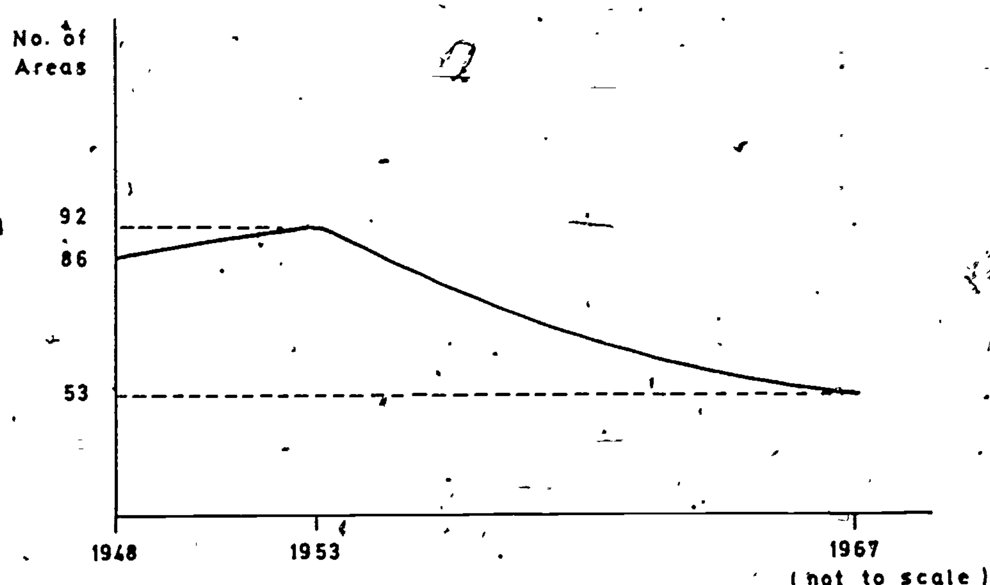


Figure 22

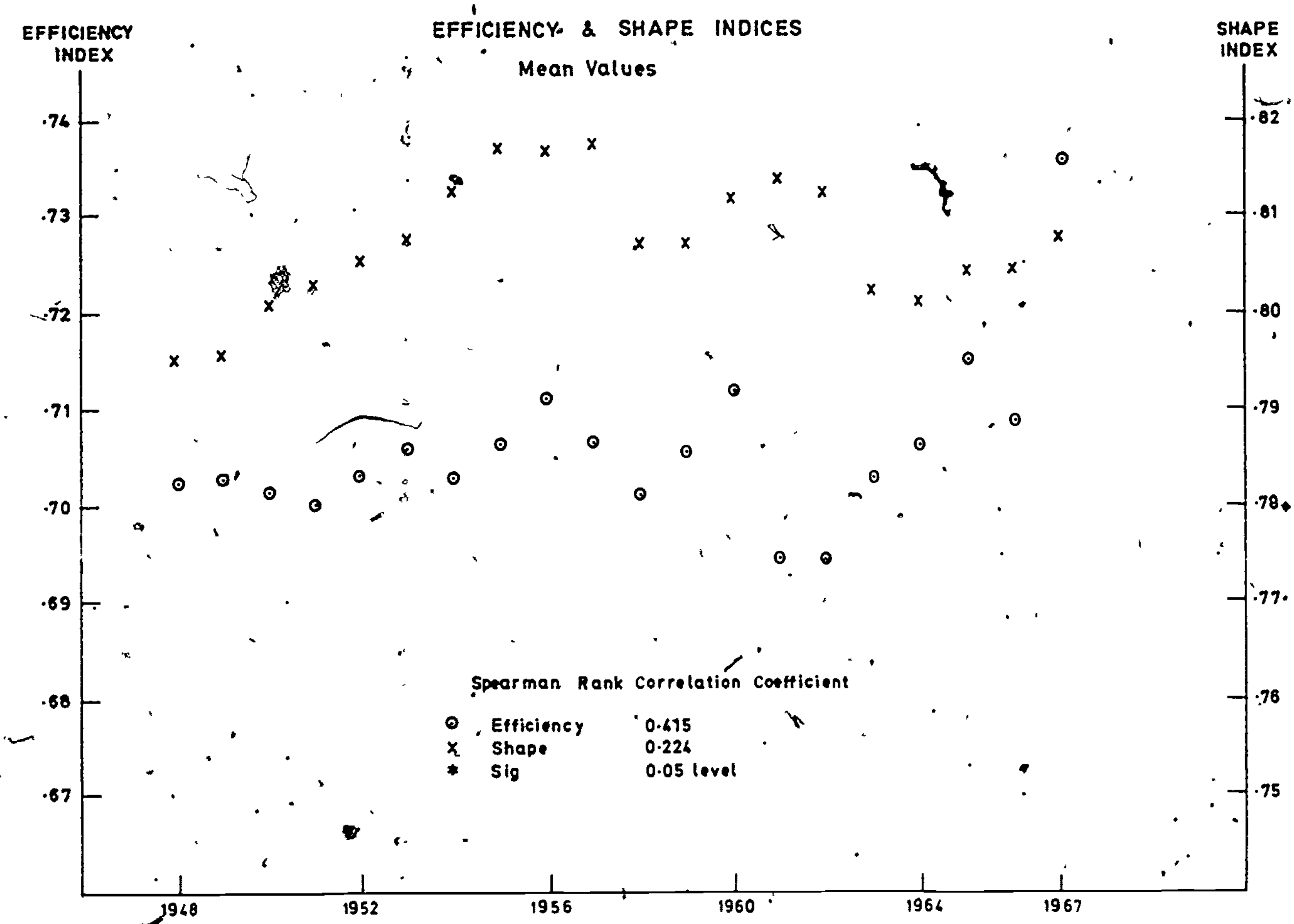


Figure 23

increase in the period immediately after. This is suggestive of a cycle of increases and decreases. We could follow this hunch and apply an objective method to determine how frequently the low points and high points occur in this trend. However, to search for a cyclic trend we need data for a longer period of time; twenty data points are insufficient.

The shape index S does not illustrate a monotonic trend, but again is suggestive of a cycle of high and low points. The basic conclusion that we might put forward from the monotonic trend analysis is that when areas were redefined in the period 1948 to 1967 the overall trend was to improve spatial efficiency and this did not produce any noticeable monotonic trend in the geometrical properties of the areas. For example, the areas did not necessarily become more compact. To amplify these conclusions we should examine the cyclic trends and see if these relate to any particular feature of the control of the system in a way that was suggested earlier in Part 5. It should be noted that we have been using the mean values of S and E. From these statistics we have no indication of the variety of shapes or levels of efficiency. Also, S and E are independent of scale, thus we do not know if it is the larger or smaller areas which have particular S and E values. The next section will examine these aspects of the problem.

The Variation in S and E Over Time

