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Central place systems in rural labor markets

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by

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CHAPTER I. INTRODUCTION

The Research Problem

The rural areas of Iowa have been losing population. The reason for this migration to urban areas is not because the quality of life is lower in the rural areas, but because there are not sufficient employment opportunities available in the rural areas.

As agriculture has become less labor intensive the rural population declines, which in turn decreases the quantities of goods and services purchased in the small rural communities. The number of people employed in small towns and supplying these goods and services has been reduced and as the populations of rural areas and small communities decline, the employment base becomes too small to attract new employers. As the number of businesses decline, essential commercial services are reduced and an additional contraction in the employment base occurs.

It is a readily observable fact that the population distribution of Iowa is shifting. The research problem is to identify and quantify the shifts and to comment on the stability of the population distributions. This study is concerned with describing and analyzing changes in the size distribution of urban places within a labor market rather than the shifts of population from one labor market to another.

Purpose and Plan of Study

The population which remains in the small rural communities may be forced to commute to larger cities for employment, shopping and social activities. The economic relationships of small rural communities to larger towns and cities must be studied to understand the growth prospects of the smallest urban settlements.

In 1967, the state of Iowa was delineated into sixteen administrative planning regions by the Office for Planning and Programming. A delineation based on commuting patterns to the place of work can be used to identify areas which provide employment for the population of surrounding communities. The development plans of the central work place and the surrounding labor supply area should be coordinated as their economic and social changes are highly interrelated.

Each of the planning regions has a city designated as the central city for administrative planning. Hierarchies can be established relating the central city to the supporting smaller cities and rural areas of the region. The regional and city populations can be predicted from the relationship between the rural population, the population of the smallest communities, and the number of levels of the hierarchy.

Regions or cities with populations smaller than estimated may have structural impediments to growth compared to regions with populations which are larger than predicted. If the cause of the overestimation is discovered (possibly a poor intraregional transportation system), a correction of the cause will greatly add to the region's ability to sustain an adequate economic base.

An empirical regularity known as the rank-size rule has been observed in previous studies of urban areas and homogeneous regions. The rank size rule can be stated as $R = CS^{-q}$ where R and S are the rank and population of a city and C and q are constants. Analyses using the rank-size rule are completed for Iowa's rural labor markets for 1950, 1960, and 1970. A comparison of the results over time will identify the changes and stability in population distributions.

The rank-size rule is a norm which can be used to test the stability of city size hierarchies. Deviations from the expected results of the rank-size rule will also identify and quantify the degree of deviation of the observed population distribution from the expected city size hierarchy.

Changes in the size distribution of urban places within labor markets will influence the origin destination patterns of shopping and commutation. If the smallest rural towns lose their commercial services employment base, larger communities may usurp this function and a centralized pattern of behavior is encouraged. Similarly, if the largest regional centers lose commercial establishments and shopping centers disperse to the immediate size cities then a decentralized pattern of trips will result. Such patterns of employment and population change are not unlike the similar decentralization within our metropolitan regions. In the high density urbanized regions, less centralized patterns of commutation and shopping have been observed over the past fifteen years.

The purpose of this study is to analyze patterns of population growth within Iowa's labor markets over the period 1950-1970; three substantive chapters discuss the principal results. Chapter II compares delineation criteria for Iowa's labor markets and discusses the effects of auto commutation patterns on existing delineations. In Chapter III central place hierarchies within labor markets are estimated for three population levels: rural towns, intermediate centers, and the regional capital are separately distinguished. Rank-size regressions estimated for the full array of cities within each region for the period 1950-1970 are the subject of Chapter IV. A concluding chapter summarizes the results of the analysis.

CHAPTER II. DELINEATION

Objective

The objective of this chapter is to delineate the state of Iowa into economic regions to explain the spatial distribution of economic activity. This distribution will show the main regional centers for employment, availability of goods and services, and the surrounding areas which support and are dependent on the centers.

Functional Economic Areas

This delineation is based on a concept of Dr. Karl Fox, who terms the economic regions Functional Economic Areas (FEA's). In 1964, Fox theorized that FEA's are spatially extended urban communities. Each FEA is a relatively self-contained economic area (or labor market) in the long run. The low density agricultural hinterland is the site of major export activities. Small cities in the periphery are analogous to outlying shopping centers in metropolitan areas and act as service centers for peripheral residents.

The central city of the FEA contains a full line of consumer goods and services, plus a well developed labor market. Central cities are also wholesale centers for the area. The central city is important to all residents of the FEA because of economies of scale; it may also be the only source of certain goods and services in the FEA.

Commuting Fields

An FEA is both a commuting field and a retail trade area. Due to the availability of commuting data which is better than trade data, the analysis in this chapter uses the commuting field to define the FEA. The FEA includes all counties with a labor market for which the proportion of resident workers commuting to a given central county is greater than the proportion commuting to alternative central counties [6, p. 118].

Commuting is broken down to the county level, and consequently delineation of the state into FEA's will involve entire counties. If commuting data had been available at the township level, the commuting field delineation would be more accurate.

Delineation Criteria

The delineation applied to the state of Iowa and areas in bordering states are not included. The sponsor of this study, the U.S. Department of Transportation, is concerned with state planning and, therefore, Iowa will be treated as a self-contained economic area.

Steps for delineation

1. Criteria for central cities
   a. All cities with a population of 25,000 or greater are possible central cities.
   b. When cities with populations of 25,000 or greater are in contiguous counties or in the same counties, the larger city will serve as the central city and the county

containing the smaller city will be part of the region surrounding and dependent on the central city.

2. Assign counties to the central cities on the basis of commuting fields. Each county is assigned to the central city where it sends the largest number of commuters.

3. If some counties are not included in a FEA under these criteria, a city of less than 25,000 may be classified as a central city. For the selection of a central city smaller than 25,000 in population, the following conditions must be met:

   a. There must be more than one county in the area with zero commuting to a central city of more than 25,000 in population.

   b. The largest city in the area is chosen as a possible central city. The wholesale receipts from this city should be close to the amount of receipts from central cities selected under step 1. Per capita wholesale receipts are not used as a criteria for selecting central cities.

The sixteen Iowa cities with populations greater than 25,000 have per capita annual wholesale receipts varying from over \$8,000 to \$600. Ames and Iowa City both have per capita wholesale receipts of \$600. Both cities contain large state universities and students are included in the population figures. Per capita wholesale receipts may inaccurately reflect the importance and size of wholesale activities in the two cities. The next lowest per capita wholesale receipts of the sixteen largest cities is $1,050.

Counties containing only cities under 5,000 in population often have larger per capita wholesale receipts than cities of over 25,000 in population. These cities of under 5,000 in population cannot be considered as regional centers. They do not offer the variety of wholesale goods that the larger cities do.

c. If conditions a or b are not met, the counties will be assigned to a region on the basis of a gravity formula,

$$P_a = \frac{A_a/D_a2}{A_a/D_a2 + A_b/(T-D_a)^2} \quad [19, p. 27].$$

P_a is the probability that a person in an area will be attracted to center a. A_a is a's attractiveness; size of population is usually used. D_a is the distance of the area in question from a and T is the distance between a and b. With an equivalent formula for P_b, an area is allocated to the center for which the probability is the highest. When calculating the probability that a county is attracted to a central city, D_a is the distance from the central city to the county seat of the county in question.

Empirical Delineation

There are sixteen cities in the state with populations greater than 25,000; see Table 2.1. Four of the cities are in counties contiguous with counties containing larger cities. Story county, containing Ames, is bordered by both Marshall and Polk counties. Since Des Moines is much larger than Ames, Story county will be absorbed into the Des Moines FEA. Marshalltown will also be a central city. Clinton is dominated by Davenport and Iowa City by Cedar Rapids. Black Hawk county has two cities (Waterloo and Cedar Falls), with populations larger than 25,000; the larger city (Waterloo) will be the central city.

The state can now be delineated into twelve FEA's. Table 2.2 and Figure 2.1 show the division of the state according to commuting fields.

Taylor and Ringgold counties have zero commuting with central cities. The largest city in each county has less than 1800 in population. In 1967, Taylor county had wholesale receipts of $13.1 million and Ringgold county had receipts of $7.4 million. Marshalltown had the lowest wholesale receipts, $26.1 million, of any of the central cities.

Ringgold and Taylor counties will be included in one of the surrounding FEA's, Des Moines or Council Bluffs. Using the gravity formula, a resident of Ringgold county has the probability of .56 of being attracted to Des Moines and .003 of being attracted to Council Bluffs. A Taylor county resident has a .12 probability of being attracted to Des Moines and .04 probability of being attracted to Council Bluffs. Both Taylor and Ringgold counties will be included in the Des Moines FEA.

Table 2.1. Cities with populations greater than 25,000, 1970[a]

City	Population
Ames	39,505
Burlington	32,366
Cedar Falls	32,964
Cedar Rapids	110,642
Clinton	34,716
Council Bluffs	60,348
Davenport	98,469
Des Moines	201,404
Dubuque	62,309
Fort Dodge	31,263
Iowa City	46,850
Marshalltown	26,219
Mason City	30,491
Ottumwa	29,610
Sioux City	85,925
Waterloo	75,533

[a]Source: [20].

Table 2.2. Twelve FEA's based on commuting fields[a]

central city	county	number of daily commuters from county to central city
Burlington	Des Moines	
	Henry	1000
	Jefferson	159
	Lee	1028
	Louisa	423
	Van Buren	101
Cedar Rapids	Linn	
	Benton	1274
	Cedar	277
	Iowa	204
	Johnson	1036
	Jones	780
	Washington	38
Council Bluffs	Pottawattamie	
	Adams	7
	Audubon	14
	Cass	72
	Crawford	14
	Fremont	24
	Harrison	309
	Mills	191
	Montgomery	33
	Page	14
	Shelby	151
Davenport	Scott	
	Clinton	736
	Muscatine	689
Des Moines	Polk	
	Adair	102
	Boone	591
	Carroll	25
	Clarke	258
	Dallas	2639
	Decatur	47
	Guthrie	354
	Jasper	890
	Lucas	139
	Madison	803
	Marion	713

[a]Source: [10].

central city	county	number of daily commuters from county to central city
Des Moines (cont'd)	Story	1043
	Union	42
	Warren	5185
	Wayne	12
Dubuque	Dubuque	
	Allamakee	7
	Clayton	375
	Delaware	382
	Jackson	476
Fort Dodge	Webster	
	Calhoun	473
	Greene	49
	Hamilton	358
	Humboldt	159
	Kossuth	7
	Pocahontas	38
	Sac	13
Marshalltown	Marshall	
	Hardin	133
	Poweshiek	87
	Tama	727
Mason City	Cerro Gordo	
	Floyd	317
	Franklin	67
	Hancock	110
	Howard	6
	Mitchell	60
	Winnebago	25
	Worth	331
	Wright	65
Ottumwa	Wapello	
	Appanoose	101
	Davis	355
	Keokuk	176
	Mahaska	235
	Monroe	327

Table 2.2. Continued

central city	county	number of daily commuters from county to central city
Sioux City	Woodbury	
	Cherokee	47
	Ida	50
	Lyon	23
	Monona	196
	O'Brien	7
	Plymouth	867
	Sioux	40
Waterloo	Black Hawk	
	Bremer	1224
	Buchanan	932
	Butler	555
	Chickasaw	170
	Fayette	349
	Grundy	641
	Winneshiek	6

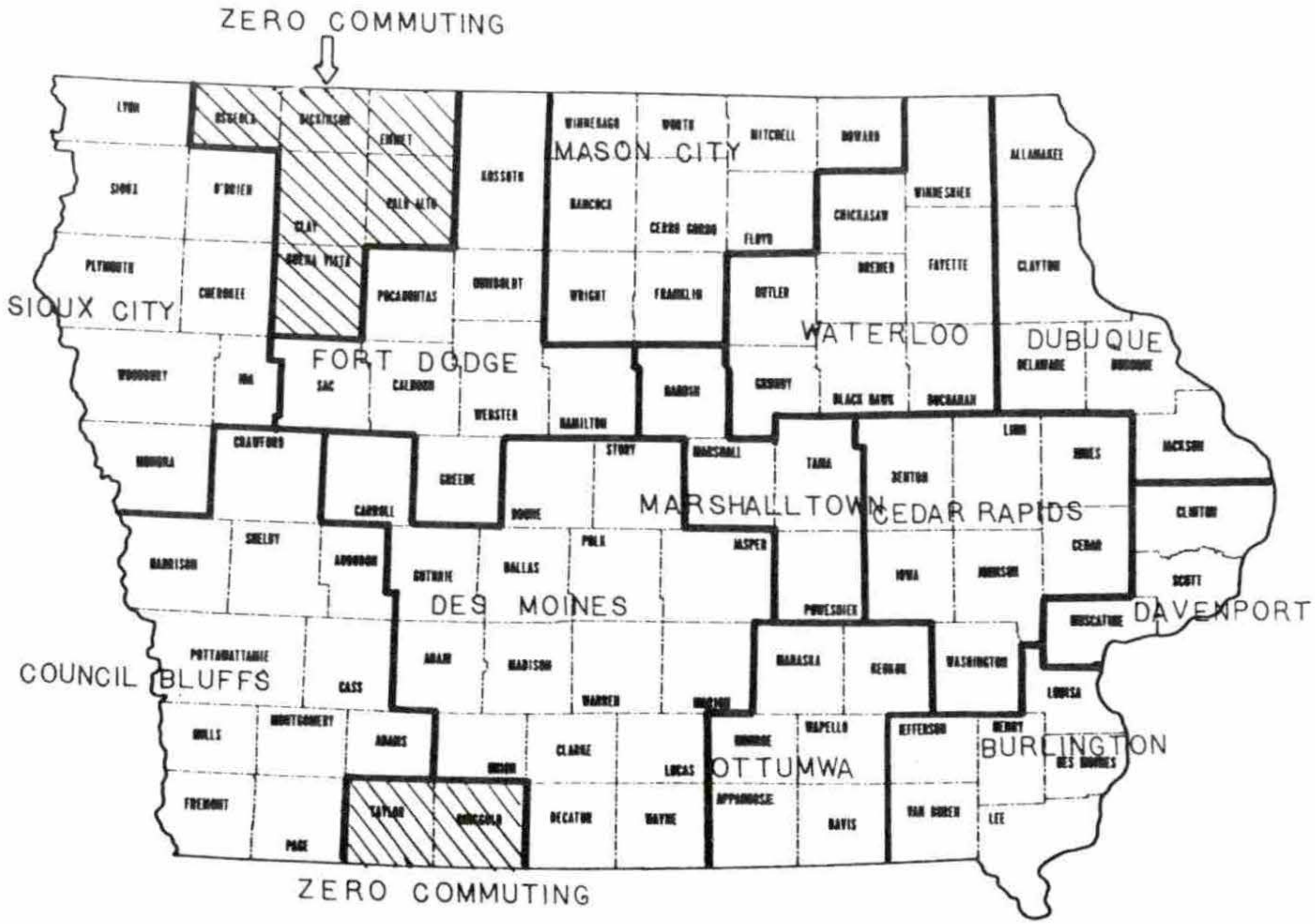

Figure 2.1. Commuting fields of 12 central cities

The six counties in the Iowa lakes area have zero commuting with a central city. Spencer is the largest city, with a population of 10,278 in 1970. In 1967, Spencer had wholesale receipts of $42.4 million. This compared with $26.1 million for Marshalltown and $33.8 million for Ottumwa.

