EMPIRICAL METHODS OF CITY CENTRALITY MEASUREMENT

BY

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CHAPTER I

INTRODUCTION

Central place theory was developed by Walter Christaller, as an explanation of ordering principles governing the size, number, and spatial distribution of towns. The premise was that towns vary in their importance, as service centers, or centrality, and that a hierarchy of central places exists, in which towns of greater centrality serve regions consisting of towns of lesser centrality. Since the advent of this theory, regional scientists have been engaged in the empirical measurement of city centrality. Using various methods of measuring centrality, data are used to classify cities according to the central economic functions which they perform. These classifications of the service functions of cities and their relationship to their hinterlands, serve as useful tools for optimal planning and resource allocation.

The Problem

Many empirical studies have been completed which measure the centrality of cities in a particular region and rank them in a hierarchy. A problem exists in the fact that the methods used to measure centrality are almost as numerous as the number of empirical studies. Therefore, the purpose of this paper is to categorize, review, and evaluate empirical methods used to measure centrality.

Justification for Study

Centrality measurement takes on theoretical and practical importance through its relationship to hierarchial ranking. The means by which hierarchial ranking takes place, the method of measuring centrality determines the functional importance of a city. Only after the centrality of various cities is measured can the cities be assigned to hierarchial ranks.

Hierarchial ranking is the basic axiom of central place theory. Empirical studies identifying hierarchies are used to determine the actual size, number, and spatial distribution of towns. Without the hierarchial concept, it is very unlikely that other theoretical laws governing the size and distribution of towns could be upheld.[1] Therefore, by serving as the determiner of hierarchial ranking results, centrality measurement takes on theoretical importance.

The hierarchial concept has several practical implications. Hierarchies of central functions and central goods can be identified.[2] Christaller says, "The model of central places furnishes a scheme for the optimum settlement structure of any area." Concerning the policy implications of central place hierarchies, he says, "It should be the object of any regional plan to supply a country or an area equally with the commodities and services of the central places."[3] The practical significance of central place theory is further illustrated in its use as a framework to determine the size, number, and spacing of

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[1]Wayne K. D. Davies, "Centrality and the Central Place Hierarchy," Urban Studies, 4:1, February, 1967, p. 61.

[2]Brian J. L. Berry and William L. Garrison, "Recent Developments of Central Place Theory," Papers and Proceedings of the Regional Science Association, Volume 4, 1958, p. 113.

[3]Walter Christaller, "The Advantages of a Space-Economical Theory for the Practice of Regional Planning," Ekistics, 20:119, October, 1965, p. 224.

central functions for new regions. Sometimes referred to as polarized regions, central regions can be delineated in any given country. Polarized regions perform similar economic functions and are part of national, regional, or local hierarchies. In some countries, the government has made a deliberate effort to institute policy measures which insure economic development corresponding to the central place concept. Regional planning is carried out with central economic functions being placed in appropriate regions, in order to insure a hierarchial landscape that is consistent with theoretical ideals.[4] Such regions have been developed in Sweden, Iraq, the Netherlands, East Germany, and France.[5] As more sophisticated methods of regional analysis are introduced, the use of centrality measures for determining hierarchial ranking should increase in importance.

Method of Approach

Central place theory, in and by itself, does not offer a "cookbook," step by step procedure by which centrality measurement should take place. Instead, it illustrates the fundamental philosophy behind centrality measurement. As a result, a wide variety of empirical techniques have been developed around the components of central place theory.

Empirical methods of measuring centrality can be classified in one of two general categories, direct or indirect. Direct methods of measuring centrality consist of an actual investigation and quantification of economic functions provided by each place. A listing of goods and services available,

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[4]Niles M. Hansen, French Regional Planning, (Bloomington: Indiana University Press, 1968), p. 109.

[5]Christaller, "The Advantages of a Space-Economical Theory for the Practice of Regional Planning," p. 226.

and a judgment about the economic importance of each good and service provided, is made. On the basis of such information, the centrality, or economic importance of each place is measured. Indirect methods of measuring centrality are characterized by the analysis of one, or a few selected indicators, which are assumed to represent the activity of many central functions. Indirect methods consider those goods and services which result because of the existence of the central place. Examples of indirect measures of centrality are the volume of air traffic and the number of daily buses passing through a central place. The accuracy of indirect methods of centrality measurement is dependent upon the degree to which the selected indicators represent the total central functions performed by the city.

The paper is organized into four parts. Chapter II contains a review of central place theory, as formulated by Christaller and Losch. Chapter III reviews and evaluates some common methods of indirect centrality measurement, while direct methods of measurement are discussed and evaluated in Chapter IV. The conclusion is a comment on direct and indirect methods as they attempt to serve as measures of centrality.

CHAPTER II

CENTRAL PLACE THEORY REVIEWED

Walter Christaller, the father of central place theory, describes his theory as being a general deductive theory designed to explain the size, number and distribution of towns in the belief that some ordering principles govern their distribution.[6] August Losch contributed to the refinement of the theory.[7] Other writers have further developed the theory, but its basic ideas, as presented by Christaller and Losch, have remained unchanged.

Higher Versus Lower Order Places

The theory states that the purpose of a city is to be a central place which provides central functions (goods and services) for the surrounding territory. Those central places which perform central functions that extend over a larger area in which other central places of less importance exist are called central places of a higher order. Those central places which have only local importance for small areas are called central places of a lower order.[8] In both cases, the region served by the central place is called its complementary region.

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[6]Walter Christaller, Central Places in Southern Germany, trans. by Carlisle W. Baskin (Englewood Califfs: Prentice-Hall, Inc., 1966).

[7]August Losch, The Economics of Location (New Haven: Yale University Press, 1954).

[8]Christaller, Central Places in Southern Germany, p. 17.

Threshold and Range

The size of the complementary region is determined by the threshold and range of each type of good and service distributed by the central place. The threshold is the minimum market area needed to induce central places to provide a particular good or service.[9] The range is the farthest distance that the population is willing to go to purchase a particular good or service at a central place.[10] Every type of good and service has its own distinct threshold and range.

Market Area Characteristics

Because each type of good and service has a distinct threshold and range, each will have an optimum market area. These circular areas overlap on the economic landscape and create areas of competition. Consumers within the areas of competition will buy the good or service from the nearest central place, causing market areas to assume the shape of hexagons, as illustrated in Figure 1. Thus, the economic landscape contains a lattice of regular hexagons which combine with other hexagons in a variety of ways. In the centers of the hexagons are various central places which provide the particular good or service. In the extreme case when all hexagonal centers overlap, a metropolis exists and every type of central good and service is provided. In most places on the landscape, only a few centers will overlap and a city of lower order exists.[11] Figure 2 portrays an economic landscape with various overlapping hexagons and places of differing centrality.

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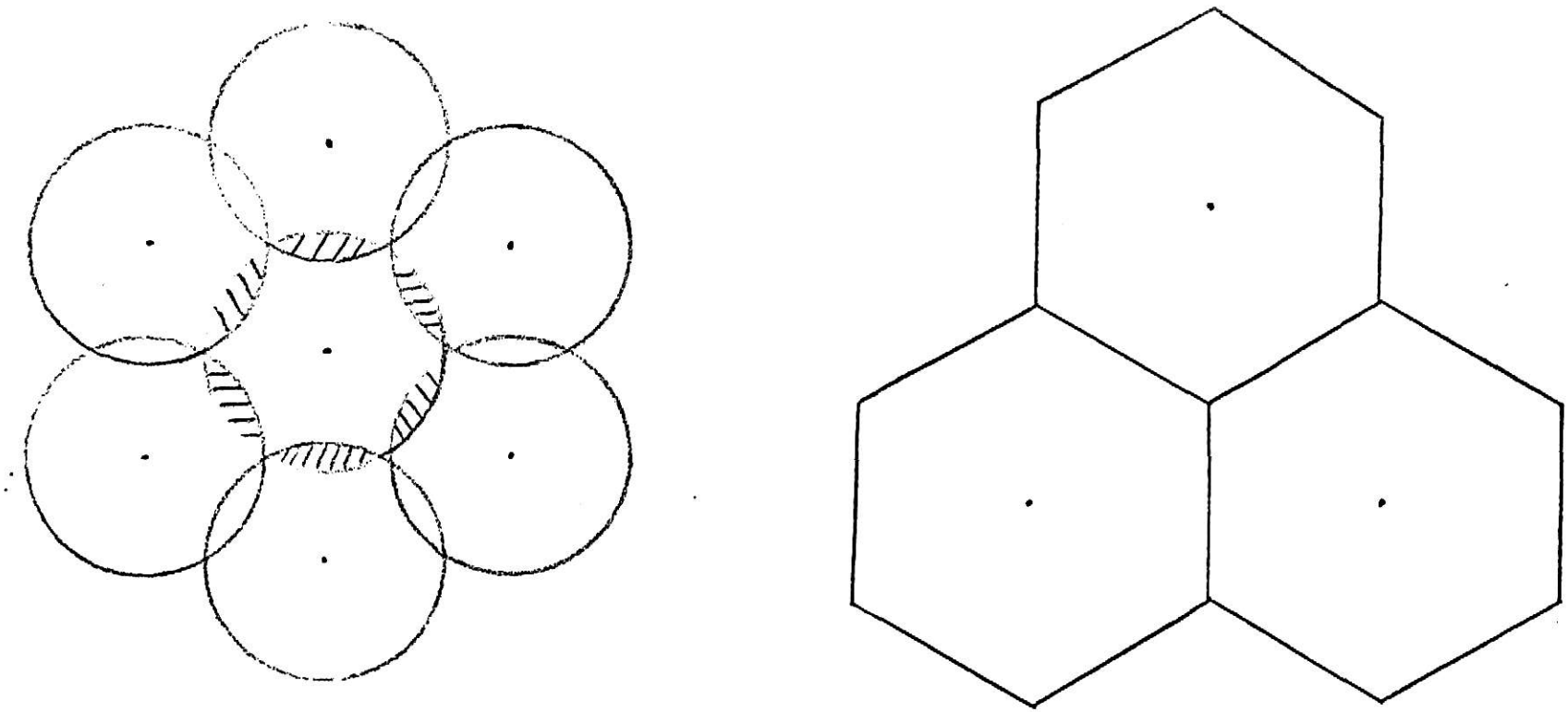
[9] Berry and Garrison, "Recent Developments of Central Place Theory," p. 111.