At any one point in time we have calculated the *mean* value for S and E. Another useful statistic to describe a distribution is the *variance* (σ^2). This is defined as

$$\sigma^2 = \frac{(x_i - \bar{X})^2}{n}, \quad \text{where } \bar{X} \text{ is the mean}$$

value, and x_i is each individual value of x. The value n is given as the number of administrative areas in a system. Thus for each year (1948-1967) we can calculate the variance and this gives us a measure of the spread of the values for S and E. If σ^2 is zero, then all the areas have the same value. As σ^2 increases, the range in values for the indices also increases. To allow us to compare administrative systems at different times with different values for n, we calculate the Index of Variation V, by dividing the variance by the square of the mean value. Symbolically this can be expressed as

$$V = \frac{\sigma^2}{\bar{X}^2}$$

this gives us a scale-independent quantity. Figure 24 shows a graph of V, for S and E. The significance of the monotonic trend was calculated using the Spearman Rank Correlation Coefficient. For E it is clear that the variation is decreasing over time. Not only is the aggregate level of efficiency improving, but the areas are becoming more similar in their spatial efficiency. With respect to S it appears that over the total period the areas are becoming less similar in geometrical form $r_s = .73$. However, with the exception of the period 1958 to 1963, the variation is not very pronounced. So far we have restricted ourselves to examining S and E over time. But we can also examine the size of the areas by using the number of customers and the physical area (square miles).