The Spencer FEA as based on the commuting field has seven counties, as shown in Table 2.3. With the addition of Spencer as a central city, O'Brien county was shifted from the Sioux City FEA and Kossuth county from the Fort Dodge FEA to the Spencer FEA.

O'Brien and Kossuth counties each had only seven commuters to a central city in the twelve FEA delineations. O'Brien county, with ninety-four commuters to Clay county, is an integral part of the Spencer FEA labor market. Kossuth county has only twelve commuters to Clay county. Kossuth county is on the outer edge of both the Spencer and Fort Dodge FEA's and does not have extensive commuting with either. Because each county must be included in an FEA and Kossuth county has a slightly larger number of commuters to Clay county, it is included in the Spencer FEA.

Table 2.3. Spencer FEA based on commuting field[a]

central city	county	number of commuters from county to central city
Spencer	Clay	
	Dickinson	149
	O'Brien	94
	Palo Alto	84
	Buena Vista	64
	Emmet	21
	Kossuth	12

[a]Source: [10].

Osceola county has zero commuting with a central county. The gravity formula gives Osceola county residents a .076 probability of being attracted to Spencer and .40 probability of being attracted to Sioux City. Osceola county will be included in the Sioux City FEA. Figure 2.2 gives the final delineation based on thirteen commuting fields.

The OPP Delineation

This paper is being done in conjunction with a study by the Engineering Research Institute at Iowa State University under a grant provided by the U.S. Department of Transportation. The Engineering Research Institute uses a delineation of Iowa prepared in 1967 by the Iowa Office for Planning and Programming, (OPP).

The OPP delineation uses sixteen central cities, which includes the thirteen regions discussed above plus Carroll, Creston, and Decorah; these are shown in Figure 2.3.

> The OPP designed these regions to meet the existing and future needs for:
>
> A common geographic base for planning, coordination, and administration of state services and programs.
>
> A base for regional planning, programming, and development - through the identification of common problems, goals, and opportunities at the regional level, and through the integration of state and local development policies and goals.
>
> A base for the greatest utility of local resources through the identification and use of the most appropriate state and federal programs.
>
> Sub-units of a statewide information system.

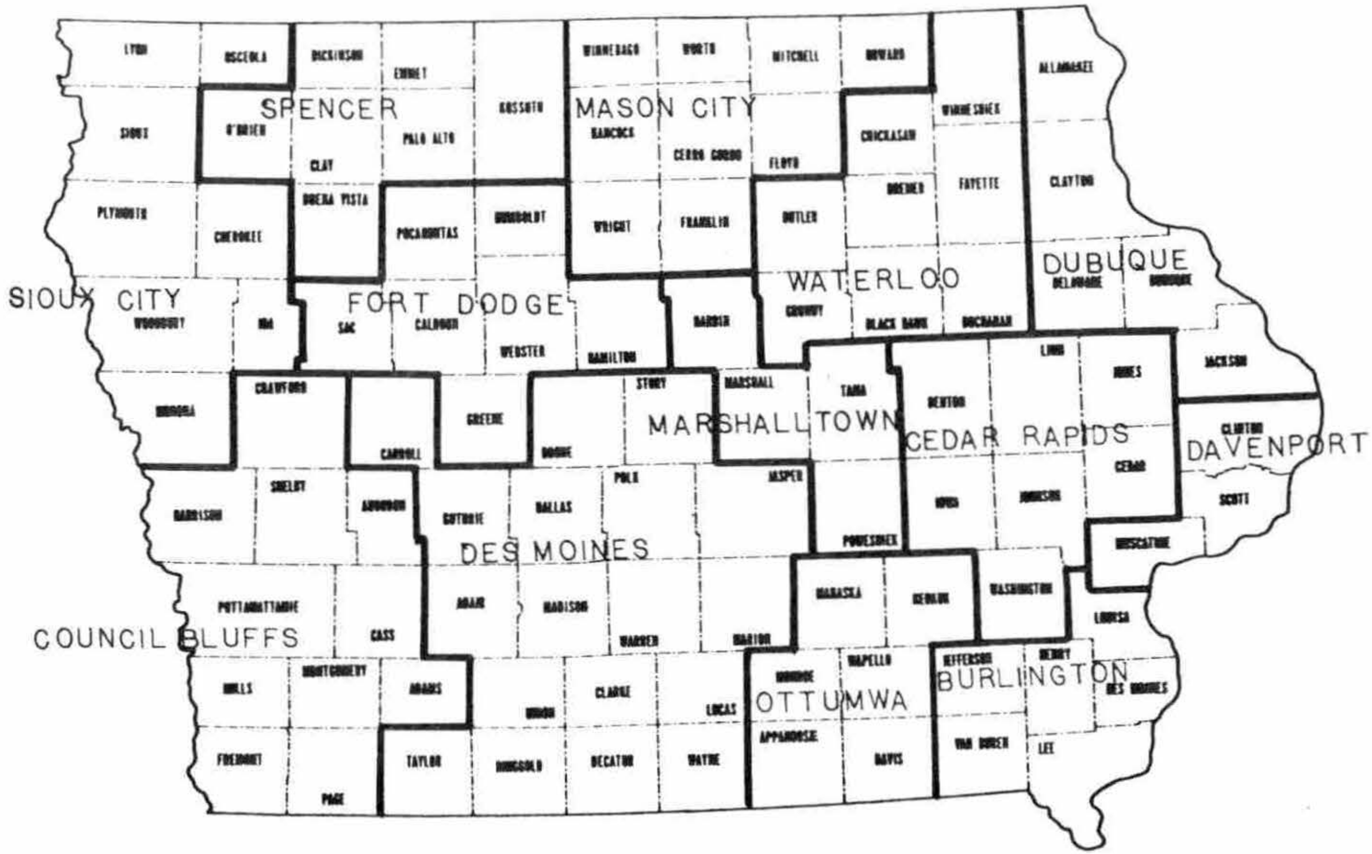

Figure 2.2. Commuting fields of 13 central cities

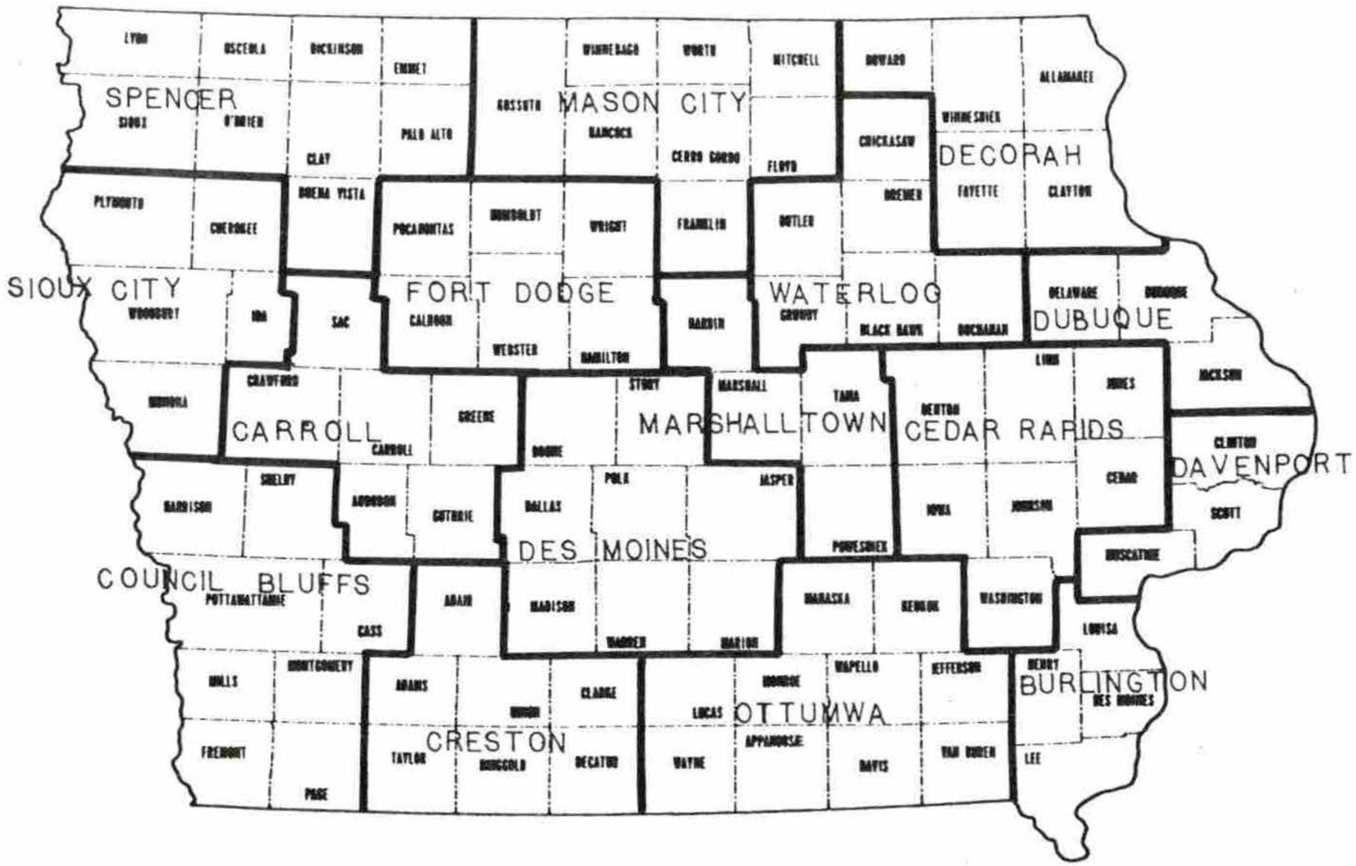

Figure 2.3. OPP Delineation

Flexibility will be an important factor in the successful implementation of these planning and administrative regions [12, p. 1].

Commuting From Counties Outside the OPP Regions

A preliminary step which can be used to predict whether the OPP delineation conforms with the delineation based on commuting is to examine the commuting patterns between the central counties and counties outside the region. If there is a substantial amount of external commutation one can assume the delineations will be different.

The only commuting that is deemed to be of importance is between the central county and counties outside the region. These flows must also be larger than daily commuting between the central county and at least one county within the region. Figures 2.4, 2.5, and 2.6 show incommuting to the central counties, outcommuting from the central counties and the total commuting flows between the central counties and those outside the region. The results of this procedure suggests that the delineations will be different.

The majority of the significant commuting between the central counties and outside the FEA's occurs in five FEA's in the east-central area of the state. Four cities of greater than 50,000 inhabitants and Marshalltown, centered around the Cedar Rapids FEA, are the location of most of the commuting. The cities (Marshalltown, Waterloo, Dubuque, and Davenport) are within a seventy-five mile radius of Cedar Rapids. There is heavy commuting both in and out of the central counties. The commuting fields of these metropolitan FEA's, which are in close proximity,

