

GROWTH/DECLINE OF EMPLOYMENT SUBCENTERS IN POLYCENTRIC  
REGIONS: THE CASE OF DALLAS-FORT WORTH METROPOLITAN AREA

by

MAHER SAYEL AL-SHAMMARI

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## ABSTRACT

### GROWTH/DECLINE OF EMPLOYMENT SUBCENTERS IN POLYCENTRIC REGIONS: THE CASE OF DALLAS-FORT WORTH METROPOLITAN AREA

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Maher Sayel Al-Shammari, Ph. D.

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Supervising Professor: Ardeshir Anjomani

This research is concerned with explaining the variation in growth rates among employment subcenters. The purpose of the study is to find answers to the question: What factors/variables contribute to the growth or decline of employment subcenters? More specifically, the study aims to 1) identify and describe employment subcenters in the Dallas-Fort Worth metropolitan area, and 2) explain the variation in their growth rate over a specified period of time through testing a set of variables extracted from related literature. A multiple regression analysis technique is employed to complete the empirical analysis.

The DFW metropolitan area was chosen as a case study sample of polycentric regions in order to explore the phenomenon. Data sets covering over six thousand Traffic Survey Zones in the metropolitan area were used in the identification and analysis of employment subcenters. The results of the study identify several explanatory variables that affect the growth rate of employment subcenters in the DFW metropolitan area. Some of the variables identified are distance to the DFW international airport, distance to highway interchanges, distance to the Dallas CBD, whether the area is served by public transportation or not, and the proportion of subcenter's area located in a floodplain zone. All of which were statistically significant in explaining the variation in the growth rate of employment subcenters in the region. Finally, the complexity of the subject covered in this dissertation requires a combined set of detailed future studies to better explain the phenomenon.

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## CHAPTER 1

### INTRODUCTION

Population and employment have both been growing more rapidly in suburbs than in inner cities throughout the United States. As a result, large American cities have changed over a few centuries and in more recent decades from the traditional monocentric form to a more dispersed urban structure characterized by sprawl and polycentricism. Firms and populations abandoned central cities to areas in the suburbs and beyond. This phenomenon was confirmed, during the second half of the 20<sup>th</sup> century, by several studies of major metropolitan areas in the U.S. in the work of Giuliano and Small (1991), Cervero (1989), McDonald (1987) and Greene (1980).

Employment relocated either in employment subcenters or in dispersed locations over the metropolitan area. There has been a major surge of research attempting to analyze this interesting phenomenon in the last few decades. Employment subcenters were chosen as the subject of this dissertation due to their emerging importance in shaping contemporary U.S. metropolitan areas. They change the spatial distribution of employment and population of contemporary metropolitan areas in the U.S. effecting its employment and population density and gradients. Consequently, they are affecting the overall urban structure (McDonald & McMillen, 1998; Small & Song, 1994). Facts and figures about employment subcenters suggest that they are an

important part of urban areas. For example, employment subcenters in Indianapolis have 29 percent of the total employment, whereas the central business district (CBD) only carries 17 percent of the total employment. Similarly, subcenter employment figures are; 25 percent in Portland, 22 percent in St. Louis and 15 percent in Cleveland (O'Sullivan, 2007).

Employment subcenters are important not only because they represent a considerable fragment of the urban web, but they can also help explain surrounding patterns of employment density, population density and land values (Anas, Arnott, & Small, 1997). In the current context of urban growth, there are strong policy debates over zoning, growth management/smart growth, infrastructure investment, environmental protection, social justice, and improvement in the quality of life of urban dwellers. All of these depend on the forces governing the spatial interrelationship of different types of areas in past and future transformation of the urban structure. Employment subcenters, as one important type of these different areas, are the object of this research.