[10] Christaller, Central Places in Southern Germany, p. 22.

[11] F. H. W. Green, "Community of Interest Areas--Notes on the Hierarchy of Central Places and Their Hinterlands," Economic Geography, 34:3, July, 1958, pp. 210-211.

Figure 1. Overlapping Circles and Hexagonal Market Areas

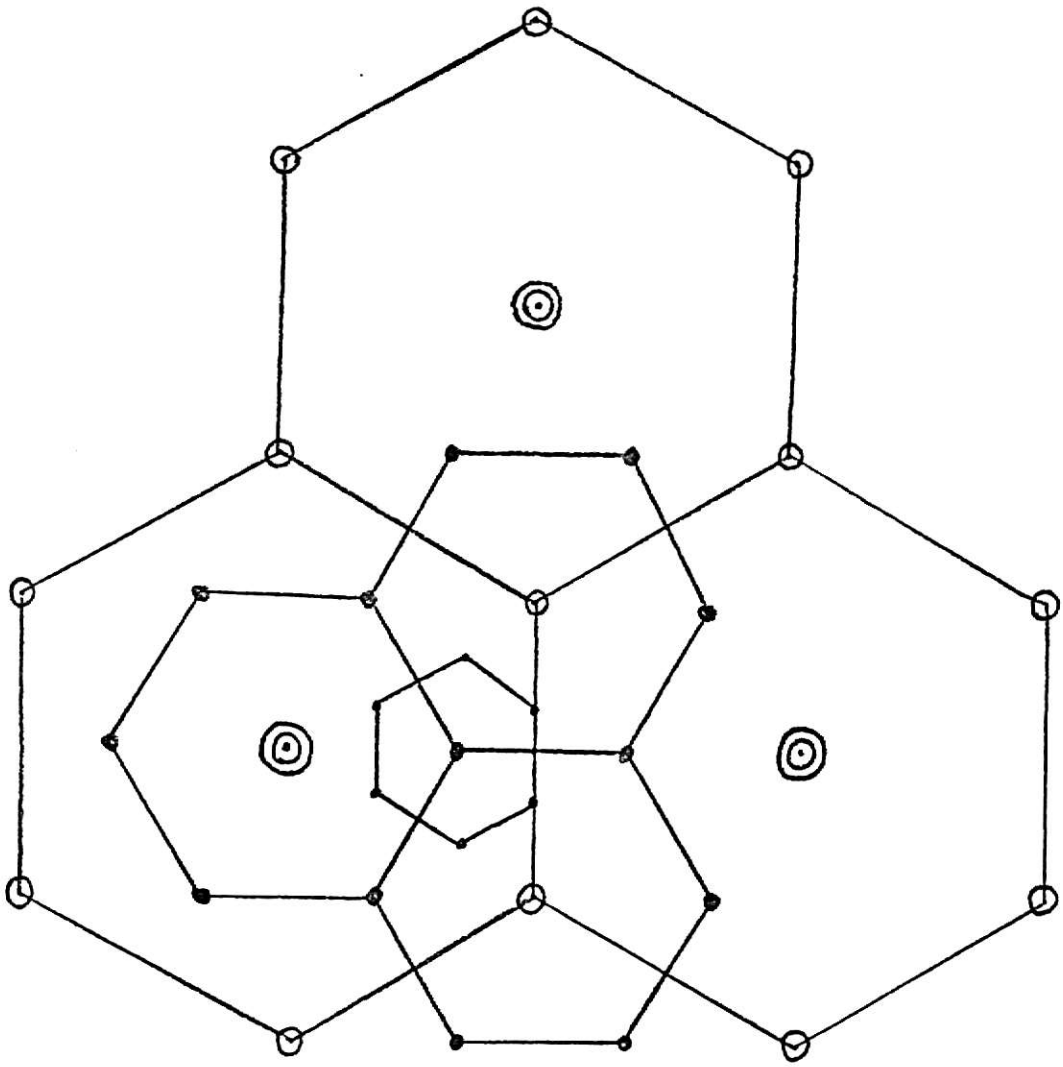
Left: Overlapping circles create areas of competition.
Right: Consumer choice leads to hexagonal market areas.



Source: Brian J. L. Berry, Geography of Market Centers and Retail Distribution.

Figure 2. An Economic Landscape

An economic landscape and places of differing centrality



Source: Brian J. L. Berry, Geography of Market Centers and Retail Distribution.

Higher Versus Lower Order Goods

Goods which are necessities and are purchased often are called lower order goods. These goods are found in the most remote places. Higher order goods are more expensive goods, for which the consumer will travel long distances. Such higher order goods are called "shopping goods."

Centrality

Regional scientists disagree on a standard definition of centrality. Generally defined as the degree to which a place is a service center for surrounding regions, centrality denotes the relative importance of a place in terms of the service functions it provides.[12] However, before one knows the meaning of "relative importance," the definition is incomplete.

Some investigators consider geographical market size and the number of central functions performed as the relative importance of a city.[13] Others look to business activity, exported goods and services, people served, income generated, or specialized services as measures of relative importance. The concept of centrality consists of many definitional components like those mentioned above. Regional scientists have not agreed on which components constitute a strict definition of centrality. Lack of such definitional agreement has undoubtedly been a reason for the large number of methods used to empirically measure centrality. In order to avoid confusion, the terms

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[12]Christaller, Central Places in Southern Germany, p. 18.

[13]Robert H. T. Smith, Edward J. Taaffe, and Leslie J. King., Ed., Readings in Economic Geography, (Chicago: Rand McNally & Co., 1968), p. 65.

"economic importance" and "centrality" will be synonomous in this paper. Each term will denote any or all of the above views as to what constitutes the relative importance of a city.

Hierarchial Arrangement

The interplay of higher and lower order goods, along with the principles of threshold and range, creates a hierarchy of central places.[14] Centers of a higher order provide all the goods and services of lower order centers, plus a set of central goods and services which sets them above the lower order centers. The result is a nesting pattern of lower order trade centers within the trade area of larger order centers, plus a hierarchy of transportation routes joining the centers. This hierarchy of centers results in the optimum production and distribution of resources.

Hierarchies may be orientated according to market, transportation or administrative principles. Although nesting patterns differ with each principle, the problem of centrality measurement remains unchanged. Thus, the differentiation of these three principles will not be a concern of this paper.

Central Place Theory as Economic Theory

Central place theory can be described as economic theory with spatial application. The assumptions of pure economic theory are accepted in central place theory. However, because of the existence of space, meaningful changes result in traditional theory.[15]

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[14] Berry and Garrison, "Recent Developments of Central Place Theory," p. 111.

[15] S. Valavanis, "Losch on Location," American Economic Review, Volume 45, 1955, p. 642.

An example of such changes are the price funnels and demand cones which result from the blending of the traditional price-quantity relationship and the concept of transportation costs. In a spatial economy, the total price paid by the consumer consists of the market price of the good, plus the transportation costs to the market place. The distant consumer will pay a higher final price than the near consumer, which induces distant consumers to demand smaller quantities of the good or service. Price funnels and demand cones result, which illustrate respectively, prices paid and quantities of goods and services demanded at various distances from the central place. Figure 3 illustrates the ideas of transportation costs, market prices, and the resultant price funnels and demand cones.

Valavanis emphasizes two general alterations of traditional economic theory as a result of central place theory. First, the idea of an economic region is derivable and not primary. Second, price funnels break up the landscape to the point where the concept of local market prices is meaningless.[16] Although central place theory brings about changes in traditional economic theory, it remains as a useful and integrated part of general economic theory.