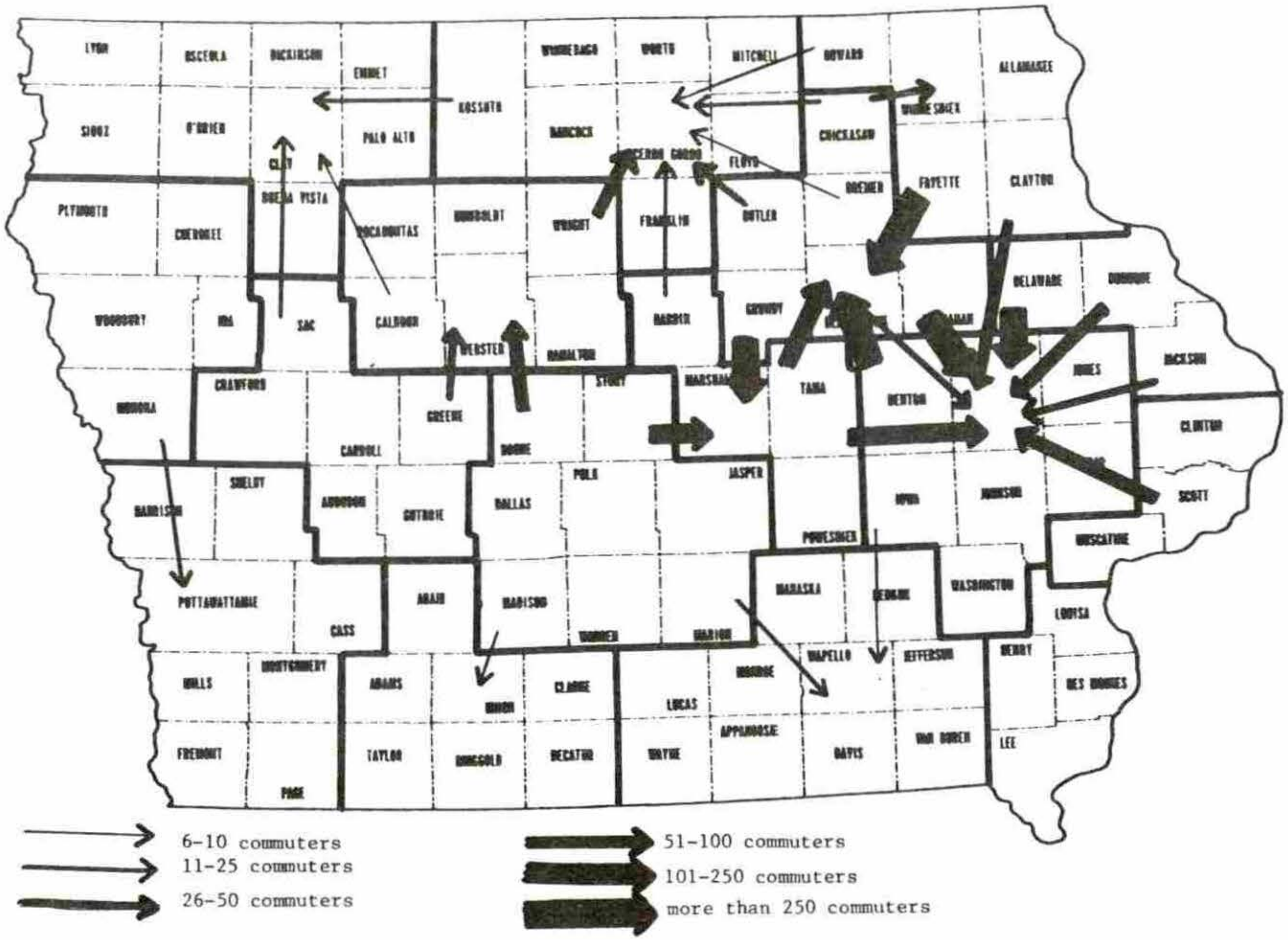

Figure 2.4. Incommuting to central counties

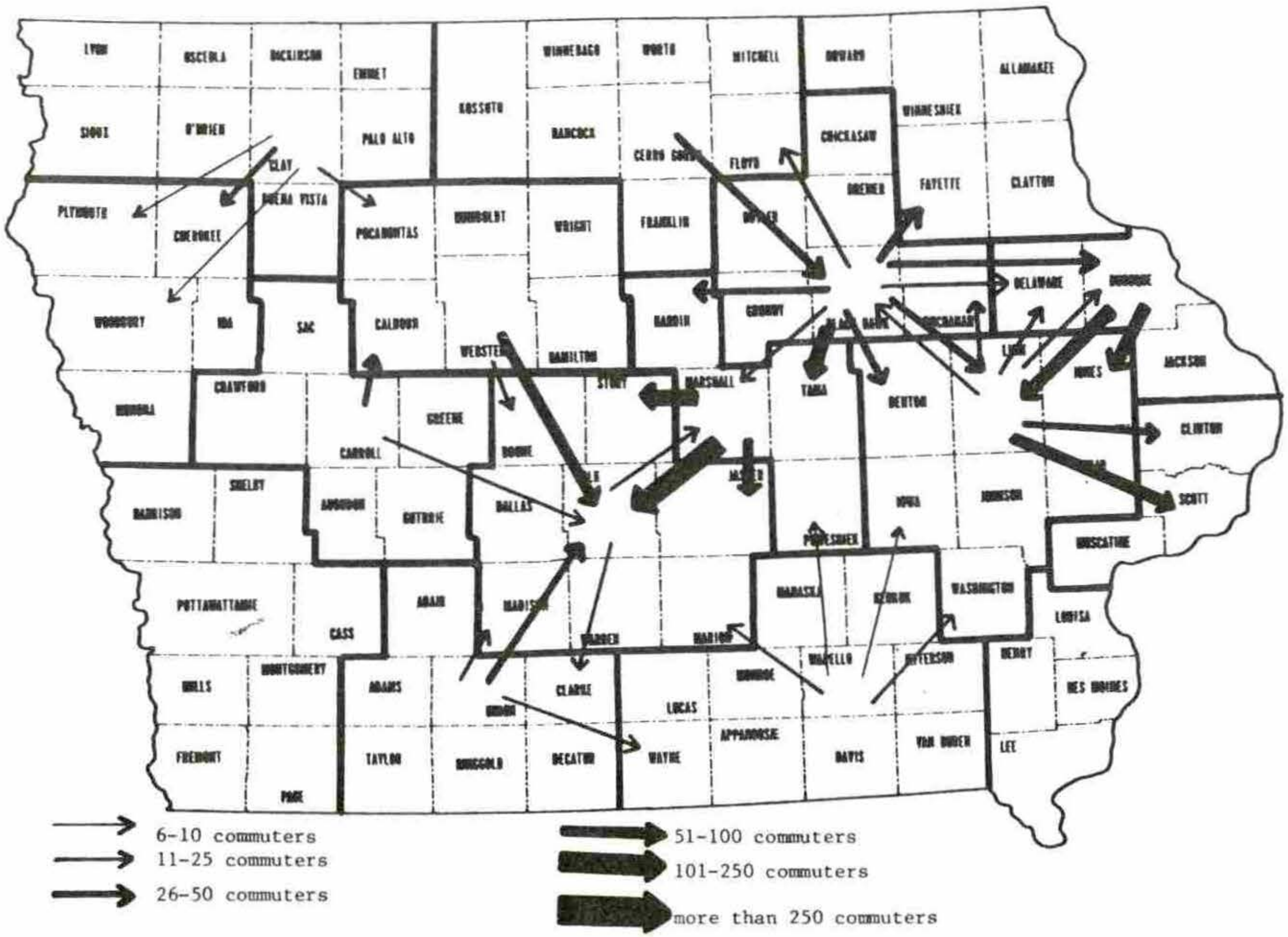

Figure 2.5. Outcommuting from central cities

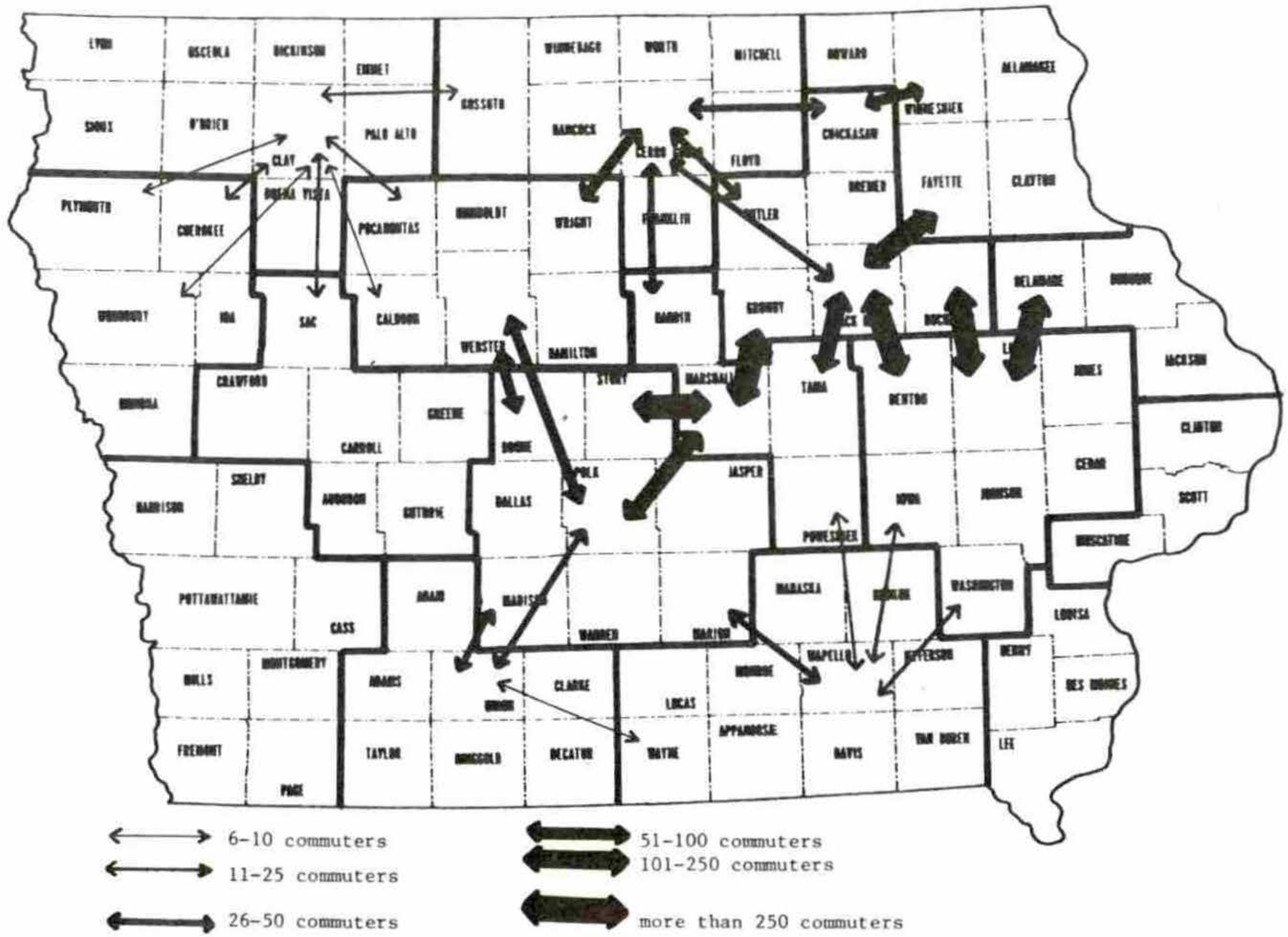

Figure 2.6. Total commuting between central counties and outside the region

overlap considerably and are not defined as definitely as in other FEA's of Iowa.

Commuting Fields Using Sixteen Central Cities

The commuting field delineation provides an understanding of how the economy is organized in a geographical space. Since the Engineering Research Institute is using sixteen central cities, the commuting fields of the sixteen central cities are shown in Table 2.4 and Figure 2.7.

Osceola county has zero commuting with a central city. The gravity formula predicts that a resident of Osceola county will be attracted to Sioux City with a .40 probability and to Spencer with a probability of .09. Osceola county is included as a part of the Sioux City FEA.

Delineation Based on the Gravity Formula

The gravity formula provides a delineation based on a minimum amount of information. It does not account for employment opportunities, government services, or goods and services a central city provides which may attract the residents of the surrounding area. This method of delineation is similar to sixteen magnetic fields. The central city attracts residents of the area with a magnitude dependent on the central city's population, the population of surrounding central cities, and the distance from the surrounding central cities.

In the future the distance from the area in question to the central city may be of more importance because of the cost and availability of fuel. This would result in the regions delineated by the gravity formula

Table 2.4. Sixteen FEA's based on commuting fields[a]

central city	county	number of commuters from county to central city
Burlington	Des Moines	
	Henry	1000
	Jefferson	159
	Lee	1028
	Louisa	423
	Van Buren	101
Carroll	Carroll	
	Audubon	111
	Crawford	92
	Sac	55
Cedar Rapids	Linn	
	Benton	1274
	Cedar	277
	Iowa	204
	Johnson	1036
	Jones	780
	Washington	38
Council Bluffs	Pottawattamie	
	Cass	72
	Fremont	24
	Harrison	309
	Mills	191
	Montgomery	33
	Page	14
	Shelby	151
Creston	Union	
	Adams	80
	Ringgold	44
	Taylor	22
Davenport	Scott	
	Clinton	736
	Muscatine	689
Decorah	Winneshiek	
	Allamakee	92
	Howard	25

[a]Source: [10].

Table 2.4. Continued

central city	county	number of commuters from county to central city
Des Moines	Polk	
	Adair	102
	Boone	591
	Clarke	258
	Dallas	2639
	Decatur	47
	Guthrie	374
	Jasper	890
	Lucas	139
	Madison	803
	Marion	713
	Story	1043
	Warren	5185
	Wayne	12
Dubuque	Dubuque	
	Clayton	375
	Delaware	382
	Jackson	476
Fort Dodge	Webster	
	Calhoun	473
	Greene	49
	Hamilton	358
	Humboldt	159
	Pocahontas	38
Marshalltown	Marshall	
	Hardin	133
	Poweshiek	87
	Tama	727
Mason City	Cerro Gordo	
	Floyd	317
	Franklin	67
	Hancock	110
	Mitchell	60
	Winnebago	25
	Worth	331
	Wright	65

Table 2.4. Continued

central city	county	number of commuters from county to central city
Ottumwa	Wapello	
	Appanoose	101
	Davis	355
	Keokuk	176
	Mahaska	235
	Monroe	327
Sioux City	Woodbury	
	Cherokee	47
	Ida	50
	Lyon	23
	Monona	196
	Osceola	0
	Plymouth	867
	Sioux	40
Spencer	Clay	
	Buena Vista	64
	Dickinson	149
	Kossuth	12
	O'Brien	94
	Palo Alto	84
	Emmet	21
Waterloo	Black Hawk	
	Bremer	1224
	Buchanan	982
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	Chickasaw	170
	Fayette	349
	Grundy	641