Figure 25 shows the trends for these two variables. In both cases the areas are becoming more similar over time. In the case of Physical Area, if we exclude the very low value for 1948, the value of r_s for the monotonically decreasing trend goes from −.71 to −.99. We should note that in 1948 the administrative system had not covered the total area *completely*. In 1949 (stage 4 in the conceptual framework) three very large areas were established in the northeast of the region. This had the effect of increasing the value of the variation at this time. The variation in the number of customers between areas has declined over time. This suggests that the work load has tended to become similar among areas through time, and regional inequalities have been ironed out. In highly developed countries with integrated transportation facilities this trend is very common. However, in the developing parts of the world we frequently find that administrative efficiency is concentrated in a few large centers and the majority of the people in the more isolated rural districts receive the poorest quality of services. Attempts to decentralize and set up

EFFICIENCY & SHAPE INDICES

Index of variation

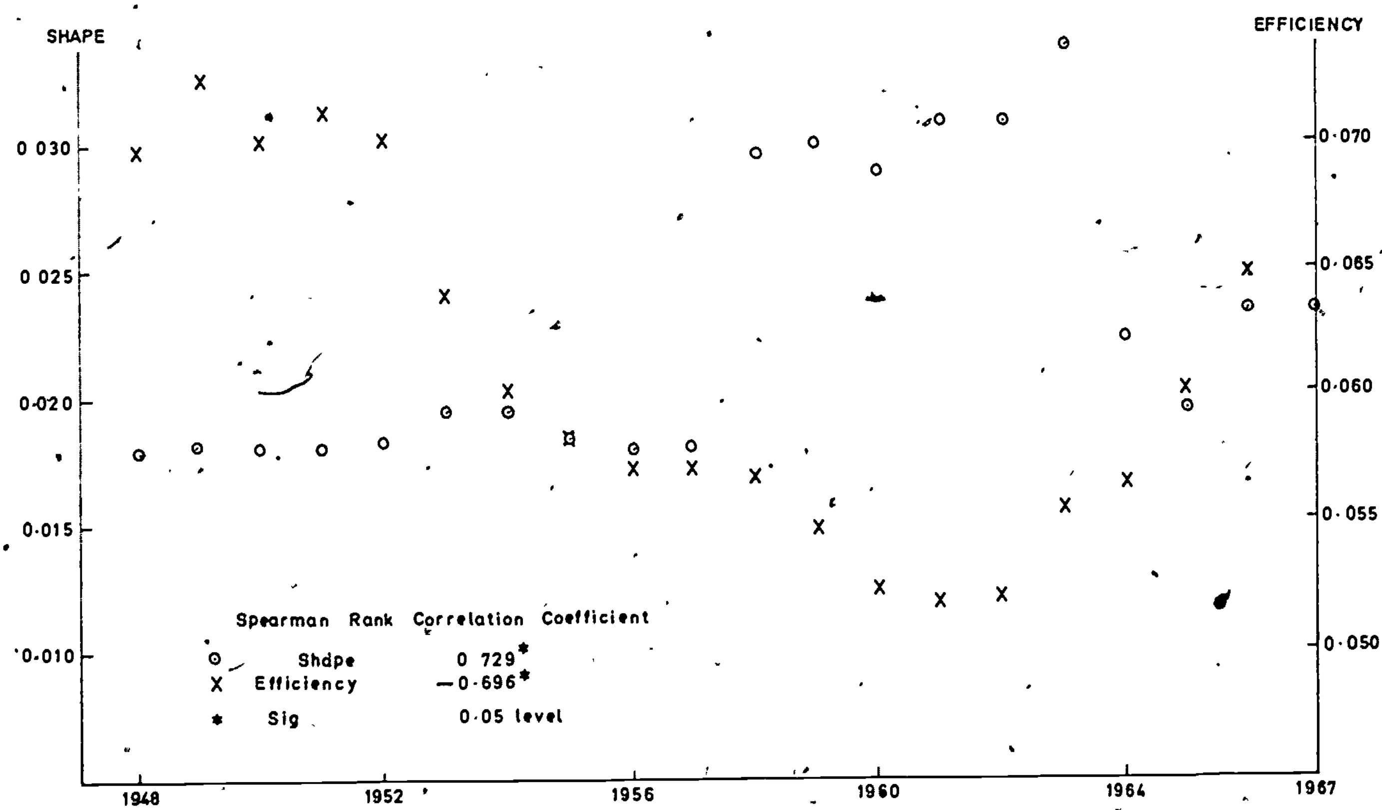
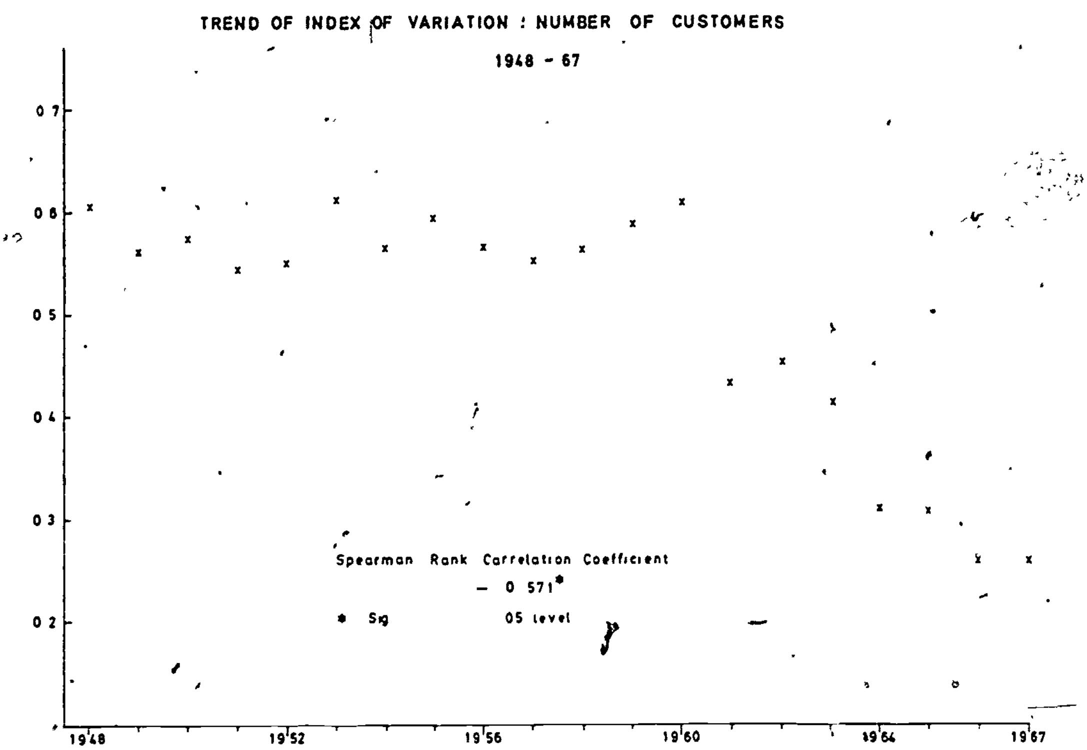


Figure 24


TREND OF INDEX OF VARIATION : NUMBER OF CUSTOMERS
1948 - 67
Spearman Rank Correlation Coefficient
– 0 571*
* Sig 05 level