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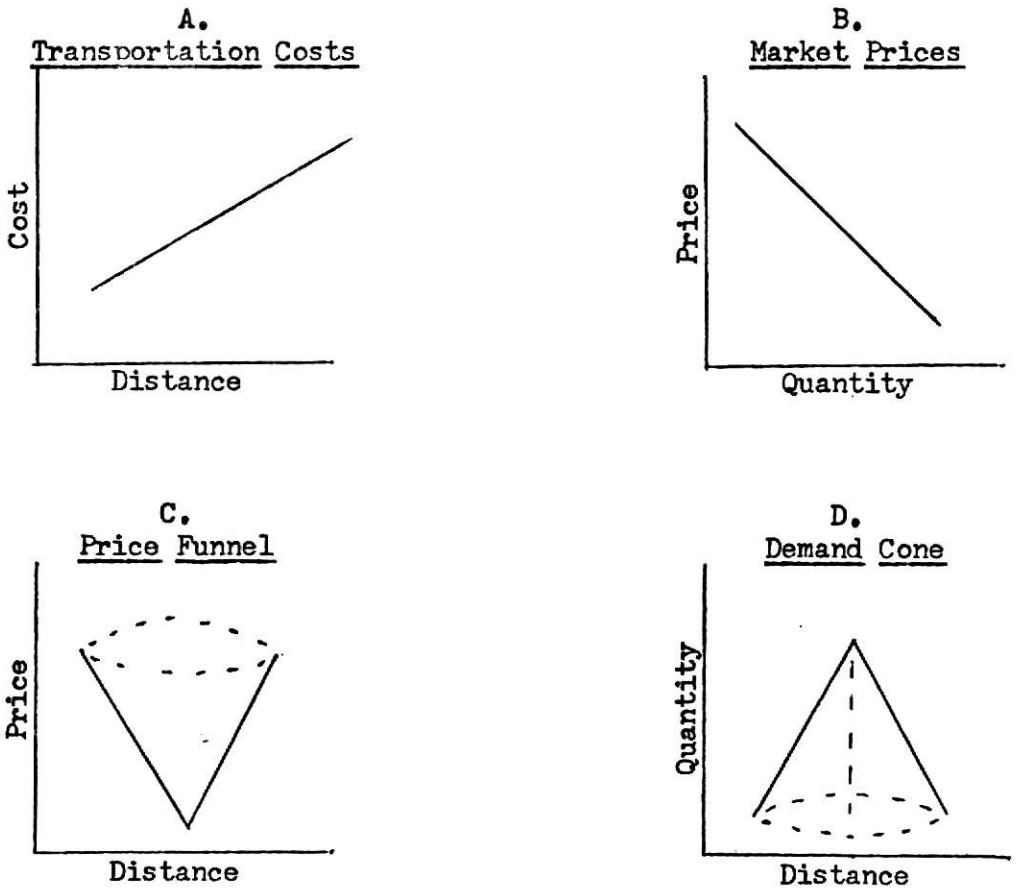
[16] Ibid.

Figure 3. Transportation Costs, Market Prices, Price Funnels and Demand Cones

When consumers must pay high transportation costs (A), their relative price goes up (B), and they will consume less, relative to the distance (D) and pay more (C).



Source: S. Valavanis, "Losch on Location," American Economic Review, 45: 1955, p. 642.

CHAPTER III

INDIRECT METHODS OF MEASURING CENTRALITY

Indirect methods of centrality measurement are characterized by the use of one, or a small number of indices as sole determinants of a place's importance. Any one of a variety of indices, from the number of daily buses, to the amount of newspaper publication is assumed to represent the whole of a city's centrality. Indirect methods have an advantage over the use of direct methods in that they eliminate the problem of weighing the contributions of the several indices.[17] Their disadvantage lies in the fact that the chosen indicator of centrality is often not a good measure of the total contribution of a city's central functions.

This chapter reviews and evaluates several indirect methods of centrality measurement that are commonly used in empirical studies. An empirical study is presented to illustrate the use of each indirect method. Although not all indirect measures of centrality are discussed, the ones presented are the most frequently used.

The Telephone as a Measure of Centrality

The telephone is a necessity to the business community. It is used to place orders, contact buyers, and to conduct daily business. As a result, the telephone is a popular measure of centrality. Two approaches to telephone analysis are discussed. One is a stock approach in which the number of telephone

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[17]Brian J. L. Berry and Duane F. Marble, ed, Spatial Analysis, (Englewood Cliffs: Prentice-Hall, Inc., 1968), p. 408.

connections serves as a measure of centrality. The other is a flow approach in which the amount of telephone traffic is analyzed. Both approaches stand as adequate methods of centrality measurement.

Number of Telephone Connections

In his application of central place theory to the Southern part of Germany, Christaller encountered difficulty in quantifying and weighing various central functions. He stated, "Because the various elements of the concrete contents of the importance of a specific place are not always easily recognizable, and because it is so difficult to quantify the importance precisely, it seems that it would be nearly impossible to find a method for quantifying the central places so that their sizes could be easily compared."[18]

Furthermore, Christaller concluded, " . . . there is a perplexingly simple and sufficiently exact method for determining through numbers the importance of a place as a central place; one need only count the telephone connections; the number corresponds rather exactly to the importance of a place."[19]

Using telephone directories as his guide, Christaller counted all telephone connections in Southern Germany and placed them locationally on a map to determine the importance of places. During the 1930's, this may have been an accurate way of determining the importance of cities. Most telephone connections were those of businesses, since few private individuals had their own telephones. Thus, the number of telephone connections was thought to represent the business activity of a particular area and, hence, its relative contribution to the surrounding region.

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[18]Christaller, Central Places in Southern Germany, p. 143.

[19]Ibid.

At this juncture, it is interesting to note that despite his theoretical insistence that centrality was a measure of the contribution of a city to its surrounding region in terms of goods and services, range and threshold, etc., Christaller could not quantify these central functions and used only one factor, telephone connections to empirically implement his ideas. This represents the gap that existed between pure central place theory and its empirical application in Christaller's time.

Using the number of telephone connections as his guide, Christaller was able to rank cities in their various orders according to their centrality. Centrality was based on the number of telephone connections a city had in excess of the regional average.[20] Table 1 illustrates the nature of the various ranks of cities and their centrality, as analyzed by Christaller.

Because many private citizens now have telephones, a repeat of Christaller's method today would probably indicate private usage, as well as business activity. Separating the two becomes difficult, and therefore, the number of telephone connections is not as accurate of an indicator of business activity as it was in the 1930's.

Amount of Telephone Traffic

A more recent attempt to use the telephone as a measure of centrality was a study completed in 1961 by Sven Illeris and Poul O. Pedersen. Instead of using the number of connections like Christaller, a factor analysis of telephone traffic was used.[21] The data were composed of the number of calls

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[20] Ibid., p. 147.

[21] Sven Illeris and Poul O. Pedersen, "Central Places and Functional Regions in Denmark; A Factor Analysis of Telephone Traffic," Lund Studies in Geography (Lund: The Royal University of Lund, Sweden Department of Geography, 1968), p. 1.

TABLE 1

RANKS OF CITIES AND THEIR CENTRALITY

Type	Population (approximate)	Number of Telephones	Centrality
H	800	5-10	−0.5- −0.5
M	1,200	10-20	0.5-2
A	2,000	20-50	2-4
K	4,000	50-150	4-12
B	10,000	150-500	12-30
G	30,000	500-2,500	30-150
P	100,000	2,500-25,000	150-1,200
L	500,000	25,000-60,000	1,200-3,000
RT	1,000,000	60,000	3,000
R	4,000,000	?	?

Source: Walter Christaller, Central Places in Southern Germany, page 158.

between each of sixty-two districts into which the telephone companies divide the country. A matrix was established including the number of calls from each district to every other district. Because the calls are an indication of commercial activity, intra-district calls were excluded. Thus, most calls used in the data were long distance and, therefore, business orientated. Factor analysis was then applied to the telephone call matrix, after which the seven most important places in Denmark were ranked according to their centrality.

Table 2 shows the results of the centrality ranking according to telephone call flows, as compared to wholesale trade and another study analyzing sixteen central functions. As can be seen, the telephone call data agrees with the other two studies in its ranking of the first four cities. However, universal disagreement follows in the last three rankings.

Although useful, telephone data is biased as a centrality measure. First, differentiation in telephone use is not considered. Not all businesses rely upon the telephone in the same degree. Some businesses which perform higher order functions do not use the telephone as much as businesses performing lower order functions. Second, differentiation of business types, for an analysis of central functions, is impossible with telephone analysis. One call generates the same input as any other call, regardless from which type of business it originates.

Routes and Flows of Transportation as a Measure of Centrality

Central places, being places of economic importance, are characterized by business and market activity. Vital to market exchange is a transportation network that brings buyers and sellers to a common place. To facilitate its

TABLE 2

THREE COMPARISONS OF CENTRALITY MEASURES

	Factor analysis of telephone traffic, 1961	Employment in wholesale trade, 1958	Occurrence of 16 central functions, 1960
1	Copenhagen	Copenhagen	Copenhagen
2	Arhus	Arhus	Arhus
3	Odense	Odense	Odense
4	Alborg	Alborg	Alborg
5	Haderslev	Randers	Esbjerg
6	Holstebro	Esbjerg	Randers
7	Esbjerg	Kolding	Horsens

Source: Illeris and Pedersen, Central Places and Functional Regions in Denmark, a Factor Analysis of Telephone Traffic.

greater market demands, a central place of higher order requires a more extensive transportation system than a place of lower order. Thus, transportation routes and flows are reasonable measures of centrality. Several transportation indicators of centrality will be discussed in this section.