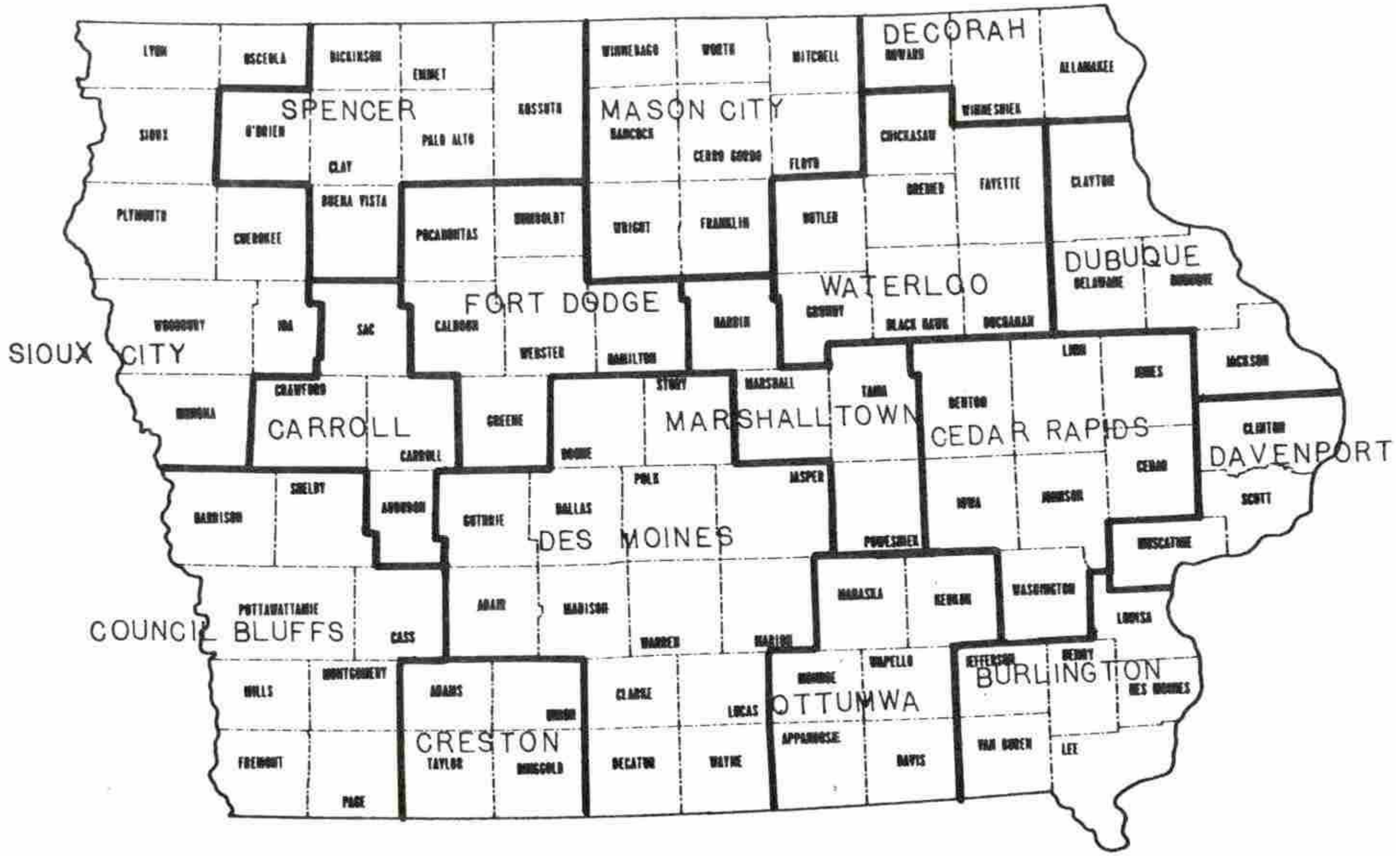

Figure 2.7. Commuting fields of 16 central cities

to be of more equal size. If future transportation is faster and relatively less expensive, then the differences in the population of central cities would be given more importance in the gravity formula.

If the gravity formula is used to delineate the state, as in Figure 2.8, the results are different than the OPP and commuting field delineations. The FEA's of the four central cities with the largest populations include more area and population in gravity formula delineation than in the commuting field and OPP delineations. In the gravity formula delineation the six smallest central cities have smaller FEA's than the OPP or commuting field delineations.

Another difference of the gravity formula delineation is the reduction of the Marshalltown and Dubuque FEA's to include only the central counties. Dubuque is dominated by the larger cities of Davenport, Cedar Rapids, and Waterloo. Marshalltown is dominated by Cedar Rapids, Des Moines, and Waterloo.

Comparisons and Criticisms of the Delineations

Table 2.5 gives the 1970 populations of the FEA's using the OPP, thirteen city community field, sixteen city commuting field, and the gravity formula delineations.

The Cedar Rapids, Council Bluffs, Davenport, and Marshalltown FEA's have the same boundaries whether the OPP delineation or the sixteen central city commuting field delineation is utilized. Under the thirteen central city commuting field delineation, the Cedar Rapids, Davenport, and Marshalltown FEA's have the same boundaries as the sixteen city

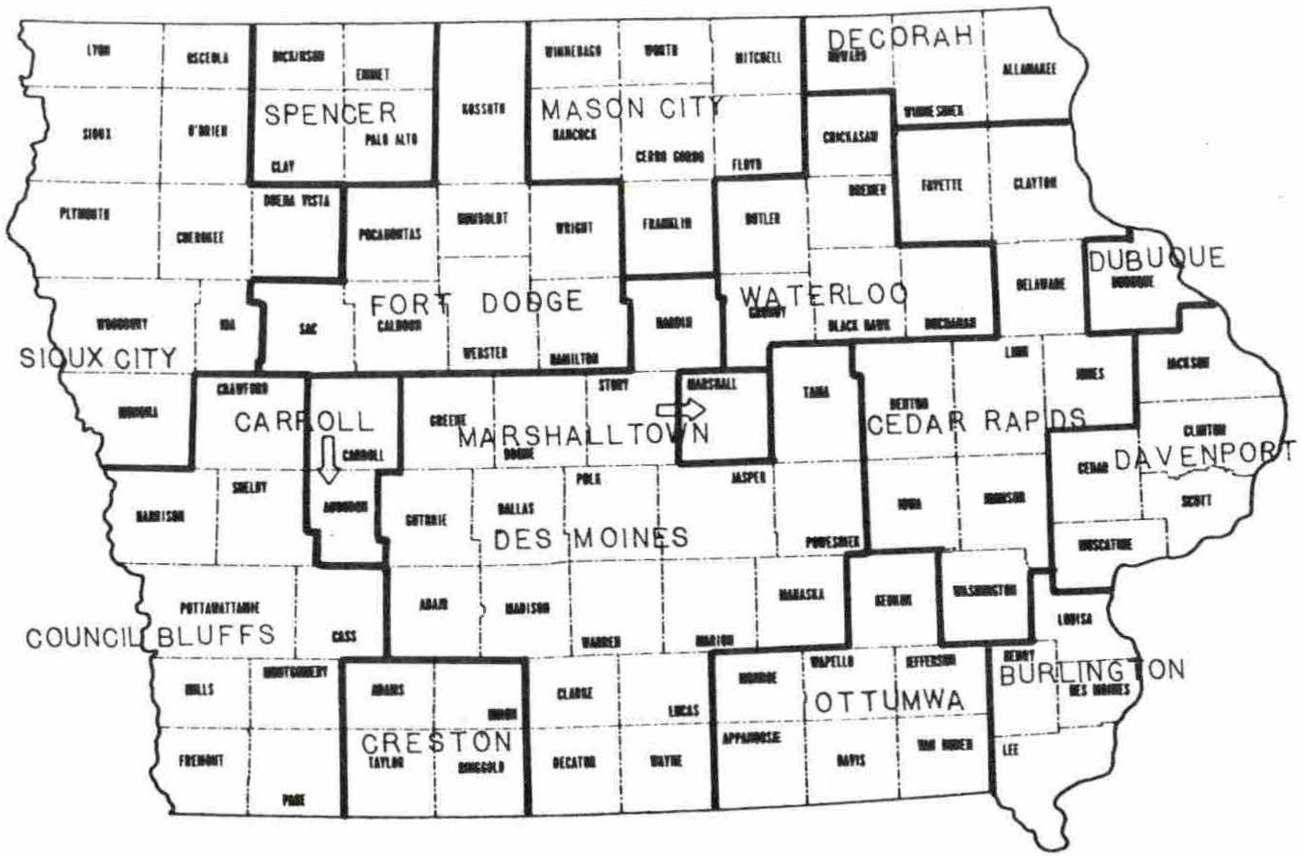

Figure 2.8. Delineation based on the gravity formula

Table 2.5. Populations of FEA's under different delineations[a]

FEA	OPP delineation	thirteen central city delineation	sixteen central city delineation	gravity formula delineation
Burlington	118,774	143,191	143,191	118,774
Cedar Rapids	344,452	344,452	344,452	378,753
Council Bluffs	187,892	222,639	187,942	206,722
Davenport	236,617	236,617	236,617	275,111
Des Moines	502,106	611,454	559,822	655,913
Dubuque	130,218	163,650	148,682	90,609
Fort Dodge	123,603	134,598	119,025	162,113
Marshalltown	102,274	102,274	102,274	41,076
Ottumwa	153,825	110,840	110,840	113,080
Sioux City	165,892	215,783	215,783	253,998
Spencer	146,433	119,479	119,479	58,327
Waterloo	223,440	272,096	250,338	223,440
Mason City	153,680	159,479	148,037	130,743
Carroll	91,819		66,860	32,507
Creston	61,847		35,042	35,042
Decorah	93,530		48,168	48,168

[a]Source: [20].

delineations. The gravity formula does not assume that each central city contains a full line of consumer goods and services, a well-developed labor market, and the complete range of state services and programs.

Central place theory is founded upon the relationship between scale economies and spatial concentration. John Friedmann refers to central place analysis as the study of the spatial ordering of those service activities which supply a centrally oriented market; by extension, it includes investigations into the hierarchial arrangement of cities classified according to their predominant service function [8, p. 229].

Fox and Kumar [7, pp. 49-54] describe the hierarchical steps among central places in Iowa as the FEA central city, complete shopping center, partial shopping centers, full convenience centers, and minimum convenience centers. The cities are classified according to population and annual retail sales. Typically, the central city has a population of more than 25,000 and annual retail sales of more than $40,000,000. Complete shopping centers have a range of 5,000 to 25,000 population and $10,000,000 to $40,000,000 retail sales. Cities with 2,500 to 5,000 population and $5,000,000 to $10,000,000 retail sales are classified as partial shopping centers.

Of the four central cities with less than 25,000 population; Carroll, Creston, and Decorah have annual retail sales of $20,000,000 to $30,000,000 and Spencer has retail sales of $36,500,000. Carroll, Creston, and Decorah fail to meet any of the criteria used to define a central city. Spencer could be considered an atypical case, failing to meet the requirement of a population of 25,000 but being near the minimum of other criteria set for a central city. Carroll, Creston, and Decorah would be classified as complete shopping centers.

The OPP delineation was designed to serve as administrative and planning regions for providing a wide variety of state services and programs. This delineation must be flexible to serve as planning and programming regions. The delineation based on commuting fields is more restricted in function since it is based only on journey-to-work patterns of transportation. If one is concerned with economic development of the regions it would be plausible to work with the commuting field delineation rather than the OPP delineation.

The restriction of not allowing the FEA's to cross state lines reduces the effectiveness of the FEA's as an explanatory tool. Each of the five central cities on the east and west boundaries of Iowa is on the state border. Four of the five have cities on the other side of the state line. The FEA's of the border cities should include counties from the bordering states or possibly the central city may be dominated by a central city in the bordering state; the labor markets and economic areas cross state lines. Iowa and the bordering states could work together in the economic development of the border counties. In the same sense that a bridge over the Mississippi River, the cost of which is shared by both states, benefits both states; the effort, expenditures, and planning on economic development of the border counties will benefit both states.

CHAPTER III. CENTRAL PLACE MODEL

Central place theory can reinforce the concept of labor markets and explain the hierarchical layers of urban classes within the FEA. Central place theory comprises models of urban areas; the latter result from the spatial concentration of economic activities which are primarily attributable to scale economies and minimum thresholds for the demand for goods and services.

Review of Literature

August Lösch has been the most important contributor to central place theory. Lösch considered market areas to arise through the interplay of purely economic forces and not to be the result of political or natural resource inequalities. Specialization and large scale production act as agents to concentrate firms and households, while shipping costs and diversified production tend to disperse population and employment locations.

In the classical tradition of location theory it is assumed that all resources are distributed at a uniform density over a homogeneous plain. The discrete and highly stratified network of cities is generated by the indivisibility of certain economic operations and the resultant economies of scale in performing the production and distribution functions of cities.

Edwin Mills is a present day urban economist whose work is based on Lösch's concepts [13, pp. 103-117]. Mills does not accept an assumption of Lösch that each industry's average cost curve is L-shaped. The

L-shaped cost curve means that no output can be produced below a minimum level at any cost and there are no scale economies above that level. A model restricted by such an assumption can accommodate the fact that some goods and services are produced in both large and small urban areas, but not if production is of a larger scale or occurs in a more competitive situation in large urban areas relative to production in smaller urban areas. Mills contends that it is not the absolute scale at which economies are exhausted, but rather the scale relative to market demand which determines the number of firms in an industry.

Martin Beckman's model of city hierarchies suggests there is a basic layer of rural population settled at a uniform density, or alternatively there is a random scattering of the smallest communities with an approximately uniform areal density [1, pp. 243-248]. The first layer of cities perform the most elementary production and distribution functions. Borchert and Adams expect the business functions of the first layer to include gasoline service stations, grocery stores, drug stores, hardware stores, banks and eating places [3, pp. 4, 38, 39].

The market area of the first layer of cities is usually limited by the largest tolerable distance to the rural population which it serves. The size of the market area and the following order of cities are explained by Beckman's hypothesis that the size of any city is proportional to the population it serves (including that of the city itself) [1, p. 243].

Beckman's model rests on two basic assumptions:

1. Each person can perform the functions for a limited number of people.
2. An urban area of a given size can serve a specific number of urban areas of the next smaller size. These urban areas of smaller size are termed satellites of the larger urban area.

After determining the number of people for whom a resident of the first layer of cities provides the functions for and the number of satellites an urban area has, Beckman's model can predict the population of the largest urban regions from the smallest market areas.

In equation form Beckman's model is written as $Pm = \frac{s^{m-1}\bar{r}}{(1-k)^m}$. Pm is the population served by an urban area of the mth smallest size. The term m refers to the layer of the hierarchy served. In the lowest layer of the hierarchy where the urban and rural areas served are the smallest in both population and area, m takes the value one. The number of satellites at a particular regional level is s and $\bar{r}$ is the average rural population served by the smallest urban areas. The term k is the fraction of a worker it takes to perform the functions for one person.