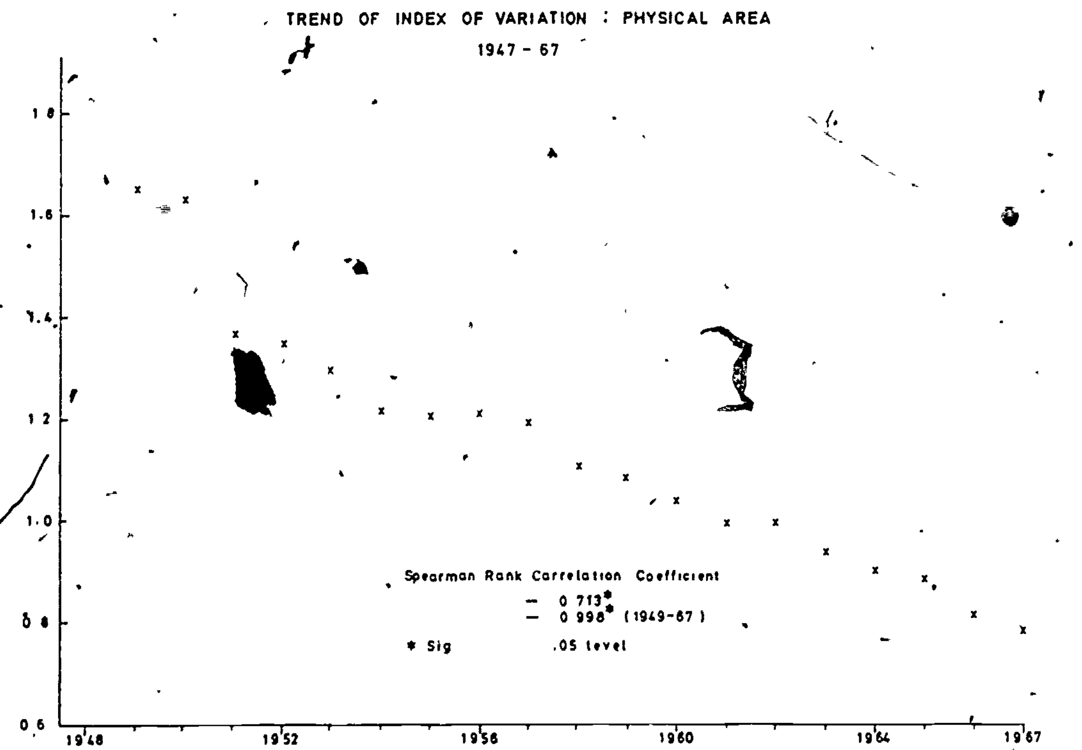

TREND OF INDEX OF VARIATION : PHYSICAL AREA
1947 - 67
Spearman Rank Correlation Coefficient
– 0 713*
– 0 998* (1949-67)
* Sig .05 level

Figure 25

centers for education, health, welfare and agricultural aid have been encouraged by national and international organizations including the United Nations, and a report[5] published in 1962 summarizes some of the work in this field in developing countries. Clearly geographers have an important role to play in this matter.

The Control of an Administrative Structure

In our day-to-day lives not all goods and services we need are provided by firms which survive or disappear through the market system which in turn is controlled by commodity prices and the shopping habits of consumers. Very frequently services are provided by local governments, and their administrative efficiency is reflected in the quality and quantity of the service provided and the tax rate or capital grants from a higher level of government. In this case the survival of a particular administrative system is dependent upon gaining and maintaining the support of those who pay for the services, and this usually means attracting and holding the attention of voters and winning their support at election time. The general problems of gerrymandering have already been examined; but we should note that within the American context, the choice of local politicians appears to be influenced by the size of the spatial unit which defines a set of voters. Kasperson (1969) has argued that incumbents have a greater chance of reelection in at-large voting systems than in ward systems. He suggests several reasons for this.

> "Incumbents have the entire period in office and ample publicity to make themselves known to the electorate, a challenger, even with ample resources has great difficulty doing the same given the size of the constituency and the usually large number of contestants. At-large campaigns are far more expensive than district campaigns. Furthermore, at-large councilmen often adopt a strategy by which, instead of competing with one another, they minimize differences in order to inhibit the voter's ability to identify councilmen with particular issues. There may even be a division of labor in which councilmen defend the council as a whole in regard to those issues he knows best. In this way, challengers must beat the entire council, not just one incumbent."

This situation should be examined further and changes made to minimize any bias in favor of the incumbent or the opposition.