Analysis of Bus Traffic

The rationale for using bus traffic as a measure of centrality is that it is considered to be an accurate reflection of the public demand for transportation to and from trade centers.[22] Two British geographers, Ian Carruthers and F. H. W. Green, are noted for their work in analyzing bus traffic as a measure of centrality.

Carruthers' method of centrality measurement involves, first, determining the number of bus journeys made into a town, and second, calculating the number of those journeys that serve no place larger than the town itself. This information is plotted on maps and used to delineate second and third order centers and their hinterlands.[23]

Green's analysis considers the direction of bus routes as well as their importance. Each bus route is mapped and analyzed according to its time table.[24] In Figure 4, the width of the line indicating the bus route reflects the number of buses on that route each day. The wider the line, the greater the number of buses on that route. The figure shows the convergence of bus routes at a central place, as well as a thinning out of the route lines

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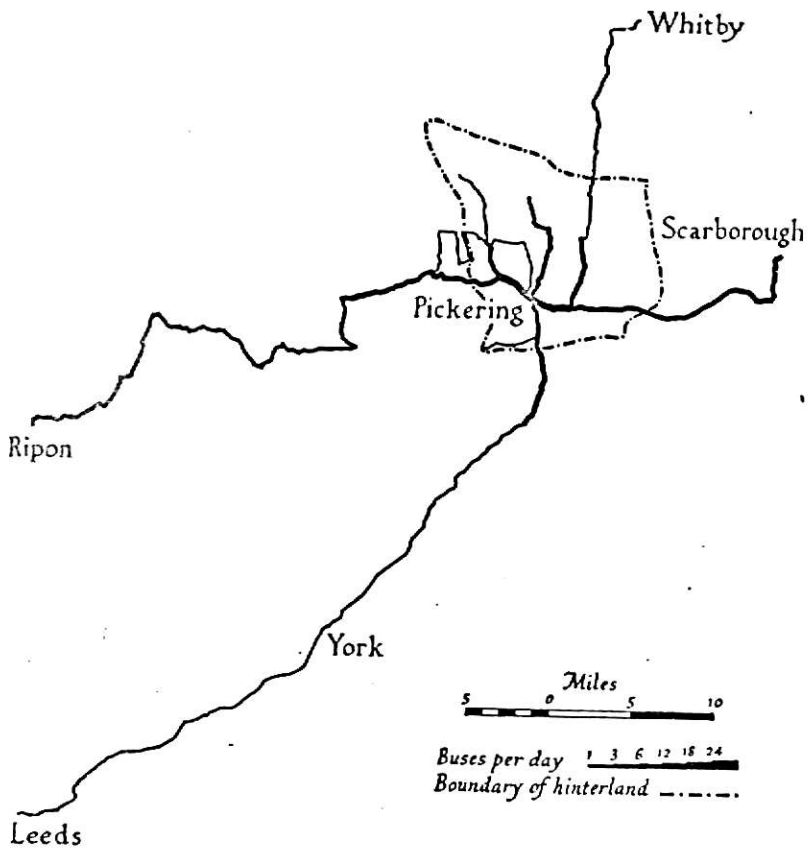
[22]John E. Brush, "Bus Service Hinterlands in Great Britain," The Geographical Review, 46:2, April, 1956, p. 267.

[23]Ian Carruthers, "A Classification of Service Centres in England and Wales," The Geographical Journal, 123:3, September, 1957, pp. 372-373.

[24]F. H. W. Green, "Urban Hinterlands in England and Wales; an Analysis of Bus Services," The Geographical Journal, 116:1-3 July-December, 1950, p. 65.

Figure 4. Pickering: Market Day Bus Services



Source: F. H. W. Green, "Urban Hinterlands in England and Wales; an Analysis of Bus Services," The Geographical Journal, 116:1-3. p. 66.

to represent the decreased demand for transportation away from the city center. Through such diagrams, Green ranks cities according to their centrality and also estimates the hinterland of each city.

The reliability of bus service as an indicator of centrality depends upon the degree to which bus service reflects demand for transportation and the extent to which buses are the most common form of public transportation.[25] Part of the success of the two studies cited lies in the fact that they were conducted in Great Britain. In European countries that rely heavily on public transit, bus routes serve as an accurate indicator of transportation demand. This is true because even the most isolated towns have some sort of bus service. In countries like the United States which have, for the most part, ignored public transit and accepted the family automobile, bus service is a less accurate indicator of transportation demand.[26]

Other Transportation Measures

Given the task of defining a set of urban centers for the Philippines, Edward Ullman used traffic flow, principle roads, and passenger air traffic density as measures of centrality.[27] Although air traffic density was appropriate for the delineation of only the larger centers, traffic flow maps, as well as principle road maps were used to help classify even the smallest centers.

Traffic flow was by far the most useful of the three measures. In his study, Ullman was fortunate to have maps of traffic flow prepared by the

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[25]P. A. Brown, "The Local Accessibility of Nottingham," The East Midland Geographer, 11:1, 1959, pp. 37-48.

[26]Raymond E. Murphy, The American City, (New York: McGraw Hill, Inc., 1966), p. 91.

[27]Edward L. Ullman, "Trade Centers and Tributary Areas of the Philippines," The Geographical Review, 50:2, April, 1960, p. 204.

Philippine Bureau of Public Highways. Using these maps, he was able to determine the volume of traffic over the road network. He was then able to draw more positive conclusions about centrality than would have been possible using only road maps.[28]

As with bus services, railroad travel, or any transportation mode, the reliability of the study is determined by the degree to which the selected type of transportation reflects public demand.

Population as a Measure of Centrality

Population is the most commonly understood and widely used method to convey the idea of centrality. Road maps are a standard example of the use of population figures in ranking central places. Despite its popular usage, population is a poor indicator of explicit central functions. A resort town can have a large population, yet it might perform lesser order services than an industrial town of the same size.

John E. Brush, in his study of central places in Southwestern Wisconsin, pointed out that by looking at population figures alone, no clear cut distinction between city ranks is apparent. As indicated by Figure 5, a smooth, exponential relationship exists between population size and city rank for the region studied.[29] Because no distinct city ranks are apparent in the relationship, Brush concludes that population cannot be solely relied upon to accurately measure centrality.

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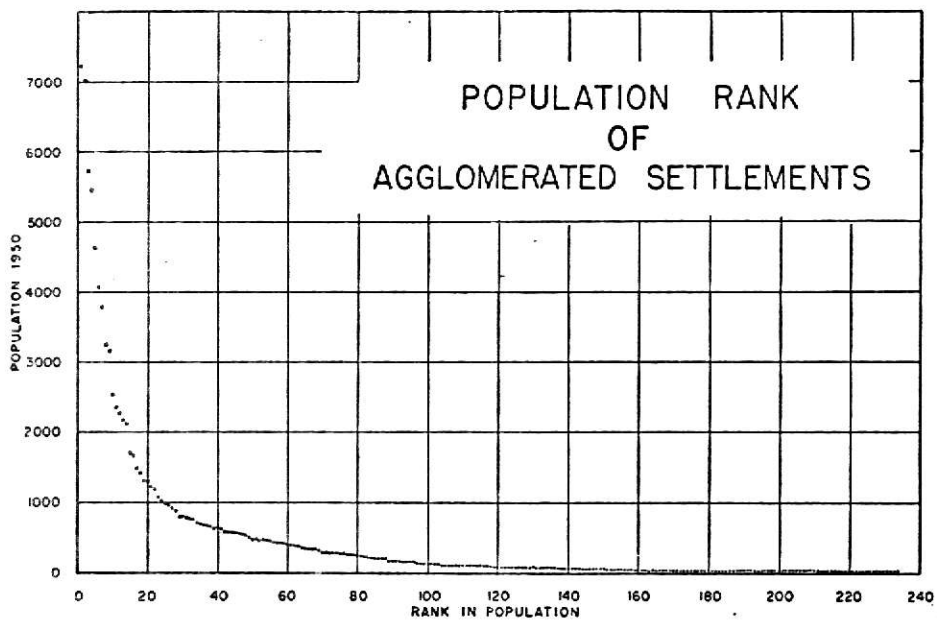
[28] Ibid., p. 207.

[29] John E. Brush, "The Hierarchy of Central Places in Southwestern Wisconsin," Geographical Review, 43:3, 1953, p. 382.

Figure 5.



Source: John E. Brush, "The Hierarchy of Central Places in Southwestern Wisconsin," Geographical Review, 43:3, 1953.

Alteration of the Definition of Centrality

The focus and objectives for which centrality measurements are made, often dictate changes in their definition. Sometimes it is the objective of a study to investigate certain types of centrality, rather than to calculate the importance of all types of good and service functions performed. Two empirical studies, one by the Iowa Office for Planning and Programming, and one by Howard J. Nelson will illustrate this point.