Beckman's model can also be used to predict the total number of cities in a FEA. This is written $T = 1 + s + s^2 + \ldots + s^{N-1}$. The first term (1) refers to the largest city in the FEA, s is the number of cities in the second layer of the hierarchy, and s^{N-1} is the number of cities in the N^{th} layer of the hierarchy.

This is an earlier model of Beckman which is in agreement with Lösch's assumption of an L-shaped cost curve. A later model of Beckman and McPherson drops this assumption and allows the larger urban areas to also provide the same functions as do the smaller urban areas [2, pp. 25-33].

The rank size rule, as observed by Zipf, is a special case of Pareto distribution which says that the size of the n^{th} largest city is approximately one-n^{th} the size of the largest city [21, pp. 1-48]. Beckman's model, through a series of substitutions, is compatible with the rank-size rule [1, pp. 245, 246].

Developing the Hierarchies

Beckman's central place model will be used to develop the hierarchies of the nine nonmetropolitan FEA's of Iowa. The FEA's used will be those delineated by the OPP. This model ignores all natural factors that contribute to the comparative advantage of particular areas. Iowa would seem to be an ideal site to test Beckman's model because of the state's relative uniformity in dispersion of mineral deposits, quality of soil, type of crops raised and industrial firms. August Lösch, a German economist, chose the state of Iowa to test his theories of the distribution of settlements because the state best fits his assumption that all resources are distributed at a uniform density over a homogeneous plain [13, pp. 389-392].

Before developing the city hierarchy, the number of urban area satellites and the number of layers in the hierarchy must be determined. The nine nonmetropolitan FEA's have populations ranging from 61,000 to 153,000, rural populations of 27,156 to 55,617, areas of 27,156 square miles to 55,617 square miles, contain thirty-one to eighty incorporated communities, and are comprised of four to ten counties. Assuming that each FEA contains the same number of layers in the hierarchy, such a large variance in the size and population of the regions leads to the assumption that the number of satellite urban areas may vary from one FEA to another. The largest city of each county is often the county seat which provides governmental services to its residents. Under these conditions, the assumption is that the number of satellite urban areas will correspond with the number of counties in the FEA.

Karl Fox suggests there is a three stage hierarchy in nonmetropolitan FEA's [6, pp. 116, 117]. The cities of the smallest to largest layers of the hierarchy will be termed convenience center, sub-regional capital, and regional capital.

Under the assumption that there are three layers in the hierarchy and allowing the satellite number to correspond to the number of counties in each FEA, there would be an expected total of 491 cities in the nine FEA's. According to 1970 census data there were 513 cities in these regions. The difference between the expected and actual total number of cities in the nine FEA's is less than the difference between the expected and actual number of cities in some of the individual FEA's. In the Marshalltown FEA the city hierarchy predicted that there would be twenty-one cities, but there are forty-four cities and in the Ottumwa FEA where one hundred eleven cities are predicted, there are seventy-five cities.

Some averaging of the regional population data must be done to use Beckman's model. In the lowest layer of the three-tiered hierarchy it is assumed that there are s^2 convenience centers. The average population of a convenience center is found by apportioning the total population of all cities in the FEA smaller than the s + 1 largest city equally among the s^2 convenience centers. The rural population is also apportioned equally among the s^2 convenience centers. Tables 3.1, 3.2, and 3.3 give the predicted populations of the subregions and the overall regions based on average rural populations and urban multipliers for each FEA for 1970, 1960 and 1950 respectively.

Discussion of Predictions

From 1950 to 1960 the rural population decreased in every FEA. With the exception of the Burlington FEA which gained rural inhabitants, the rural population from 1960 to 1970 declined at a much faster rate than during the previous decade.

The rural population, though declining, still needs to be served by the lowest level cities. With a smaller rural population, there will be fewer trips originating from rural areas to the lowest level cities.

The decreased rural population should require fewer people in the lowest level cities to provide the same convenience functions. If the proportionality factor (k) were to remain constant, some of the inhabitants of the lowest level cities would migrate to a higher level of the hierarchy or outside of the hierarchy. If the population of the lowest order cities does not decline, then the convenience centers would be less efficient in providing services to the population of the lowest order of the hierarchy or they are providing additional or specialized services.

Table 3.1. 1970 population estimates

FEA	$\overline{r}$	$\overline{k}$	$\overline{P}_2$	$\hat{P}_2$	$\frac{\hat{P}_2-\overline{P}_2}{\overline{P}_2}$	P_3	$\hat{P}_3$	$\frac{\hat{P}_3-P_3}{P_3}$
Spencer	670	.430	15,128	18,549	.226	146,433	292,871	1.00
Ottumwa	556	.300	12,422	11,351	-.086	153,825	162,157	.054
Burlington	1983	.334	21,602	17,880	-.172	118,774	107,388	-.096
Creston	554	.285	7,659	7,588	-.009	61,847	74,292	.201
Carroll	1048	.400	13,850	17,460	.261	91,819	174,600	.902
Decorah	1705	.351	17,215	20,240	.176	93,530	155,930	.667
Marshalltown	2009	.415	19,014	23,483	.235	102,274	160,566	.570
Fort Dodge	1077	.421	15,390	19,269	.252	123,603	199,674	.615
Mason City	865	.349	15,399	16,328	.060	153,680	200,656	.306

where $\overline{P}_1 = \overline{r} + \overline{p}_1$

$\overline{k} = (\overline{p}_1/\overline{P}_1)$

$\hat{P}_2 = (s\overline{r})/(1-\overline{k})^2$

$\hat{P}_3 = (s^2\overline{r})/(1-\overline{k})^3$

s: number of urban area satellites

$\overline{r}$: average rural population serviced by convenience center

$\overline{p}_1$: average population of convenience center

$\overline{P}_2$: average population of the subregions

P_3: population of the regions

$\hat{P}_2$: predicted population of subregional capital and hinterland

$\hat{P}_3$: predicted population of FEA

Table 3.2. 1960 population estimates

FEA	$\bar{r}$	$\bar{k}$	$\bar{P}_2$	$\hat{P}_2$	$\frac{\hat{P}_2-\bar{P}_2}{\bar{P}_2}$	P_3	$\hat{P}_3$	$\frac{\hat{P}_3-P_3}{P_3}$
Spencer	805	.384	15,862	19,093	.204	151,621	278,958	.840
Ottumwa	628	.293	13,335	12,564	-.058	167,216	177,706	.063
Burlington	1849	.319	21,218	15,948	-.248	117,289	93,673	-.201
Creston	697	.258	8,746	8,862	.013	69,032	83,602	.211
Carroll	1246	.366	15,038	18,599	.237	97,912	176,016	.798
Decorah	2058	.306	18,895	21,365	.131	100,910	153,924	.525
Marshalltown	2311	.380	19,677	24,051	.222	101,230	155,168	.533
Fort Dodge	1355	.368	17,034	20,354	.195	130,602	193,237	.480
Mason City	1034	.313	16,643	17,527	.053	163,787	204,094	.246

Table 3.3. 1950 population estimates

FEA	$\bar{r}$	$\bar{k}$	$\bar{P}_2$	$\hat{P}_2$	$\frac{\hat{P}_2-\bar{P}_2}{\bar{P}_2}$	P_3	$\hat{P}_3$	$\frac{\hat{P}_3-P_3}{P_3}$
Spencer	880	.361	16,083	19,397	.206	152,194	273,190	.795
Ottumwa	734	.278	14,720	14,081	-.043	180,831	195,022	.078
Burlington	2026	.292	21,089	16,167	-.233	114,967	91,340	-.206
Creston	865	.250	10,328	10,764	.042	80,614	100,817	.251
Carroll	146	.344	16,069	19,743	.229	102,644	180,574	.759
Decorah	2180	.294	19,170	21,868	.141	101,911	154,875	.520
Marshalltown	2471	.355	19,760	23,758	.202	98,861	147,338	.490
Fort Dodge	1453	.323	20,795	19,021	-.085	129,091	168,578	.306
Mason City	1110	.297	16,953	17,968	.060	163,607	204,473	.250

The total populations of the lowest order cities in the nine FEA's remained constant from 1950 to 1970. The Ottumwa, Creston, and Carroll FEA's were the only regions which lost population in the lowest order cities during this period.

The proportionality factor (k) increased in all FEA's from 1950-1960 and 1960-1970 because the average population of the lowest order cities remained constant while the rural population declined. Although the rural population declined, the services provided to them have increased. The number of service establishments in the FEA's has doubled from 1948 to 1967 [18, pp. 170-185, 112-131, 150-185]. The number of service establishments per capita from 1958-1967 has increased from a low of twenty percent in the Marshalltown region to a high of forty-six percent in the Decorah region.

The increase in the rural population in the Burlington FEA and the decrease in $\overline{p}_1$ in the Creston and Ottumwa FEA's account for the smallest increase in k in these three FEA's from 1950-1970. Not only do these FEA's have the lowest rate of increase in k, they also have the smallest k's of the nine FEA's.

In contrast the three FEA's which have the largest k values from 1950-1970 (Spencer, Carroll, and Fort Dodge) have the largest increase in k during this period. These FEA's include three of the largest four number of service establishments per FEA and have three of the largest four number of service establishments per capita among the FEA's.

The average populations of the subregions ($\overline{P}_2$) were greater than the estimated population (P_2) in three of the nine regions. The populations of the Burlington and Ottumwa subregions were underestimated for 1950, 1960, and 1970; the Creston subregions were underestimated in 1960 and 1970; and the Fort Dodge subregions were underestimated in 1950.

The county seats of these regions may be more important as subregional capitals than expected from Beckman's model. The county seats of the remaining six FEA's serve a smaller population than estimated from Beckman's model. The population served is less than expected and thus the trips into the subregional capitals are less than expected based on the population of the lowest order of the hierarchy.

From 1950-1970 the regional populations of the nine FEA's are overestimated in every instance except for the Burlington FEA. Burlington as a regional capital serves a larger population than expected. The subregional capitals of the Burlington FEA also serve a larger population than expected. In 1967 and 1958 Burlington had the largest number of paid employees in the service industries and the largest number of per capita paid service industry employees, but the smallest number of service establishments and service establishments per capita. From 1958-1967 the number of service establishments in the Burlington FEA is increasing at the fastest rate of any of the nine regions. Burlington as the regional capital will continue to increase in importance because its high rural population per convenience center (r) requires more service establishments and employees.

In contrast with the Burlington FEA, the Creston and Ottumwa FEA's have the smallest $\bar{r}$, but also have the largest number of service establishments per capita. The growth rates of the service establishments in these two regions are the smallest of the nine regions. The increases of k in the Creston and Ottumwa regions are also the smallest of the nine regions. The total population of the cities in both of these regions is declining, but at a rate slower than what is occurring in the rural population in these regions. In both cases additional services are being offered in the cities, but the cities are losing population and cannot absorb the outmigration of the rural population. Additional or specialized services are being provided, but to a smaller population than previously.

In the other six regions which are losing rural population the total city populations of the cities are increasing, but only in the Marshalltown FEA is the increase in the population of the cities large enough to absorb the outmigration of the rural population.

The correlation coefficient between the percentage error of the estimate of the subregion population $(\frac{\hat{P}_2 - P_2}{P_2})$ and the percentage error of the estimate of the regional population $(\frac{\hat{P}_3 - P_3}{P_3})$ is declining over time. The correlation (r) has declined from .922 in 1950 to .769 in 1960 to .526 in 1970. The correlation coefficient was significant in 1950 and 1960, but nonsignificant in 1970. The reason for the deviation of the estimated from the true populations could possibly be traced to the same factor in 1950 and 1960, but in 1970 this is not possible.

By looking at the rankings of the percentage error in the estimation there appears to be three areas in the state where the regions reflect similar percentage errors.

In the southern tier of the state in the Burlington, Ottumwa, and Creston regions the estimations of the subregional populations are less than observed and the regional estimations are negative or slightly positive.

There is a band across the central part of the state including the Carroll, Fort Dodge, and Marshalltown regions where the percentage errors of these regions and subregions are positive and continually rank in the middle of the nine regions. These regions surround the Des Moines FEA and are bordered on the east and west by FEA's containing central cities of 60,000 or more inhabitants. The percentage error of the Decorah region is consistent with the central regions and in Iowa the Decorah region is surrounded by FEA's containing central cities of 60,000 inhabitants or more. The percentage error of the Mason City region appeared to be most consistent with the southern tier until 1970 when it moved closer in appearance to the central group.

The Spencer region, as in the commutation delineation, appears to be quite independent and has the largest overestimation of any of the regions. The Carroll region is the closest in the rankings of percentage error to the Spencer region. The northern regions (Spencer, Decorah, and Mason City) and Carroll had percentage errors which were stable from 1950 to 1960, but had large increases from 1960 to 1970.

The southeast and the northwest corners of the state are the extremes of underestimation and overestimation. The Burlington region continually has the largest underestimation of population and the Spencer region is the most overestimated. From the Burlington region along the southern border through the Carroll region to the Spencer region the percentage of overestimation increases progressively. This has occurred continually from 1950 through 1970.

The remaining four regions have continually remained in the middle of the rankings of percentage error. Although the state has been used in various studies because of the uniformity of its population and natural resource distribution, the state exhibits nonuniform characteristics as shown through Beckman's model.

Criticisms of the Model

The model does not fit well. Either the model is in error or one can expect the population distribution to change. The reason the model does not fit could be that the population distribution of the state is not uniform enough to give uniform predictions.

The actual number of lowest order cities would serve a more uniform area than the predicted number of lowest order cities. The average area served by convenience centers varied from 49.44 square miles per city to 153.56 square miles per city when using s^2 as the number of convenience centers. Using the actual number of cities the average area per convenience center only varies from 60.02 to 64.02 square miles per city.

Beckman's model assumes a constant number of satellites (s) and projects s^2 convenience centers, which differs from the observed number of convenience centers. The rural population of the regions, when apportioned equally among the s^2 convenience centers, has a greater range and variance than when the rural population is divided among the observed number of convenience centers; see Table 3.4. The model using the observed number of convenience centers in the derivation of the average rural population per convenience center ($\overline{r}$) would be expected to project estimations of regional populations ($\overline{P}_3$) which are more uniform and accurate than previous estimations.