In a more general framework we can conceptualize the two main decision-making components of an administrative system as consumers and administrators. We can consider them as members of opposite teams who are trying to achieve certain objectives. The consumers want good service at reasonable costs and the administrators want to maintain their authority while expending a fair level of effort. This situation can be viewed within a *game theory* framework in which both groups have several courses of action open to them and each has a particular goal. In Figure 26 we have set up three theoretical courses of action for each side in the form of a square pay-off matrix. We will consider each cell in turn. The values assigned to each cell represent the probability of the consumer taking a certain action. If the administrator does nothing, there is a high probability (eight chances out of ten) that the consumers will vote him out of office. This is a poor course of action if the administrator wishes to maintain himself in office. If a poor quality of service is provided, there is a fifty-fifty chance that he will lose his authority. In this case the vote is split between consumers who vote against (50%), those who vote for (30%), and those who do not vote (20%). The third course of action of the administrator is to provide good service. By following this strategy there is a probability of .5 that the consumers will vote for him, but in this case there is a relatively high percentage of non-voters (40%). The opposition vote is low, only 10%. If each of the three strategies is equally possible for the administrator he should choose C, and thus maintain his authority. It should be noted that the sum of each column is 1.0. This tells us with perfect certainty that the consumer will choose strategy 1, 2, or 3; he has no other choices open to him.

Let us consider the case when each strategy (A, B, or C) requires different effort for the administrator. This may be represented by the amount of money he has to find from the municipal budget or the number of meetings he has to attend or the relative importance he attaches to his position as administrator. Clearly, strategy A is the one requiring least effort; it is also the one which guarantees least success

PAY-OFF MATRIX

ADMINISTRATOR

CONSUMER	*Do Nothing*	*Provide a Poor Quality Service*	*Provide Good Service at Reasonable Cost*
Vote for Opposition	0.8	0.5	0.1
Do not Vote	0.2	0.2	0.4
Vote for current Administration	0.0	0.3	0.5

Figure 26

[5] United Nations *Decentralization for National and Local Development* st/tad/m/19, (United Nations: New York, 1962).

of staying in office. Strategy B may require 10 units of effort and strategy C, 20 units of effort. Now the problem facing the administrator can be stated as follows. Are the extra 10 units between B and C really worth the chances of staying in office? This is a risky situation, but the information in Figure 26 suggests that there is a low chance of losing office if C is selected, so the administrator may decide that the extra effort will be worthwhile. His expected probability of success is high. Consider the situation in which the values in column C were replaced by .3, .3, and .4. In this case the chance of staying in office is less and the administrator has to think carefully whether this reduced chance is worth the extra effort to follow strategy C. Here we are trying to link the effort involved in following a certain action and the chances of the action producing the desired results. It would be foolish for an administrator to spend a lot of time, effort and inconvenience attending meetings, making plans and giving speeches if he did not think that there was a reasonable chance of success. A word of caution—the success in the game discussed above is in the short-run Many opposition political parties hope for success in the long-run. Their chances of winning at the next election may be low but they are hopeful for the future.

The concepts outlined here are from the field of decision theory. Using the notion of *expected utility* (E.U.) and the assumption that the action of the rational decision-maker is to maximize this, either in the short-run or the long-run, we can state formally that

E.U. = Probability of Success x Value of Success –
Probability of Failure x Cost of Failure .

Though we can state the concept in precise terms we have great difficulty in assigning actual values to the probabilities and to the value of success and the cost of failure.

The ideas expressed through game theory and decision theory have attracted much attention since their conception during the Second World War period. They provide conceptual frameworks for viewing conflict-type situations and decision-making sequences. They help us link actions, values and goals of decision-makers who are in competition *or* in cooperation. The current state of the art does not allow us to explain real-world conflict situations completely, but the utilization of these theories may help to unravel the complexities of the world. Williams in his book the *Compleat Stratygist*, a primer for game theory, draws our attention to a pressing point.

> "One of the conceptual problems . . . is reached when we try to fill in the boxes with the values of the payoff, . . . in general we have to assume that the payoff can, in principle, be measured numerically. Further the units of measurement must be the same in all boxes . . . the stakes may be money and prestige. Unless we are prepared to adopt an exchange ratio between prestige and money, our analysis is likely to be in trouble."