Restricted Variables as Measures of Centrality

Planners in Iowa found that because various state agencies divided the state into differing regional districts, overall coordination and administration of state services and programs was very difficult. Their goal was to identify uniform districts from which all state activities could be better coordinated. The criterion was not, then, to discover central places in Iowa from the standpoint of total economic activity, but rather, to determine the central places with regard to the location of state activities and administrative functions.[30]

The data collected consisted of the location of the offices of thirteen major state agencies. Plotted on a map, these locations were used to determine nine "area cities" in which the bulk of state activity takes place. After the nine obvious area cities were identified, as indicated in Figure 6, other factors were considered such as citizen-consumer convenience, the efficiency of field workers, and the economic tax bases of various counties. The final result was a sixteen district delineation in which all state functions are to take place, as illustrated in Figure 7. The major point to be remembered

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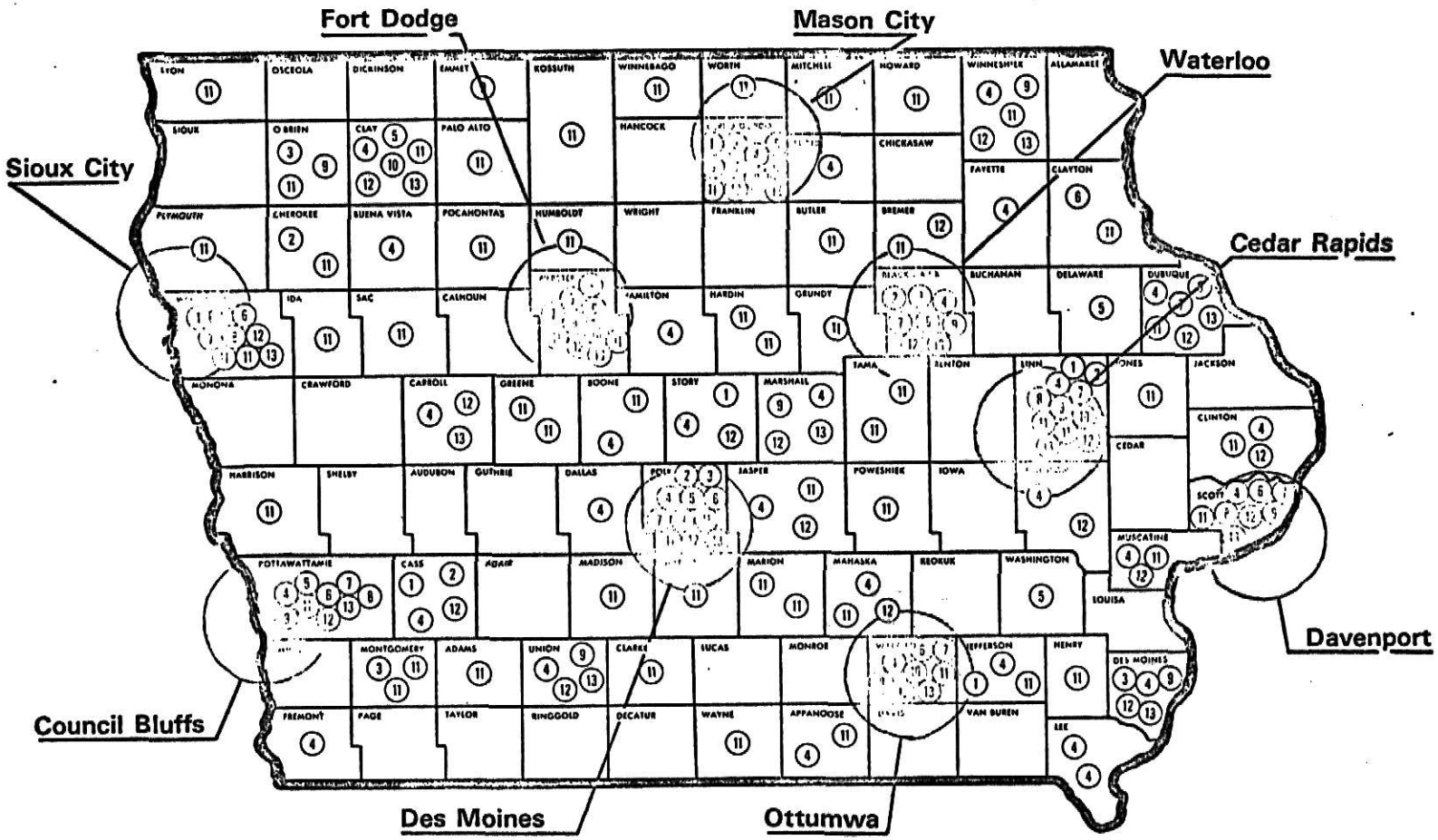
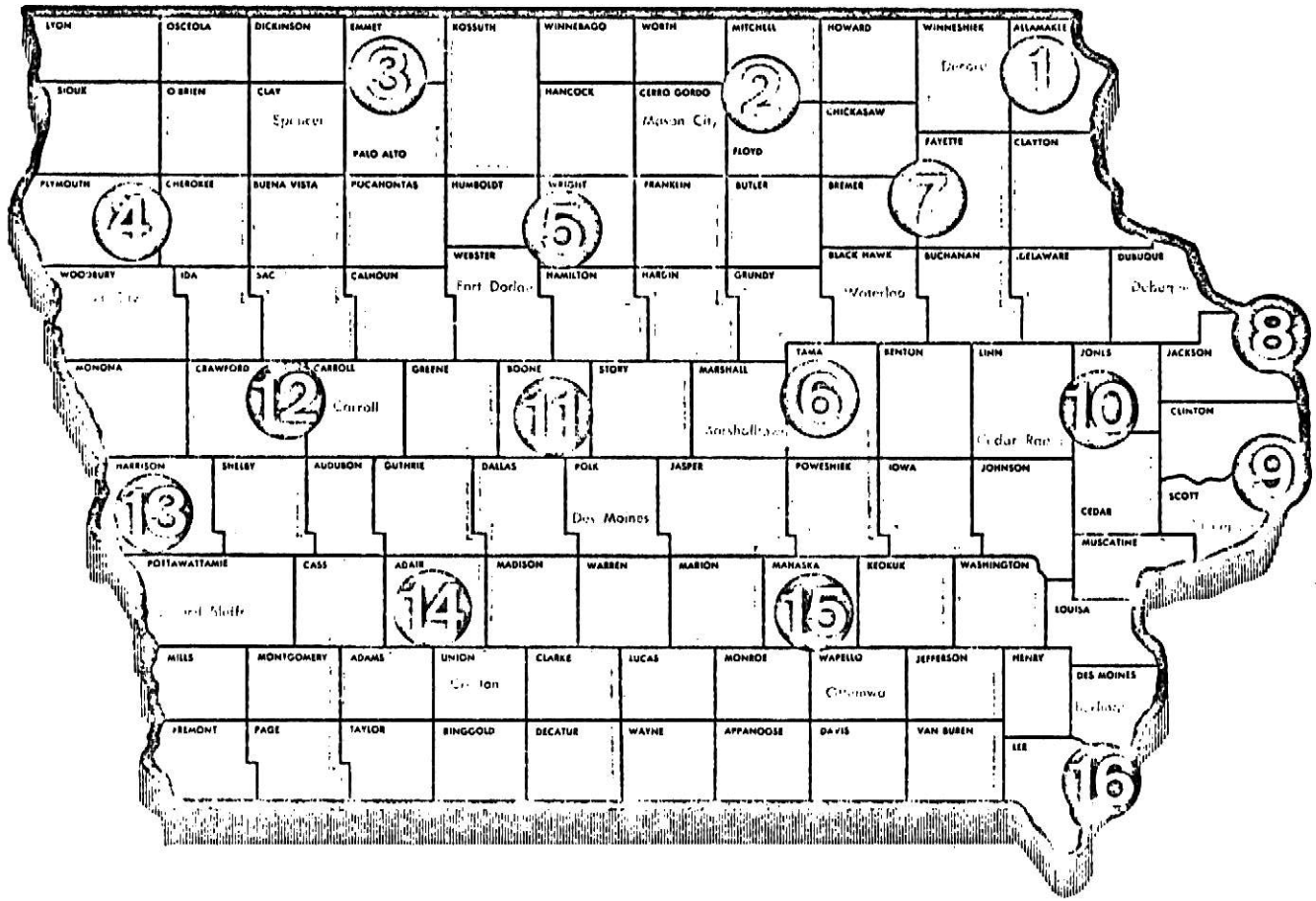
[30]Iowa Office for Planning and Programming, A Regional Delineation for the State of Iowa. (Des Moines: December, 1967).

Figure 6. Concentration of State Services in Major Cities



Source: Iowa Office for Planning and Programming, A Regional Delineation for the State of Iowa, (Des Moines: December, 1967).

Figure 7. Multi-County Areas Recommended by the Office For Planning and Programming



Source: Iowa Office for Planning and Programming, A Regional Delineation for the State of Iowa, (Des Moines: December, 1967).

is that planners in the Iowa study did not want a total measure of city centrality; only the centrality of state agency location was pertinent to their needs.

Centrality with Respect to Isolated Economic Functions

Howard J. Nelson completed a study in which it was his purpose to determine the centrality of various United States cities, with respect to single economic functions.[31] He made separate centrality studies for each of many economic functions, including retail trade, wholesale trade, transportation and communication, mining, professional services, public administration, finance, insurance and real estate, and personal services. In each study, cities were classified in one of three ranks, according to their importance with respect to the particular economic activity.