To use Beckman's model with the observed number of convenience centers, the number of subregions per region must be assumed to conform with the number of convenience centers per subregion. Again, the number of satellites at each level of the hierarchy is constant and Beckman's model can be used to estimate the regional population. This estimation is grossly inaccurate because of the error in the number of subregions used. To correct this, the missing or extra subregional populations are added to or subtracted from the regional population estimate to arrive at a final adjusted estimation.

An example of the procedure used was the Ottumwa region which has sixty-four convenience centers. When divided equally among the ten subregions, there are six convenience centers per subregion and an assumed number of six subregions in the region. The same equations were used to estimate the subregional population ($\hat{P}_2$) and the regional population ($\hat{P}_3$).[1] Only six subregions were used to estimate the regional population but the Ottumwa FEA has ten subregions. The population of four subregions was added to the estimate using six subregions to arrive at an adjusted figure; see Tables 3.5, 3.6, and 3.7.

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[1] $\hat{P}_2 = s\overline{r}/(1-k)^2$

$\hat{P}_3 = s^2\overline{r}/(1-k)^3$

Table 3.4. 1970 average rural population of convenience centers

region	observed number of convenience centers	s^2 convenience centers	$\bar{r}$ of observed number of convenience centers	$\bar{r}$ of s^2 number of convenience centers
Spencer	70	81	775	670
Ottumwa	64	100	869	556
Burlington	26	16	1220	1983
Creston	41	49	662	554
Carroll	49	36	770	1048
Decorah	44	25	1017	1705
Marshalltown	39	16	824	2009
Fort Dodge	54	36	718	1017
Mason City	58	64	955	865
range			(558)	(1455)

This procedure does not improve the uniformity or accuracy of the estimated regional populations. The estimations using the observed number of convenience centers has a somewhat smaller range, but the variance of the estimations is approximately equal to the results when s^2 convenience centers were used. In five of the nine regions less accurate estimations were arrived at with the procedure using the observed number of convenience centers. As was the case with s^2 convenience centers the predictions using the observed number of convenience centers are becoming less accurate over time. The removal of one of Beckman's most restrictive assumptions (a constant number of satellites within each region) does not improve the accuracy of the results.

The number of convenience center residents in relation to the area served varies and is another example of nonuniformity. The density of convenience center residents in the area served varies from 3.15 to 9.29 convenience center residents per square mile.

The rural population per square mile varies from 17.84 rural inhabitants in the Burlington FEA to only 7.88 in the Creston FEA. The rural population density is more uniform for the other seven FEA's ranging from 11.20 to 13.08 rural inhabitants per square mile.

The population distribution in the state of Iowa is changing so that Beckman's model is becoming less effective in developing hierarchies which reflect the true relationships between the rural population and the urban population in the different levels of the hierarchy. Relationships specified in the model are becoming less predictable over time. Beckman's model would provide a better fit in regions which have a higher percentage of rural population and fewer services available than presently in Iowa.

Table 3.5. 1970 population estimates using the observed number of convenience centers

region	s	$\hat{P}_2$	$\frac{\hat{P}_2-\overline{P}_2}{\overline{P}_2}$	adjusted $\hat{P}_3$	$\frac{\hat{P}_3-P_3}{P_3}$
Spencer	7	16,695	.104	238,420	.628
Ottumwa	6	10,641	-.143	133,771	-.130
Burlington	6	16,504	-.236	115,680	-.026
Creston	5	6,478	-.154	58,254	-.058
Carroll	8	17,104	.235	193,851	1.111
Decorah	8	18,685	.085	170,430	.822
Marshalltown	9	21,675	.140	225,090	1.201
Fort Dodge	9	19,268	.252	241,693	.955
Mason City	7	15,776	.024	185,406	.206

Table 3.6. 1960 population estimates using the observed number of convenience centers

region	$\overline{r}$	$\hat{P}_2$	$\frac{\hat{P}_2-\overline{P}_2}{\overline{P}_2}$	adjusted $\hat{P}_3$	$\frac{\hat{P}_3-P_3}{P_3}$
Spencer	932	17,193	.084	229,761	.515
Ottumwa	980	11,764	-.118	146,888	-.122
Burlington	1138	14,723	-.306	100,273	-.145
Creston	833	7,565	-.135	66,107	-.042
Carroll	915	18,211	.211	193,369	.975
Decorah	1169	19,417	.208	165,578	.641
Marshalltown	948	22,196	.128	211,215	1.086
Fort Dodge	903	20,347	.194	228,708	.751
Mason City	1141	16,923	.017	189,352	.156

Table 3.7. 1950 population estimates using the observed number of convenience centers

region	$\bar{r}$	$\hat{P}_2$	$\frac{\hat{P}_2-\bar{P}_2}{\bar{P}_2}$	adjusted $\hat{P}_3$	$\frac{\hat{P}_3-P_3}{P_3}$
Spencer	1018	17,452	.085	226,083	.485
Ottumwa	1146	13,191	-.104	162,380	-.102
Burlington	1247	14,926	-.292	96,642	-.159
Creston	1034	9,191	-.110	79,656	-.012
Carroll	1041	19,352	.204	197,300	.922
Decorah	1239	19,886	.037	165,681	.626
Marshalltown	1014	21,936	.110	196,406	.987
Fort Dodge	968	19,008	-.086	195,670	.516
Mason City	1225	17,351	-.023	190,120	.612

Beckman's model is based on Losch's theories which were developed in the 1930's. The population was more uniformly distributed at that time, the rural population density was greater, and the population required fewer services. The population has too few rural residents and the population is too mobile using the present transportation system for the Beckman model to reflect a stable hierarchy.

CHAPTER IV. THE RANK-SIZE RELATIONSHIP

Review of Literature

In the distribution of populations within human settlement systems there has been shown to be a statistical regularity known as the rank-size rule. As the populations of cities increase their numbers decrease, and this has led to the rank-size hypothesis.

George Zipf expressed the rank-size rule in the form $R \times S = C$, where R is the rank and S the population of the city in question. C is a constant which is equal to the largest city of the region [21, p. 11].

Edwin Mills expressed the rank-size rule as $R = CS^{-q}$, where R is the rank of the city (the number of cities with at least S inhabitants), S is the population of the city, q is a constant (often assumed to be unity), and C is a constant determined by the data [14, p. 105]. When q is assumed to be unity, then C is the size of the largest city and the size of the n^{th} largest city is one-n^{th} the size of the largest city.

Martin Beckman [1, pp. 245-248] showed that the rank-size rule is compatible with theories of hierarchies of market areas and their central cities. By allowing the populations of centers to vary somewhat around the expected value for their level, as if a random disturbance were operating, the distinctiveness of the size classes is lost and the observed rank-size regularity is compatible with the hierarchies of cities.

E. P. G. Haran and Daniel R. Vining, Jr. [9, pp. 421-437] expect a different relationship between rank and size than the log-linear relationship. Haran and Vining use a probabilistic model to derive the frequency distribution of populations. Where the rural population component is still large and where births exceed deaths by a significant margin, probabilistic models have been shown to be equivalent to the rank-size rule.

Under certain conditions (a relatively small rural population, declining birth rate and a small excess of births over deaths), Haran and Vining expect a curvilinear relationship between the logarithms of rank and size. Growth of city populations will then be the result of intercity migration.

Previous probabilistic models used to explain the rank size relationship assumed that when a city reached a minimum population, the probability of adding a new member to its population is in direct proportion to its size. Each city was assumed to be an independent random variable evolving in accordance with the linear birth process. Haran and Vining contend that when city growth through intercity migration obeys the law of proportionate effect, the resultant steady-state frequency exhibits greater upward curvature away from the straight line predicted by the rank-size rule.

Regression Analysis

When converted to logarithms the rank size rule becomes $\log R = \log C - q \log S$. The relationship between rank and size is linear on a double-log scale with an absolute slope of q.

A regression analysis was completed on the relationship between the rank and size of the city distributions. The nine regions exhibit similar variations from the linear relationship, but also have dissimilar characteristics. A summary of the statistical results is given in the Appendix.

Figures 4.1, 4.2 and 4.3 show the regression lines of the nine regions for 1950, 1960 and 1970. In each region the slope has decreased over the period 1950 to 1970. (Burlington's slope coefficient remained constant from 1960 to 1970 and is the sole exception.) Since the variance in R is constant for given regions over time, a declining slope implies an increase in the population variance or dispersion of city sizes within regions; absolute growth differentials of cities within regions characterize patterns of population change over the period. Also as the slope coefficient declines, the product of rank and population becomes relatively larger for central cities compared to the smaller rural communities. Alternatively for given ranks, smaller sizes for cities at the lower end of the population spectra and larger central cities are expected. Subject to several qualifications below, the centrality of the size distribution within regions increases over time.

Several characteristics from Figures 4.1 through 4.3 should be noted. As the number of cities per region increases the constant term rises shifting the regression plane upward. This reflects the increased variance in R for regions with a greater number of cities. Rankings of the regions by size of slope coefficient provide a better basis for comparing the regression equations. For 1970, the Mason City, Carroll and Ottumwa regions have the steepest slope coefficients suggesting the relative strength of their city size distributions within the lower end of the size spectra. Spencer and Fort Dodge comprise a second group with Creston,