### 1.1 Study Purposes and Research Question

Previous studies have observed that employment subcenters' size and their growth rate vary within a metropolitan area (Giuliano & Small, 1991; Small & Song, 1994; McDonald & McMillen, 1998; Bogart & Ferry, 1999). In other words, some employment subcenters grow fast, while others barely experience any growth or might even decline in size by losing employment. This dissertation aims to investigate this phenomenon through an empirical analysis that explains such differences over a

specified period of time in the Dallas-Fort Worth metropolitan area (DFW). Its purpose is to examine the determinants of such phenomenon in one of the fastest growing metropolitan areas in the U.S. The main research question of this study is: what factors/variables contribute to employment subcenters' change in size over a specified period of time in fast growing metropolitan areas? In other words, what variables relate to the variation in the change in size and the variation in growth rate among employment subcenters?

The literature review in this Dissertation shows a wide range of theoretical and empirical research concerned with employment subcenters, but none was found exhaustive that specifically explore factors that contribute to the rate in which their size changes. Most focused on the definition and the identification of employment subcenters, the effects of subcenters on land values or real estate values, the effects of subcenters on the overall spatial distribution of employment and population in urban areas, and the factors that cause employment subcenters to exist and their influence on urban structure and travel patterns. This empirical study makes a distinct contribution to research through identifying factors/variables that contribute to changes in the size or in the variation in growth rate of employment subcenters over a specific period of time.

The change in size of employment subcenters in this study refers to the change in their number of employees. The growth, decline, or no change in employment subcenter in this study will also refer to their number of employees. In order to identify the forces affecting the present size of employment subcenters (the present number of employees in subcenters), an analysis of the change in size of employment subcenters

over a specified period of time was chosen rather than at one point in time. The reason for this is that urban areas are dynamic in nature and the form that existing land development takes is the result of a cumulative process rather than a static one. The traditional models for analyzing urban areas, such as the three business location models the “classical” or Weberian model, central-place theory, and extensions of the Alonso-Muth-Mills model (Gomez-Ibañez, 1975), fail to account for such dynamic nature of urban areas (i.e. growth or decline of employment subcenters). Such models are based on a static theory of economic equilibrium and assume a complete spatial equilibrium between the supply and demand for urban land at one point of time (this is discussed in more detail in the literature review). In contrast, later urban economic studies emphasize time as an important factor in analyzing the spatial structure. This study believes that changes in the size of employment subcenters are the result of a historical momentum rather than a current one. However, due to the lack of consistent time series data representing this dynamic equilibrium, this study will examine change data (the measurement difference between two points of time).

The scope of this study is the internal structure of the metropolitan area. Therefore, spatial factors believed to affect the concentration of employment, and consequently, affect the variation in growth rate of employment subcenters within the metropolitan area will be considered. Other important factors on a different level than the internal structure are certainly essential to the creation, growth or decline of subcenters. For example, the effects of globalization on urban areas and the transformation of regional industrial structure are factors that change the spatial

structure of many metropolitan areas (UNCTAD, 2004; Porter, 2000). Nevertheless, the spatial effects of such forces are articulated indirectly through spatial means at a local level (e.g.: the variation of accessibility between sites, local amenities, site-specific characteristics, and agglomerative resources). It is through spatial linkages at the local level that regional and national level factors are translated geographically into local employment concentration in subcenters. Global, national, or regional level factors that affect the economic growth of metropolitan areas require a different approach and therefore are beyond the scope of this study. For instance, the spatial consequences of regional-level forces essentially require cross-regional/interregional study. Thus, only factors within the internal structure of metropolitan space that affect the spatial structure and the employment concentration in subcenters are chosen for hypothesis testing.

Urban economic theory discusses some of the factors at the internal structure level of metropolitan areas, where it explains the phenomenon through the following logic: Due to the cost associated with congestion, such as pollution, longer commute time, higher land values and rents, etc., and due to the benefits associated with advances in transportation (e.g.: urban highway construction; faster, safer, and more fuel efficient vehicles; more efficient and less noxious public transit systems, such as bus rapid transit, light rail/commuter train and subways), and advances in communication technologies (telecommunication, teleconferences, videoconferences, and the internet) firms start to rethink their location benefits and tend to move to locations that maximize their profit. The new location selection process, theoretically, is carried out through a bidding process, which is the essence of the bid rent theory. For example, a highly



accessible location (i.e., a location well served by highways, rail lines, etc.) may attract many firms. If this location reaches both a high density and a high quantity of employment, then it will qualify to be an employment subcenter (O'Sullivan, 2007; McDonald & McMillen, 1998). This study will adopt this argument in developing independent variables to explain the variation in the growth rate of employment.