The method of ranking cities into each of the three categories was not a complicated one. Total retail sales, mining revenues, and other simple indicators were used. The important fact is that the definition of centrality need not be expanded to reflect the total sum of central functions performed in a place. As illustrated by the studies of the State of Iowa and Nelson, in some situations, a total-function measure of centrality is meaningless. Measures of the total service functions performed by cities are obtained best by the use of direct methods, which will be discussed in the next chapter.

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[31]Howard J. Nelson, "Some Characteristics of the Population of Cities in Similar Service Classifications," Economic Geography, 33:2, April, 1957, p. 95.

CHAPTER IV

DIRECT METHODS OF MEASURING CENTRALITY

The main weakness of indirect methods of centrality measurement is that one or two factors are used to determine the importance of a place. In a theoretical sense, this method is open to criticism. Centrality is the total contribution of all central functions (goods and services) provided by a place. Using telephone call data or bus routes as sole indicators of centrality is questionable from the standpoint of pure central place theory and its definition of centrality. This is because, theoretically, each and every central function must be weighed and totaled in order to reach an accurate conclusion about a place's centrality.

Direct methods of measuring centrality focus on the examination, weighing, and quantification of many central functions to arrive at a measure of centrality. These centrality measures are then used in the ranking process. Christaller's problem (and the reason that he turned to telephone connections as his sole measure of centrality), was that he could not find a method to weigh and quantify the importance of various central functions. These problems of weighing and quantification have been gradually solved during the last twenty years.

This chapter contains a discussion and evaluation of three, direct method approaches to centrality measurement. Each approach employs a different procedure to weigh and quantify central functions.

Subjective Weighing and Numerical Tabulation as a Measure of Centrality

The most uncomplicated way of weighing the importance of various goods and services is to pass value judgments and weigh central functions subjectively. After weights have been subjectively assigned, one needs only to observe the numbers of each type of establishment, multiply them by their respective weights, and total the amounts to obtain a measure of centrality. Two studies, one by Smailes and one by Brush, are examples of the "subjective weighing and numerical tabulation" approach to centrality measurement.

One of the first direct method approaches to centrality measurement was made by Arthur E. Smailes. In attempting to rank the urban centers of England and Wales, measurement of centrality was based on an analysis of business services available.[32]

In weighing business functions, Smailes used a subjective approach. He identified several economic functions, which he called a "trait complex." When all four categories of the trait complex are present, a place's status as a town is unquestioned. The first category of the trait complex represents the economic status for a town, which must include at least three banks and several retail establishments. The second category is the presence of both a secondary school and a hospital. The third category is fulfilled by the existence of one or more cinemas, and the publication of a weekly newspaper makes up the fourth category. Other features of British towns, which were given less weight, were the range of professional people, insurance offices, church denominations, government offices, and a head post office.[33]

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[32]Arthur E. Smailes, "The Urban Hierarchy in England and Wales," Geography, 29, 1944, p. 41.

[33]Ibid., p. 44.

The quantifications of all places, with respect to the types of businesses and the numbers of each type of business, gave Smailes a centrality measure for each town. These towns were then ranked in a hierarchy consisting of cities, minor cities, and towns. Because Smailes was one of the first people to tabulate many central functions, instead of relying on only one indicator of centrality, his study is considered to be a classic.

A study by John E. Brush in Southwestern Wisconsin was also based on a subjective weighing and quantification of central goods and services provided by various places. He identified many different "functional units," such as retail trade and school enrollment; several of which were subjectively selected, examined, and plotted in star-shaped patterns on a map of the area.[34] As seen in Figure 8, central places were classified as being either towns, villages, or hamlets. Brush went on to make some conclusions about the distribution and size of towns, as compared to pure central place theory, but the important fact is that he, like Smailes, used a multi-functional, direct method approach to centrality measurement.

The main criticism of the subjective weighing and quantification method of centrality measurement is that it is, as its name suggests, subjective. The entire outcome of the study depends upon those central goods and services that are selected by the researcher. Thus, the reliability of the study is contingent on the assumption that the researcher has analyzed the most important central functions.

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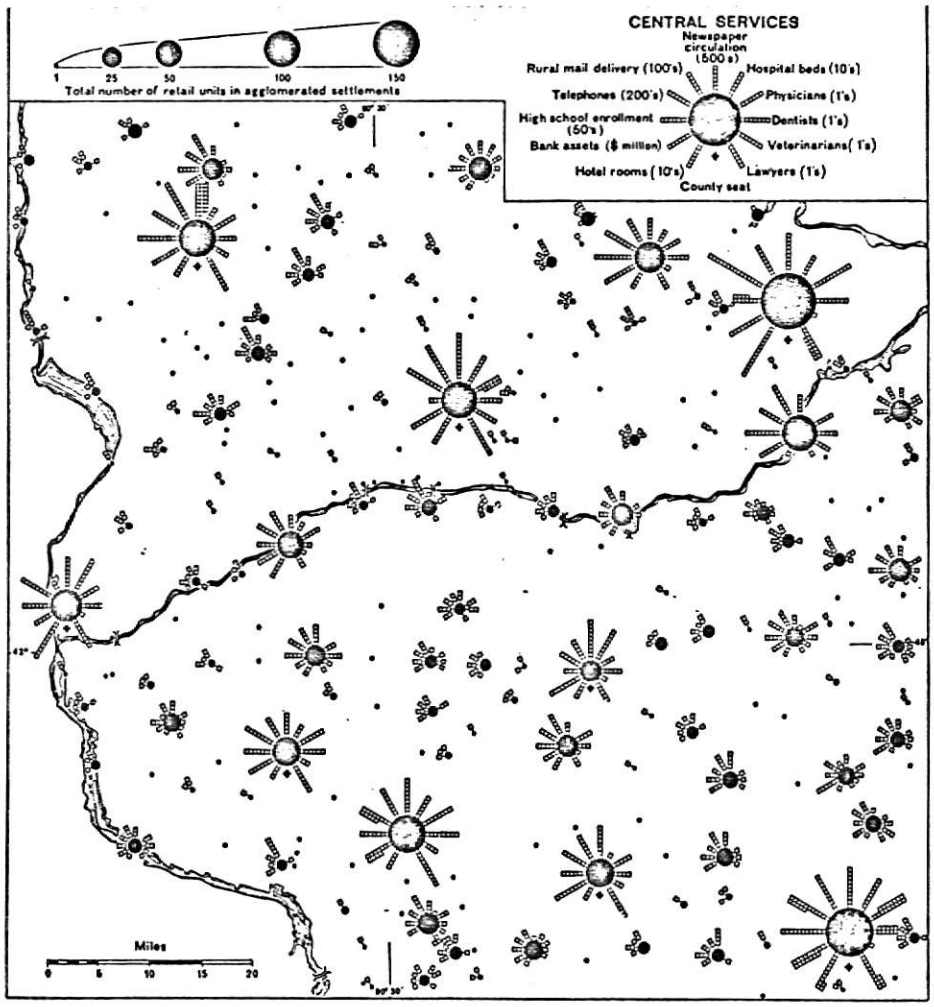
[34]Brush, "The Hierarchy of Central Places in Southwestern Wisconsin," p. 390.

Figure 8. Trade Centers, Showing Central Services Provided



Source: John E. Brush, "The Hierarchy of Central Places in Southwestern Wisconsin," Geographical Review, 43:3, 1953.

Consumer Behavior as a Measure of Centrality

Centrality can be measured by examining consumer behavior. Gwyn Rowley measured the centrality of cities in rural Wales by obtaining interview information about twenty goods and services, and their place of purchase.[35] From these data, he measured the centrality of each place by calculating the percentage of total purchases obtained in each center. Using these sales percentages for each center, as illustrated in Table 3 and Figure 9, the hierarchy of central places was determined.

Unlike the studies of Smailes and Brush, which totaled the number of business establishments in various towns, Rowley's study data were measures of where the populace shopped. In one respect, the consumer behavior approach is superior to that of Smailes and Brush; by use of interviews, the consumer behavior approach seeks out measures of the business activity of each place, whereas the numerical tabulation approach merely totals the number of establishments. Because centrality implies some sort of economic activity, rather than the simple existence of business establishments, the consumer behavior approach to measuring centrality has merit. However, in another respect, the consumer behavior approach suffers from the same weakness as the numerical tabulation approach, in that both rely on subjective decisions as to which central functions will be analyzed.

Direct Factor Analysis as a Measure of Centrality

Although the efforts of Smailes, Brush, and Rowley offered a direct approach to centrality measurement, all three used arbitrary, subjective

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[35] Gwyn Rowley, "Central Places in Rural Wales," Annals of the Association of American Geographers, 61:3, September, 1971, p. 540.