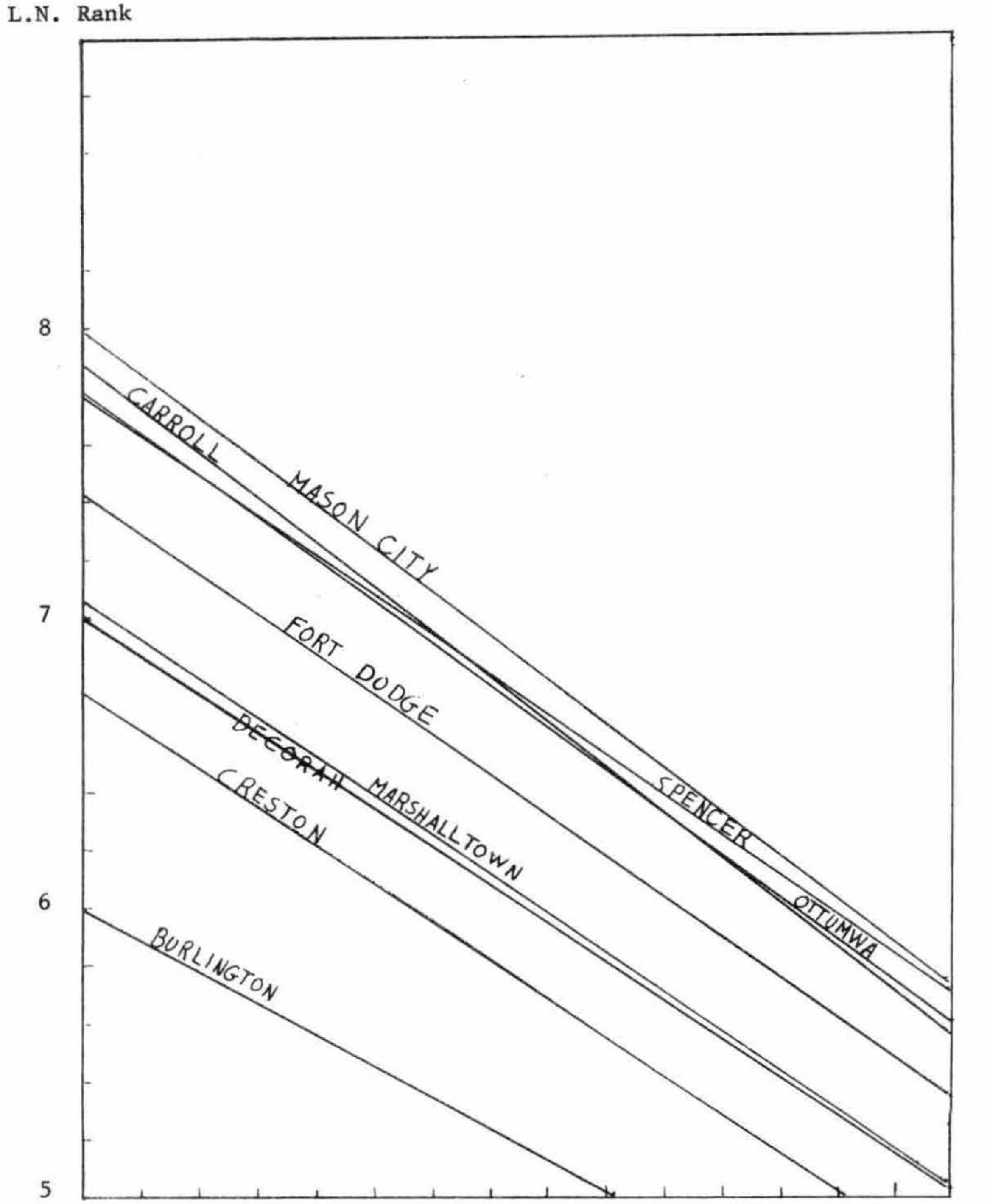

Figure 4.1. 1970 regression planes of nine regions

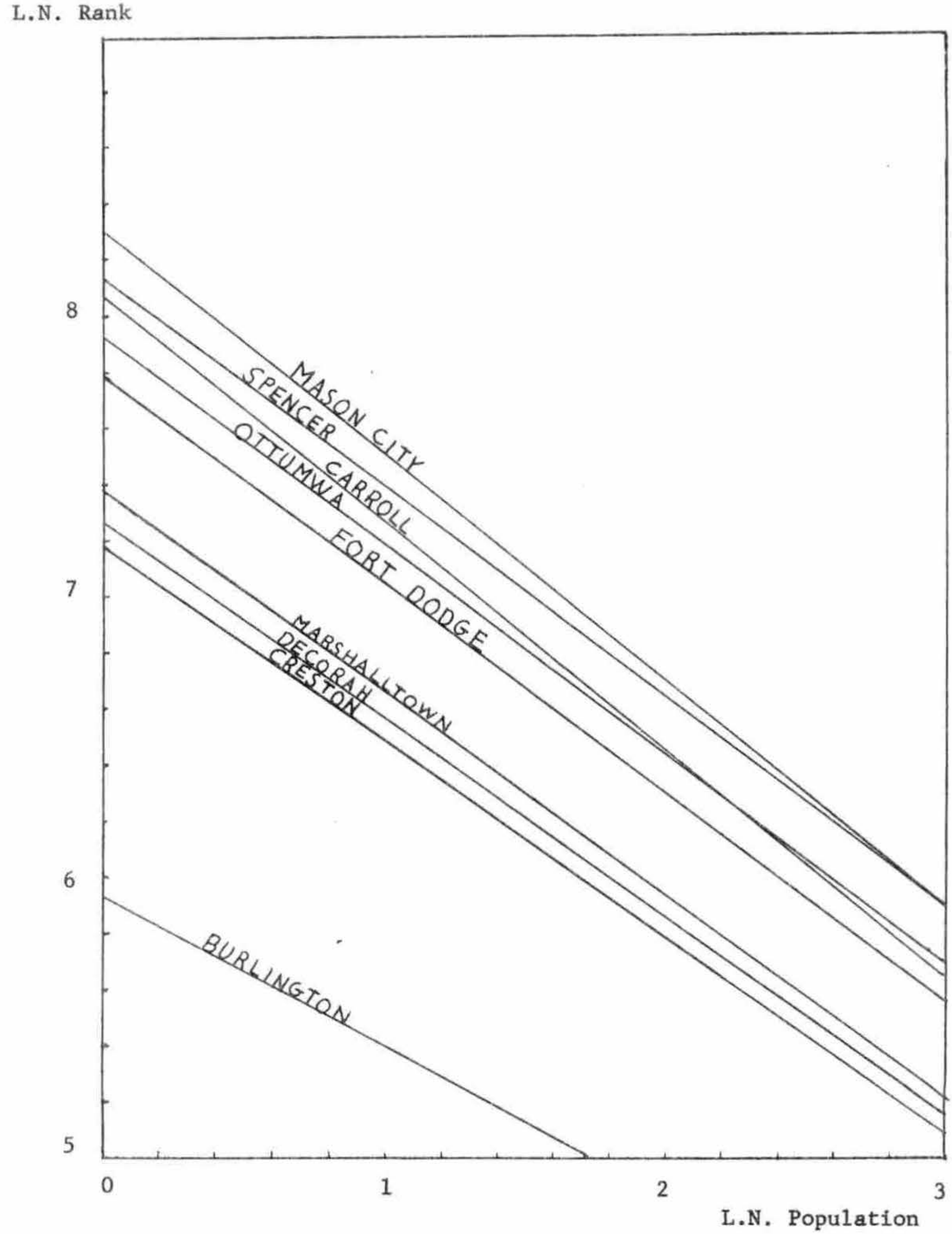

Figure 4.2. 1960 regression planes of nine regions

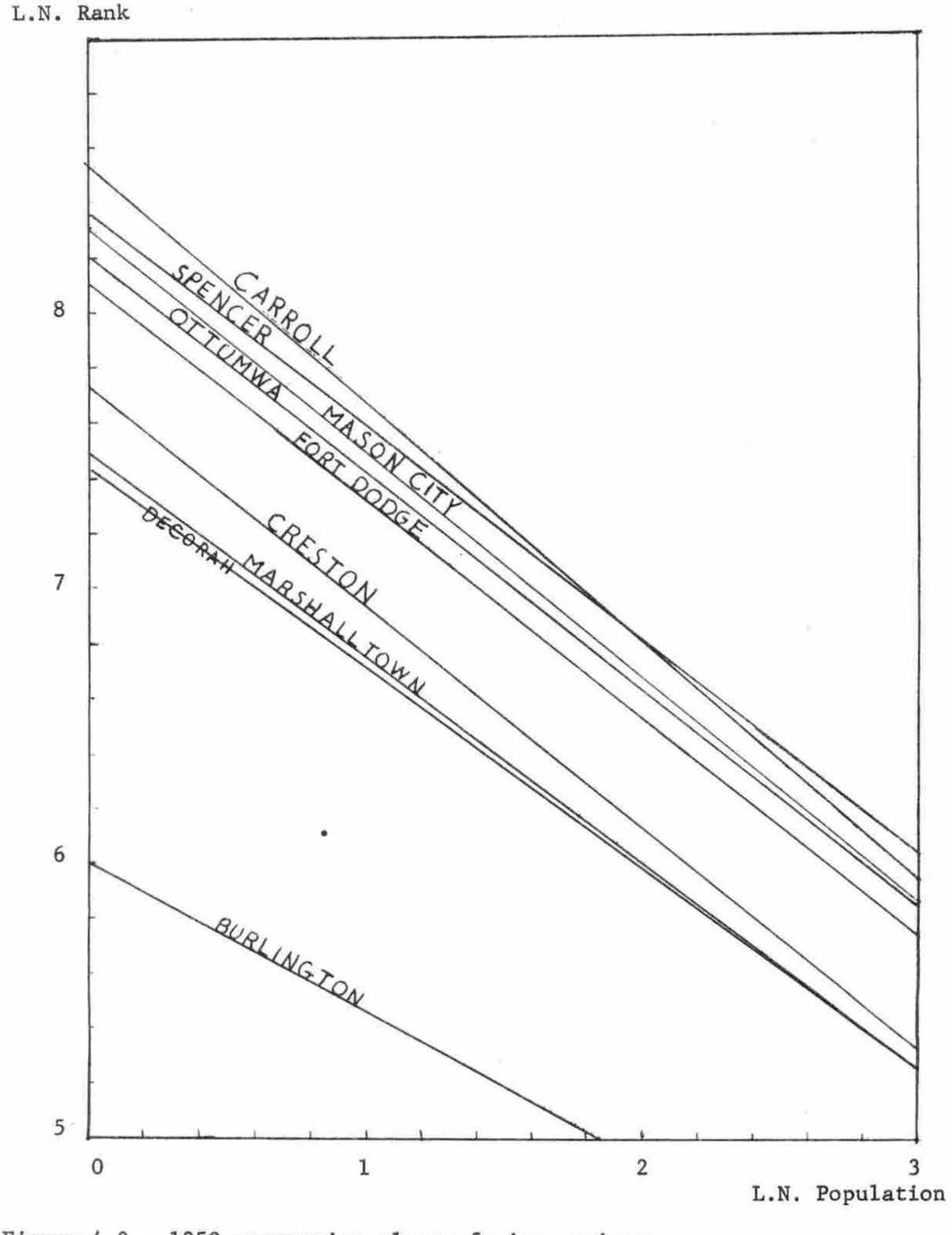

Figure 4.3. 1950 regression plane of nine regions

Decorah and Marshalltown having coefficients within the range of -.656 to -.667. The Burlington region has the consistently lowest coefficient among the nine regions.

The appendix provides equational tests of significance and the constant terms estimated from the logarithmic regression equations. From these tabulations it can be seen that, with the exception of the Burlington region, the regression lines are shifting downward through time for given regions. This reflects the generally declining populations of these regions over the period, 1950-1970; the Burlington and Marshalltown regions are the sole exceptions to the trend of population decline. With the exception of the increase in Burlington's constant term from 1960-1970, the constant terms of these two regions also decline over time. The shift in population growth favoring larger cities more than offsets the general increase in regional population.

The same pattern of residuals distribution holds for each region in each of the three time periods. A plot of the observed ranks compared to the expected ranks for the Marshalltown region in 1970 serves to illustrate the residual variation shown by all regions; Figure 4.4 shows this regression equation. The ranks of the cities within the largest and smallest size classes are less than predicted from the regression plane. Generally the negative residuals occur within cities having populations above 2,000 and below 200 inhabitants. The observed ranks of the cities in the midrange of the population distribution are larger than expected.

Over time in eight of the nine regions the maximum negative residual is increasing or remains constant in the highest and lowest size classes and the maximum positive residual is decreasing. The curvilinearity

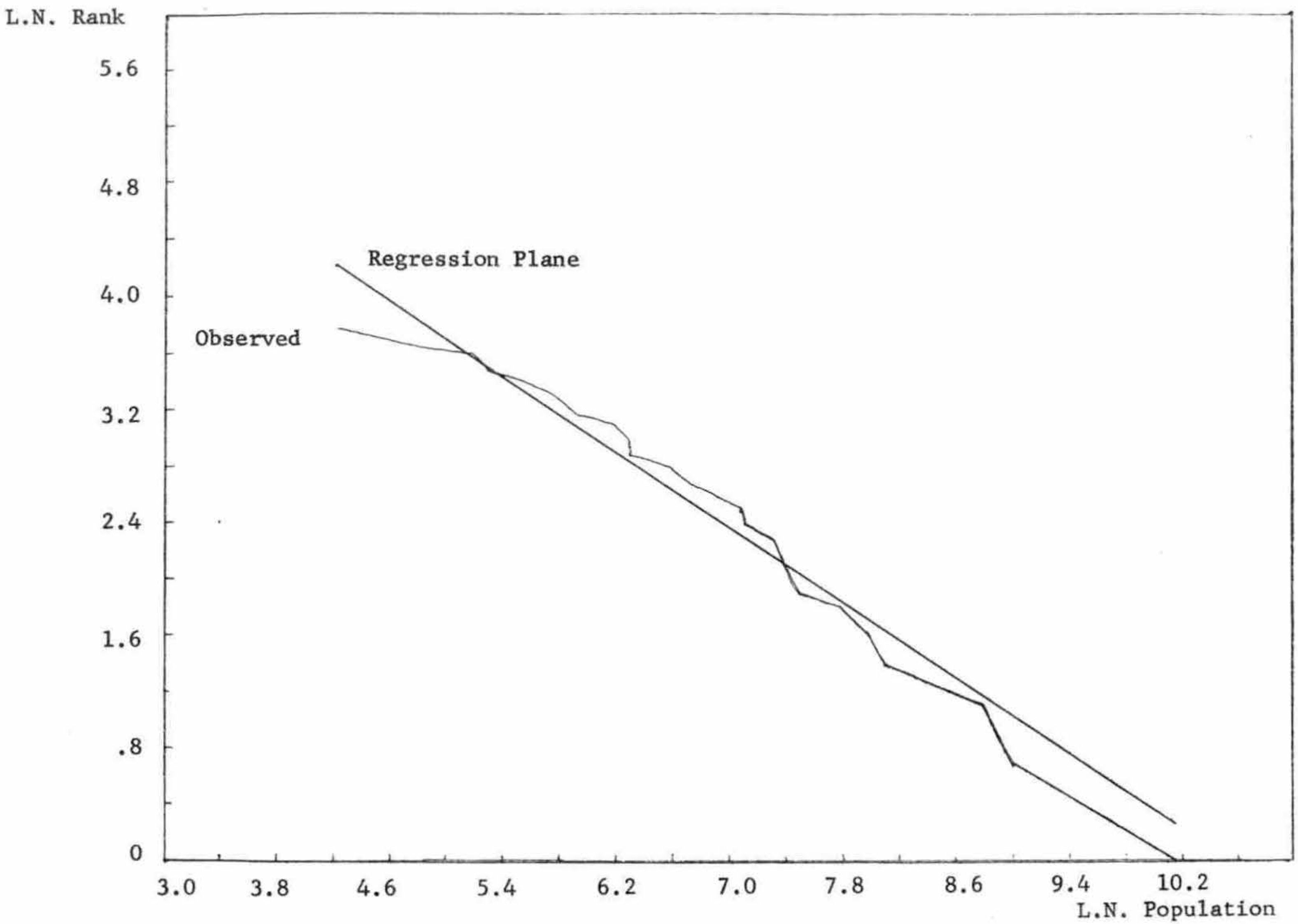

Figure 4.4. Regression equation for Marshalltown in 1970

increases at the extreme tails of the population distribution and the increasing population variance probably accounts for the decreasing positive residual in the middle-sized city classes.

The equational measures of the fitted regression lines (R^2) may be divided into two groups. Regions containing the larger central cities (25,000 inhabitants or more) have larger R^2 than the four regions with the smaller central cities (10,000 inhabitants or less). The regions with larger central cities conform more closely to central place theory and would be expected to be in closer agreement with the rank-size rule. There is, on the other hand, a notably small range (.094 for 1970) among R^2 measures for the nine regions and no particularly consistent pattern of change over time. Despite the range of population, area and number of cities per region the rural labor markets of Iowa generally conform quite well to the urban size distributional criteria used here.

Conclusion

There are two characteristics of rank-size distributions calculated for Iowa's labor markets that are quite consistant for the period 1950 to 1970. First, the slope coefficients inversely relating the logarithms of rank to size are declining. This reflects relative population declines occurring within the smaller, dispersed communities of these regions. Second, the residual variation around the regression equations reflect a consistent negative, positive and negative pattern from smallest to largest city size class. This may reflect various structural problems at the extreme ends in the population spectra; the impacts of agricultural technology on the smallest rural service centers, the decentralization of shopping centers to intermediate sized cities in these regions and the general diffusion of manufacturing employment opportunities are the most likely explanatory factors. These statistics suggest that small town population changes account for most of the distributional shifts occurring over the period. Declining slope coefficients and the negative residual pattern indicate the continued difficulty of maintaining population level within the smallest towns. Though declines in regression slopes suggest a relative degree of centralization, most of the changes occur within the intermediate sized cities of the rural labor market as evidenced by the negative residual pattern for the very largest cities in the distribution. As with our largest metropolitan regions, the regional centers have lost residentiary and secondary employment opportunities to intermediate sized centers dispersed throughout the regions.