But perhaps one of the most important lessons that game theory can teach us is to define our problems crisply. Analysis cannot follow loose definitions and vague generalizations.

A discussion on game theory, decision-making and understanding of man's organization in space would be far from complete without a mention of the work of Walter Isard. He is one of the founders and most imaginative workers in the field of regional science. In his book *General Theory* he takes us through several examples of game theory after stressing that,

> "Much of political science, especially the new behavioristic political science, emphasizes processes whereby individuals and groups act to maximize, for example, their vote, their power, their control over influence networks, or the probability of their retaining a position or status already achieved "

The study of these processes is not easy but Isard's work has much to offer the advanced student of spatial organization.

PART 6
CONCLUSIONS

It is clear that the supply of public services by governments contributes greatly to the overall welfare of society. The location of supply centers and the spatial definition of service areas strongly influence the efficiency with which the services are provided, and it is imperative that if we are to use taxes and government investments wisely, we must understand clearly the relationships between efficiency and the spatial attributes of the service system. This Resource Paper has been designed to help in this direction and to outline the contributions which are being made by geographers. Within the North American context, Teitz (1968) has outlined the impact of public services on the lives of individuals. He deplores the failure of location theorists to place more attention on public-determined facilities when one considers the role of the facilities in shaping both the form of cities and the quality of life.

> "Modern man is born in a publicly financed hospital, receives his education in a publicly supported school and university, spends a good part of his life travelling on publicly built transportation facilities, communicates through the post office or the quasi-public telephone system, drinks his public water, disposes of his garbage through the public removal system, reads his public library books, picnics in his public parks, is protected by his public police, fire and health systems, eventually he dies, again in a hospital, and may even be buried in a public cemetery."

Location theory has primarily been concerned with industrial, commercial and residential decisions, but for a complete picture of human organization we need to develop theories to explain public facilities locational decisions. March and Simon (1958) in their text *Organizations* discuss the "... great disparity between hypotheses and evidence. Much of what we know or believe about organizations is distilled from common sense and from the practical experience of executives. The great bulk of this wisdom and lore has never been subjected to the rigorous scrutiny of scientific method. The literature contains many assertions, but little evidence to determine—by the usual scientific standards of public testability and reproducibility—whether these assertions really hold up in the world of fact." At the moment there is a lack of solid theoretical basis to help us determine the size or location of public facilities and Teitz claims that "rules of thumb have been developed, but for the most part without ways to evaluate the results or to stimulate investigation of new systems." It appears that *crisis* is the mechanism which generates appraisal of an administrative system and *ad hoc* reform is the result. Long-term plans and constant objective appraisal of government administration is the ideal. It has not yet been achieved, though there have been some significant moves in this direction by both local and central governments.

The search for the ideal system of government and the optimum size and shape for a political entity is a problem which has fascinated thinkers since early times. The writings of Plato and his student Aristotle are devoted in part to the definition of a pattern for the organization of a harmonious state. At one stage Plato tackled the specific problem of defining the optimum size for a political unit. He arrived at the figure of 5040 citizens which was determined by the capacity of the Greek forum. When we think of an ideal state, the name Utopia springs to mind. Derived from two Greek words *ou*, not, and *topos*, place, Thomas More coined the term to describe an ideal social system for an island. The book, written in the sixteenth century, makes fascinating reading for the geographer, particularly the section which discusses the size and spacing of settlements, the location of the administrative center and the criteria used for achieving a balanced society and harmony. The totality of human organization is explicitly defined. Laws are made to defend certain principles, locations chosen to achieve specific objectives and people encouraged to practise a variety of activities to derive satisfaction in the immediate future, and in the long-run. All aspects of social organization are integrated to provide general satisfaction for the people. In the second half of the twentieth century we are still far from Utopia, but now we have some tools to examine the basic spatial elements of administrative systems. As our analysis of administrative patterns continues, we will be in a stronger position to understand and improve the world we live in.

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