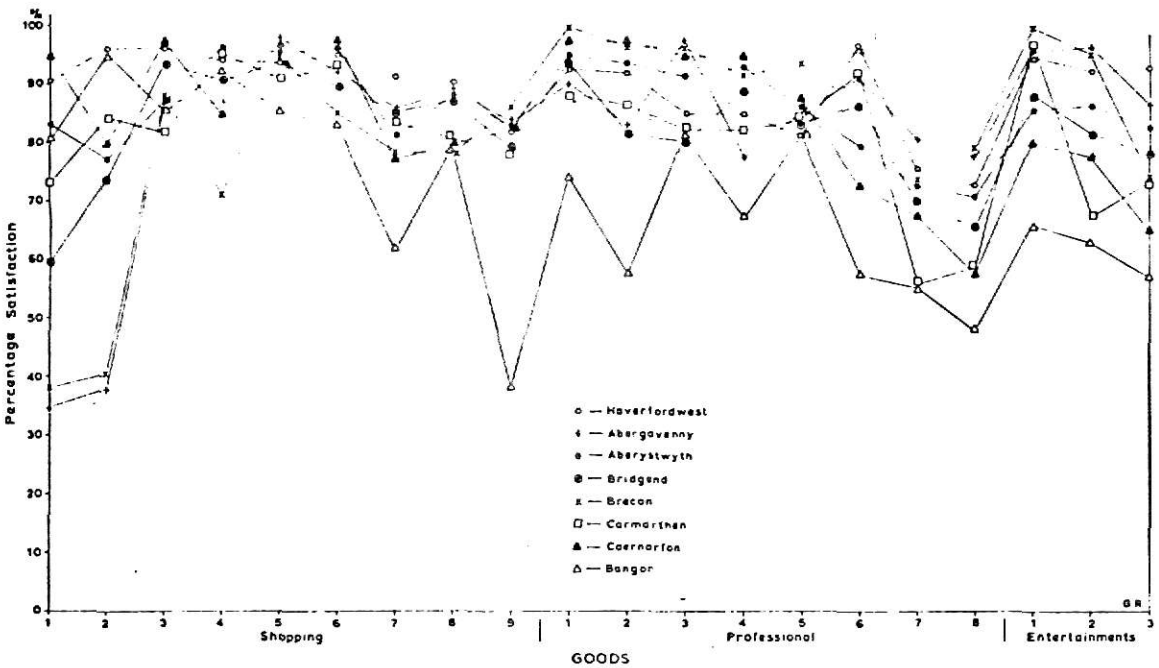
TABLE 3

PERCENTAGE OF GOODS AND SERVICES OBTAINED IN SPECIFIC CENTERS BY CONSUMERS

Goods and Services	Centers						
	Swansea	Haverford-west	Fishguard	Milford Haven	Narberth	St. Davids	Others
Shopping							
1. Evening dress	7.2	90.9	—	1.9	—	—	—
2. Ladies' winter coat	3.1	96.2	—	0.7	—	—	—
3. Furniture (suite)	—	96.4	2.1	—	—	—	1.5
4. Gents' outfitting (suit)	1.2	94.2	3.3	—	1.3	—	—
5. Gramophone (phonograph) records	—	94.0	3.6	—	1.3	—	1.1
6. Jewelry	—	95.2	3.6	—	1.2	—	—
7. Footwear	—	92.5	2.0	1.2	1.5	—	3.8
8. Electrical goods	—	90.7	4.3	0.7	2.4	—	1.9
9. Hardware	—	82.4	6.1	2.4	2.5	0.9	5.7
Professional							
1. Accountant	—	81.6	6.0	4.3	—	3.2	—
2. Dentist	—	92.9	4.5	1.4	1.2	—	—
3. Auctioneer	—	92.1	2.2	2.9	—	2.8	—
4. Solicitor (lawyer)	—	85.3	7.2	2.7	3.5	1.3	—
5. Optician	—	75.6	7.3	4.0	3.6	2.8	—
6. Insurance	—	85.3	3.5	4.1	3.1	—	—
7. Bank	—	72.9	6.6	8.6	1.3	2.8	7.8
8. Chemist (pharmacist)	—	95.4	1.4	1.7	0.3	0.9	0.3
Entertainments							
1. Cinema (movies)	—	94.5	3.5	2.0	—	—	—
2. Dance	—	92.8	3.5	1.3	—	2.4	—
3. Library	—	92.4	3.5	2.0	—	2.4	—

Source: Gwyn Rowley, "Central Places in Rural Wales," *Annals of the Association of American Geographers*, September, 1971.

Figure 9. Consumer Behavior Within Market Areas



Source: Gwyn Rowley, "Central Places in Rural Wales," Annals of the Association of American Geographers, 61:3, September, 1971.

methods to weigh central functions. The entire study was then based on the analysis of these arbitrarily devised weights.[36] Frustration with this type of subjectivity lead to a new school of thought headed by Brian J. L. Berry and others. Endeavoring to objectively weigh the importance of economic functions, they found the answer in the use of factor analysis and other statistical and mathematical techniques.

Factor analysis is a technique used to combine or reduce variables which are linked to each other into indexes reflecting basic structural features of the total situation being studied. Unlike regression and variance analysis, factor analysis does not attempt to explain statistically the variation in a dependent variable by variation in a set of independent variables. Instead, factor analysis retains the many variables relevant in a study by attempting to account for their behavior in terms of a few basic identities.[37]

Using factor analysis, Berry and Barnum studied a nine county area in Southwest Iowa to determine the existence of a continuum and a hierarchy of central places.[38] The authors identified 47 centers and 104 central functions to be used in the eventual ranking of the centers. These were placed in a 47 by 104 matrix, placing the business centers in rows and the central functions in columns. Those centers performing the given central functions were assigned an incidence value of one in the matrix, while those not performing the functions were assigned an incidence value of zero.

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[36]Brian J. L. Berry and H. Gardiner Barnum, "Aggregate Relations and Elemental Components of Central Place Systems," The Journal of Regional Science, 4:1, 1962, p. 46.

[37]Walter Isard, Methods of Regional Analysis; an Introduction to Regional Science, (Cambridge: The M. I. T. Press, 1960), pp. 294-295.

[38]Brian J. L. Berry and William L. Garrison, "The Functional Bases of the Central Place Hierarchy," Economic Geography, 34:2, April, 1958, p. 146.

The theoretical postulate was that the various hierarchial levels of centers are a function of certain interactions of central functions. Being a method used to determine the number and nature of underlying variables among large numbers of measures, factor analysis adapts well to a large matrix. In this case, the underlying variables or components, which were extracted, were relationships between the hierarchial ranks of cities, and the central functions analogous to those ranks.

Using factor analysis, the first pair of components identified a continuum of centers on the basis of population size, and a continuum of central functions on the basis of ubiquity. This result was expected, and accounted for 60 percent of the total number of incidences. By eliminating the effects of population size and ubiquity variations from the matrix, it was hypothesized that the remaining components represent the crucial interaction between levels of centers and central functions.

The second component (the first interaction term) was bipolar, which indicated the presence of two distinct groups of centers. Ranked on the basis of their correlations with the first interaction term, six cities emerged with high positive correlations. These centers performed an average of 68 central functions. More than 20 villages with high negative correlations also existed. They performed an average of 18 functions. Table 4 represents centers ranked on the first interaction term.

Complementing the two classes of centers were two types of central functions. Rankings of correlations of functions with the first interaction term indicated eight functions with very high negative correlations. These were village-level functions. Also, about 50 central functions had high to medium positive correlations and were considered to be city-level functions. Table 5 represents functions ranked on the first interaction term.

TABLE 4

CENTERS RANKED ON THE FIRST INTERACTION TERM

Rank	Towns	No. of Business Types in Town	Correlation
		Positive Correlations	
1	Red Oak	86	0.693*
2	Harlan	75	0.667*
3	Glenwood	60	0.577*
4	Corning	68	0.544*
5	Greenfield	57	0.448*
6	Avoca	59	0.435*
7	Stuart	50	0.221
8	Villisea	42	0.110
9	Walnut	38	0.084
10	Exira	43	0.026
		Negative Correlations	
47	Gray	10	-0.689+
46	Silver City	19	-0.658+
45	Bently	6	-0.632+
44	Bridgewater	18	-0.605+
43	Hastings	11	-0.598+
42	Hancock	15	-0.592+
41	Portsmouth	20	-0.590+
40	Carbon	5	-0.575+
39	Defiance	22	-0.570+
38	Brayton	15	-0.556+
37	McClelland	9	-0.554+
36	Marne	13	-0.546+
35	Minden	24	-0.515+
34	Brooks	5	-0.505+
33	Westphalia	12	-0.503+
32	Underwood	14	-0.482+
31	Macedonia	18	-0.455+
30	Bagley	24	-0.452+
29	Wiota	12	-0.448+
28	Emerson	24	-0.446+
27	Lewis	20	-0.405+
26	Cumberland	24	-0.395+
25	Yale	16	-0.370
24	Dickieville	2	-0.352
23	Fisk	2	-0.352
22	Jacksonville	5	-0.341
21	Grant	16	-0.332
20	Casey	31	-0.322

TABLE 4 (Continued)

Negative Correlations			
Rank	Towns	No. of Business Types in Town	Correlation
19	Bayard	32	-0.293
18	Kimbalton	28	-0.292
17	Lyman	10	-0.265
16	Montieth	4	-0.259
15	Fiscus	2	-0.179
14	Massena	38	-0.134
13	Mt. Etna	3	-0.122
12	Malvern	38	-0.071
11	Fontanelle	32	-0.063