These results coincide closely to what Haran and Vining have suggested. The conditions necessary for the residual patterns discussed above include a small rural population, declining birth rate and only a small excess of births over deaths. The rural population is small and decreasing in the nine regions. In 1970 the rural population comprised one-half to one-sixth of the total regional populations; Figure 4.5 shows the falling birth rate in Iowa versus the steady death rate over this time period. The lack of internal growth in the nine regions is further illustrated by the fact that seven regions containing central cities of 50,000 inhabitants or more contain the majority of counties where the birth rate exceeds the death rate by at least five per one thousand. In

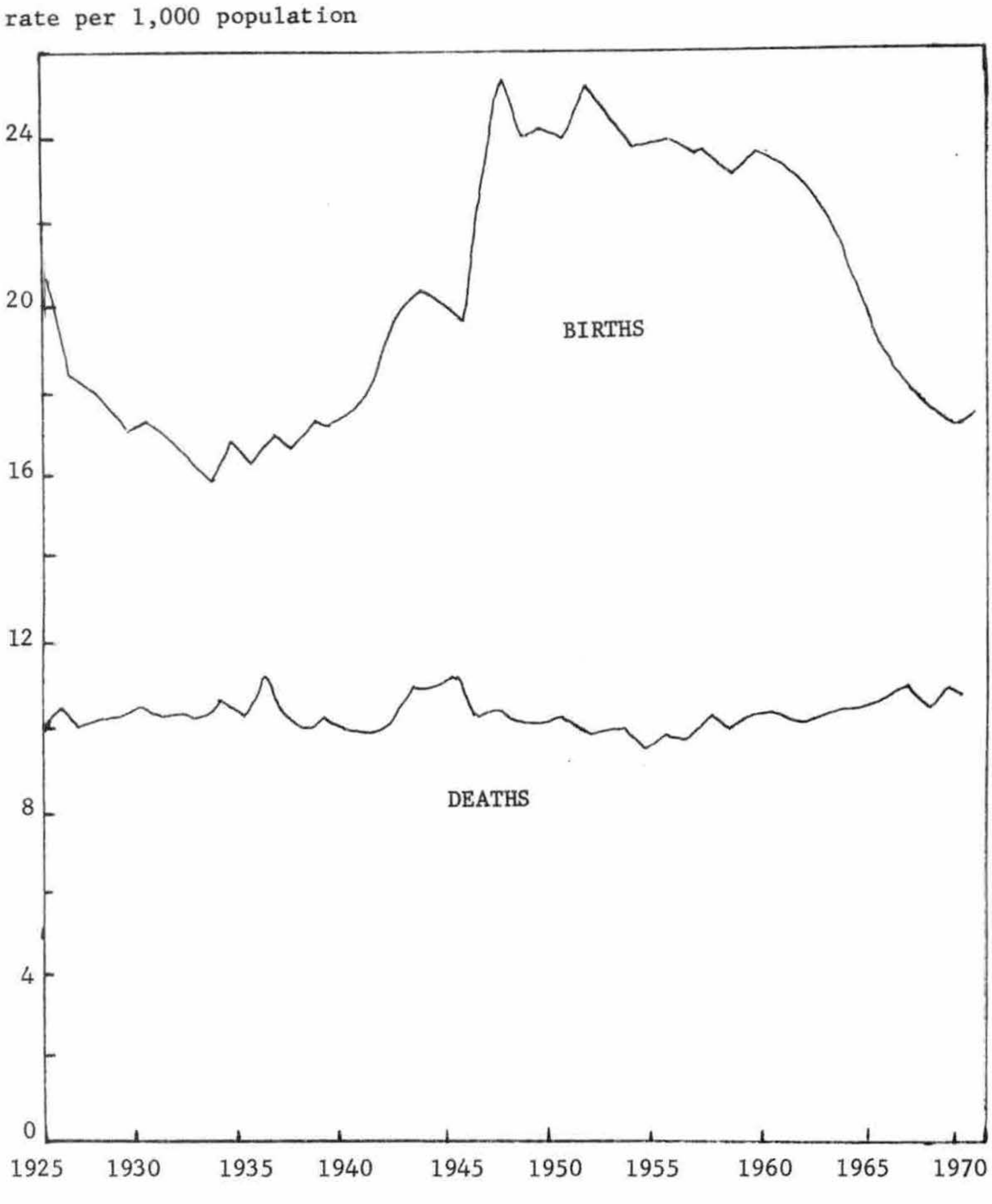

Figure 4.5. Birth and death rates for Iowa residents 1925-1969

twenty-eight counties of Iowa the birth rate exceeds the death rate by at least five per one thousand, but only eight of these counties are from the study regions. In 1969, the average Iowa birth rate was seventeen per one thousand and only in five of the fifty-nine counties in the study regions did the birth rate exceed the average birth rate for the state. The Haran-Vining conditions conform to regional trends in Iowa and further shifts in the distribution away from linearity seem likely.

A dispersed pattern of trip origins and destinations seem apparent from these statistics. The smallest service centers continue to lose rural shoppers to larger cities in the region; the latter may also experience growth which is diverted from the regional capital. Decentralized manufacturing growth exacerbates the dispersed nature of trip patterns and centrality in the transportation network declines. The daily pattern of journey-to-work and shopping trips is somewhat more erratically dispersed through the rural labor market.

CHAPTER V. SUMMARY AND CONCLUSION

Summary

Martin Beckman stated that the size of a city is proportional to the population it serves. This could be taken as the basis of the three methods of analysis of the population distribution of Iowa.

Delineations based on commuting or the gravity formula vary significantly from the OPP delineation. The ratio the central city population to the population of the region has the largest range with the OPP delineation and the smallest range with the gravity formula delineation.

The ratio of the regional population to the central city population can be divided into three groups, which are most evident in the OPP delineation. With this delineation the ratios involving the seven central cities of greater than 50,000 inhabitants are 1.9-3.1, the five central cities with populations of 26,000 to 33,000 have ratios of 3.7-5.2, and the four smallest central cities with populations of 7,400-10,500 have ratios ranging from 7.5 to 14.2. The commutation and gravity formula delineations exhibit the same pattern but on a smaller scale.

The commutation and gravity formula delineations both suggest that the larger central cities serve larger areas and that the smaller central cities serve smaller areas than in the OPP delineation. The counties containing the three smallest central cities (Carroll, Creston and Decorah) have more workers commuting to outside the county than the number of incommuting workers.

The hierarchical regions of Iowa have been assumed to have three layers. The lowest level of the hierarchy surrounds convenience centers which provide everyday functions to the convenience centers' population and the surrounding rural residents. The centers of the second level (subregional capitals) are usually the county seats and the centers of the top layer are the OPP designated central cities. As the level of the hierarchy increases, the number of people providing the higher order functions increases relative to the population of the level.

From 1950-1970 the total population decreased in seven of nine regions, the populations of the central cities and subregional capitals increased in seven of nine regions, the convenience center's population decreased in six regions, and the rural population decreased in every region. The proportionality factor (k) has increased indicating a larger number or more specialized functions are being provided.

The populations predicted through Beckman's model are increasingly overestimated over time. Although the cities are growing, it is at a smaller rate than expected. This is especially evident of the central cities of the regions.

Rank-size analysis indicates three groupings of city size distributions. Cities above 2,000 and below 200 residents have a smaller rank than expected and cities with populations of 200-2,000 are ranked higher than expected. The retail sales per capita of cities with populations of 200-2,000 are also larger than for many of the larger cities.

The relationship between rank and size is not log-linear as expected, but is becoming increasingly curvilinear over time. Haran and Vining attribute this to a declining rural population and a declining birth rate, which are both evident in Iowa. This is in agreement with the results of Beckman's model where the cities of the top two levels of the hierarchy are smaller than expected.

The range of populations of the cities is increasing. The largest city of each region is becoming larger and more important relative to the size of other cities of the region. Cities above 2,000 and below 200 inhabitants are less important than expected and those between 200-2,000 inhabitants are more important than expected.

Conclusion

Four delineations of Iowa have been presented. Divergent results can be obtained by basing the delineations on different criteria, such as population, area, or commuting.

Although Iowa is usually characterized as being rural in nature, seven cities which have populations greater than 50,000 are considered urban areas. Delineations complying strictly to one criteria give undue importance to urban or rural areas. The OPP delineation makes allowances for the divergent population densities and facilitates planning centered around cities which reflect the characteristics of the region.

Size of the region and relative importance of each level of the hierarchy are constantly changing. Previously, commuting time was the limiting factor to the size of a region. As speed and quality of transportation increased the regions became larger and more dependent on central cities. The increasing costs of transportation are becoming a more important factor and are changing the size and importance of the different levels of the hierarchies.

The rank-size analysis implies a clear weakness in the smaller city size classes. Cities with larger populations are growing relative to other cities of the region, but not as much as expected. The dominance of the central cities is reduced by the appearance of complete shopping centers and manufacturing facilities in cities dispersed throughout the region. Convenience centers are declining in importance because of the declining rural population and the influence of the dispersed shopping centers.

The origin-destination patterns of trips are changing. Fewer trips are originating from rural areas and larger number of trips are terminating in cities dispersed throughout the region which are the sites of manufacturing facilities and shopping centers.

REFERENCES

1. Beckman, Martin J. "City Hierarchies and the Distribution of City Size." Economic Development and Cultural Change 6 (1958): 243-248.

2. Beckman, Martin J. and McPherson, John. "City Size Distribution in a Central Place Hierarchy: An Alternative Approach." Journal of Regional Science 10 (1970):25-33.

3. Borchert, John R. and Adams, Russell B. Trade Centers and Trade Areas of the Upper Midwest. Upper Midwest Economic Study, Urban Report No. 3, September 1963.

4. Christaller, Walter. Central Places in Southern Germany. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966.

5. Fox, Karl A. "Change and Community Adjustment: The Metamorphis of Rural America." Paper prepared for a conference on Implications of Structural and Market Changes on Farm Management and Marketing Research, Chicago, 24-26 April 1967.

6. Fox, Karl A. "Delimitations of Regions for Transportation Planning." In Perspectives on Regional Transportation Planning, pp. 91-137. Edited by Joseph S. Desalvo. Lexington, Ky.: Lexington Books, 1973.

7. Fox, Karl A. and Kumar, T. Krishna. "Delineating Functional Economic Areas." In Research and Education for Regional and Area Development, pp. 13-55. Ames, Iowa: Iowa State University Press, 1966.

8. Friedmann, John. "Focus on Public Policy." In Research and Education for Regional and Area Development, pp. 215-233. Ames, Iowa: Iowa State University Press, 1966.

9. Haran, E. P. G. and Vining, Daniel R., Jr. "A Modified Yule-Simon Model Allowing for Intercity Migration and Accounting for the Observed Form of the Size Distribution of Cities." Journal of Regional Science 13, No. 3 (1973):421-437.

10. Iowa Employment Security Commission. Commuting Patterns in Iowa. Des Moines, Iowa, 1973.

11. Iowa, State of. 1969 Iowa Vital Statistics. Des Moines, Iowa: Iowa Department of Health, Records and Statistics Division, 1969.

12. Iowa, State of. A Regional Delineation for the State of Iowa. Des Moines, Iowa: Office of Planning and Programming, 1967.

13. Lösch, August. Economics of Location. Translated by William H. Woglom. New Haven, Ct.: Yale University Press, 1954.

14. Mills, Edwin S. Urban Economics. Glenview, Illinois: Scott, Foresman and Company, 1972.

15. Prescott, James R. and Lewis, William C. "Rural Communities and Regions." Paper prepared for Western Agricultural and Economics Association. Department of Economics, Iowa State University, 1972.

16. Singer, H. W. "The 'Courbe Des Populations.' A Parallel to Pareto's Law." The Economic Journal 46 (June 1936):254-263.

17. U.S. Department of Commerce. Bureau of the Census. Census of Business:1967 2, Retail Trade Area Statistics, pt. 2.

18. U.S. Department of Commerce. Bureau of the Census. County and City Data Book:1952; 1962; 1972.

19. U.S. Department of Commerce. Bureau of the Census. Metropolitan Area Definition: A Re-Evaluation of Concept and Statistical Practice. Bureau of the Census Working Paper 28, 1958.

20. U.S. Department of Commerce. Bureau of the Census. United States Census of Population: 1950; 1960; 1970. Number of Inhabitants, Iowa.

21. Zipf, George Kingsley. National Unity and Disunity. Bloomington, Indiana: The Prinepia Press, Inc., 1941.

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APPENDIX

Regression Results

Spencer region

	1970	1960	1950
q	-.694	-.749	-.784
Student's t	-24.350	-25.257	-25.483
F	592.911	637.927	649.404
R^2	.884	.891	.893
Intercept	7.770	8.131	8.348

Ottumwa region

	1970	1960	1950
q	-.732	-.744	-.777
Student's t	-49.132	-51.318	-62.344
F	2413.992	2633.581	3886.773
R^2	.971	.973	.982
Intercept	7.789	7.918	8.191

Burlington region

	1970	1960	1950
q	-.530	-.530	-.542
Student's t	-23.124	-26.234	-25.949
F	534.718	688.231	673.353
R^2	.949	.960	.959
Intercept	5.981	5.932	5.990

Creston region

	1970	1960	1950
q	-.660	-.700	-.726
Student's t	-25.725	-20.918	-21.460
F	661.772	437.568	460.553
R^2	.934	.901	.906
Intercept	6.665	7.272	7.432

Carroll region

	1970	1960	1950
q	-.773	-.797	-.867
Student's t	-22.309	-22.140	-24.482
F	497.690	490.197	599.386
R^2	.902	.901	.917
Intercept	7.884	8.062	8.541

Decorah region

	1970	1960	1950
q	-.656	-.700	-.726
Student's t	-19.014	-20.918	-21.460
F	361.527	437.568	460.553
R^2	.883	.901	.906
Intercept	7.001	7.272	7.432

Marshalltown region

	1970	1960	1950
q	-.667	-.717	-.737
Student's t	-33.460	-42.298	-41.291
F	1119.592	1789.136	1704.968
R^2	.964	.977	.976
Intercept	7.049	7.372	7.482

Fort Dodge region

	1970	1960	1950
q	-.692	-.743	-.794
Student's t	-30.958	-38.962	-50.368
F	958.423	1518.022	2536.970
R^2	.943	.963	.978
Intercept	7.426	7.779	8.111

Mason City region

	1970	1960	1950
q	-.743	-.796	-.813
Student's t	-51.616	-61.843	-58.210
F	2664.252	3824.595	3388.372
R^2	.977	.984	.981
Intercept	7.986	8.300	8.399