*Cities +Villages

TABLE 5

FUNCTIONS RANKED ON THE FIRST INTERACTION TERM

Positive Correlations		
Type	Incidence	Correlation
Fruit & Vegetable stands	1	.939*
Jewelry	8	.743*
Government, county & higher	7	.724*
Cleaners operation	11	.714*
Florist	5	.706*
Shoes--sales	8	.703*
Liquor	8	.666*
Clothing-women	9	.664*
Shoe repair	10	.649*
Drive-in catery	11	.639*
Clothing-children	2	.628*
Drug-ethical	1	.617*
Amusements	8	.614*
Movie theater	9	.599*
Newspaper publisher	13	.597*
Bakery	5	.585*
Clothing-men	8	.581*
Motel	9	.573*
Photographer	3	.562*
Supermarket	10	.557*
Labor union	4	.552*
Records & Music	3	.532*
Dentist	10	.532*
Self service laundry	14	.530*
Auto sales, new	15	.529*
Other medical service	11	.519*
Lawyer	14	.500*
Furniture	17	.489*
Auto accessories	11	.488*
Monument sales	2	.488*
Other retail sales	2	.488*
Job printing	14	.484*
Hotel	11	.474*
Doctor	14	.466*
Variety store	16	.459*
Loan Company	4	.434*
Currency exchange	5	.434*
Fix-it shop	7	.434*
Auto sales, used	12	.425*
Plumbing	10	.422
Second hand	3	.419
Auto repair, specialized	16	.419
Mission (store) church	2	.407
Clothing, Men & Women	9	.401

TABLE 5 (Continued)

Type	Incidence	Correlation
Gift, Stationery, Novelty	5	.381
Drug-complete	18	.367
Other service, business	6	.366
Nursery & Landscape	1	.359
Office equipment, supplies	1	.359
Boats, marine supplies	1	.359
Auction sales room	1	.359
Stock, commodity broker	1	.359
Veterinarian	12	.333
Funeral home	7	.329
Drive-in theater	1	.297
Feed, seeds, pets	1	.297
Real Estate	14	.272
Sporting goods	3	.262
Radio & TV, sales, service	10	.256
Billards	15	.254
Beauty	18	.228
Transit station (bus)	6	.226
Candy	1	.192
Insurance	18	.191
Dairy	3	.182
Telegraph office	7	.181
Other building service	18	.171
Electrical repair	4	.155
Telephone exchange	7	.127
Other building and construction	4	.115
Coal yard	7	.111
Tailor	2	.091
Blacksmith, metal work	10	.081
Commercial garage	7	.079
Cameras & supplies	1	.046
Junk yard, auto wrecking	4	.041
General merchandise	1	.032
Other service, personal	1	.013
Meat & Poultry	2	.010
Radio & TV station	1	.009
Negative Correlations		
Restaurant	38	-.815+
Gas station	45	-.791+
Bar, no entertainment	37	-.776+
Auto repair garage	40	-.769+
Grocery	39	-.653+
Post Office	30	-.600+
Farm materials	34	-.525+
Farm sales & elevator	30	-.501+

TABLE 5 (Continued)

Type	Incidence	Correlation
Banks	30	-.419
Government, local, municipal	26	-.386
General store	17	-.346
Church	30	-.313
Farm equipment & supplies	29	-.292
Meeting hall	21	-.237
Cleaners-pick up	2	-.228
Hardware	25	-.195
Bicycle sales	1	-.182
Bulk fuel oil station	21	-.174
Lumberyard	25	-.151
Drapes & window shades	1	-.109
Barber	24	-.069
Food locker	14	-.036
Movers & haulers	7	-.035
Appliance sales	23	-.002

The third pair of components (the second interaction term) indicated the presence of town-level functions and town centers. These centers were performing an average of 30 central functions. Five pairs of components were generated in the study; however, the first three were the only significant components for the purposes of measuring centrality and ranking the cities.

Despite the appearance of objectivity in factor analysis, subjectivity exists. First, the choice of relevant central functions depends on the decision of the researcher and the availability of data. Second, the researcher must decide on the appropriate amount of data. Third, because of the many alternative sets of factor arrangement possible for given intercorrelation data, the interpretation of factor analysis results depends upon the conceptual construct judged to be the most significant by the researcher.[39] Nevertheless, the use of factor analysis has added a new dimension to centrality measurement.

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[39] Ibid., p. 305.

CHAPTER V

CONCLUSION

In reviewing the validity, or effectiveness of empirical methods of centrality measurement, attention must be drawn to the accuracy of those methods in determining the functional economic importance of a place. It can be concluded that indirect, single functional approaches should be regarded with a high degree of skepticism. It is invalid to assume that one or two indices can serve as an accurate reflection of the economic significance of a place. At best, indirect methods of centrality measurement are only a partial indicator of a place's importance. Eliminating considerations of the many economic functions of a place, indirect methods are used by the researcher that is faced with either a lack of data, or a shortage of time.

Direct methods, although a definite improvement over indirect approaches, also face certain criticisms. Direct method approaches that rely on a subjective weighing of central functions, result in equally subjective conclusions. The accuracy of such studies depends upon the fortunate or unfortunate guesses of their authors, as to which central functions are most important. Direct approaches using factor analysis, or other statistical methods, seem to enjoy an advantage over all other approaches in that the weighing of central functions is an objective construct that is inherent in mathematics. However, mathematical analysis, while objective, is highly dependent on the limitations and peculiarities of data. Biased data, which might be quickly discarded by a subjective researcher, will often be generated into mathematical analysis. The researcher can become so blinded by mathematical

constructs that they become his master, rather than his method of analysis. Consequently, it is likely that direct, subjective weighing methods are as valid as those using direct factor and other mathematical analysis. In short, direct methods have a definite advantage over indirect methods, but as to which type of direct method is the most valid, it is still open to question.

Wayne K. D. Davies says that if the concept of hierarchial ranking is to retain significance, three requirements must be met. First, the technique used to measure centrality must be completely objective and capable of being tested. Second, it should be possible to directly compare the results obtained in any area with the results obtained elsewhere. Third, the final index of centrality should be capable of being subdivided into its component parts.[40]

Regional scientists have not yet reached an accord, as to which method of centrality measurement meets Davies' requirements, and there is good reason to believe that they will never agree. In the first place, it is difficult to identify central goods and services, because the division between central and dispersed goods changes over time.[41] Secondly, because of national and cultural differences, centrality measures common to one place will not be appropriate for use in other areas.[42] Thus, it seems that many different methods of centrality measurement will continue to exist.

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[40]Davies, "Centrality and the Central Place Hierarchy," p. 61.

[41]Harry W. Richardson, Regional Economics (New York: Praeger Publishers, 1969), p. 163.

[42]Murphy, The American City, p. 49.

Despite the lack of agreement on a specific, optimum method of centrality measurement, progress has been made to increase the accuracy of such methods. Harry W. Richardson, in his regional economics text, describes central place theory as being, " . . . one of the most fruitful theoretical and operationally feasible approaches to the study of urban growth."[43] In a society where urban growth is so prevalent, the persistence of regional scientists, in trying to devise better methods of centrality measurement, should reap substantial social benefit.

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[43]Richardson, Regional Economics, p. 162.

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EMPIRICAL METHODS OF CITY CENTRALITY MEASUREMENT

by

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Central place theory was developed by Walter Christaller as a statement of ordering principles governing the size, number, and spatial distribution of towns. Every town has importance, with respect to the region surrounding it, in terms of the degree to which it performs economic functions. This economic importance, according to Christaller, is known as centrality. A basic premise of the theory, is that towns vary in their centrality, creating a hierarchy of central places, in which towns of greater centrality serve land areas containing towns of lesser centrality.

For theoretical and planning purposes, it has been desirable to make empirical studies of regions, in order to rank towns in a hierarchy, according to their centrality. Many such studies have been made, but a problem exists in the fact that the methods used to measure centrality are almost as numerous as the number of studies. The purpose of this report was to categorize, review, and evaluate empirical methods used to measure centrality.

Methods of centrality measurement can be classified in one of two general categories, direct or indirect. Direct methods consist of an investigation and quantification of central economic functions provided by each town, which is obtained by an analysis of goods and services provided. Indirect methods of centrality measurement are characterized by the analysis of one, or a few selected indicators, which are assumed to represent the activity of many central functions. The amount of traffic flow, and the number of daily newspapers are examples of indirect methods of centrality measurement.

Among the indirect methods discussed were the number of telephone connections, a factor analysis of telephone traffic, an analysis of bus traffic, flows of vehicle and air traffic, and population. Direct methods

included a subjective weighing and numerical tabulation approach to centrality measurement, a consumer behavior investigation, and a direct factor analysis of central places and their various central functions. Each method, direct and indirect, was evaluated as to its ability to measure centrality.

The conclusion was that indirect methods of centrality measurement should be regarded with skepticism. It was unrealistic to assume that one, or two indices could serve as accurate reflections of the economic significance of a place. Direct methods, because they offered a multi-functional approach to measurement, were considered more accurate than indirect methods. However, a great deal of work will be required to perfect direct methods to the point where they can be said to offer a totally accurate approach to centrality measurement.