Location preferences of owners of firms in employment subcenters are multidimensional and differ from other land uses in the metropolitan area. Previous studies of employment subcenters, have stressed the varying location preferences between owners of firms in employment subcenters and owners of firms and other activities outside employment subcenters (McDonald & McMillen, 1998). The studies attribute this variation to "attraction agglomeration economies". These attraction agglomeration economies cause businesses to concentrate at certain locations creating employment subcenters. For example, firms from one industry that place very high value on access to transportation systems outbid firms from other industries for land near highway interchanges, airports, public transportation, and in some cases the CBD. According to urban economic literature, the transformation in employment distribution in metropolitan areas is caused by such attraction agglomeration economies (O'Sullivan, 2007; McDonald & McMillen 1998).

Even though, agglomeration economies usually refer to economic forces that operate over an entire urban area, yet, there are some agglomeration economies that can generate employment subcenters at certain locations within an urban area, such as accessibility, proximity to other employment subcenters, site specific characteristics and

certain local government policies (O’Sullivan, 2007; McDonald & McMillen, 1998). This study hypothesizes that a decrease in the “attraction agglomeration economies” would have negative influence on the degree of concentration and consequently the growth rate and vice versa.

Previous studies of employment subcenters have emphasized several factors that can be correlated to the concentration of employment at certain locations in urban areas. This study is utilizing such variables to explain the variation in size and growth rate of employment subcenters. Literature review, theoretical consideration and data availability for this study led to the inclusion of four types of factors, all of which affect the employment concentration in subcenters. The four types are:

1) Accessibility to Transportation Network:

- Distance to Highways interchange, Airports, rail stations, etc.

2) Site-specific characteristics:

- Assess construction cost through variables such as steepness of slope, proportion of subcenter in a floodplain; etc.

3) Proximity to other subcenters:

- Lowers production costs through sharing Infrastructure, Simplified communication, lower Shopping Cost for Customers, etc.

4) Local government policies:

- If local governments offer tax incentives, incentive Packages, and whether the local government has economic development plan or not.

Each of the four will be described in more detail in chapter 2 and will be tested for their contribution to the variation in an employment subcenter's growth rate.

### 1.2 Planning and Policy Implications and Importance

The significance of this study has two dimensions: 1) Its potential contribution to the ongoing research regarding employment subcenters in rapidly growing urban areas, using the DFW metropolitan area as a selected study area; and 2) Its analysis and exploration of a set of variables extracted from related literature and inform on their possible effect on the change in the size of employment subcenters over a period of time. Both of these dimensions can lead to the development of improved sets of information to be used in preparing policies and long range plans for urban growth.

Several urban problems can be minimized through better sets of information that will be produced in this study. For example, the concept of "spatial mismatch" as an urban problem discussed by Kain (1968) and Ihlanfeldt and Sjoquist (1990) can be treated. A well designed public transportation system can alleviate the problems of "spatial mismatch" between suburban jobs and central city workers and vice versa (Sanchez, 1999). In contemporary U.S. metropolitan areas, spatial mismatch is not only observed between suburban jobs and central city workers, but also between jobs, housing, roads, and mass transit. A well designed public transportation system also can be planned to relieve congestion and serve the employees at these employment subcenters by connecting them to their place of residence. Moreover, housing can be planned to be located close to or around major employment subcenters lowering the commuting costs. This trend of transformation in the urban structure (housing

development chasing employment subcenters) has already been noted in the Los Angeles urban area (Small & Song, 1994).

In summary, this study will examine variables related to the variation in growth rate of employment subcenters. The results of this empirical research will help policy makers, planners and other concerned professionals achieve more effective planning and policy outcomes. Sequentially, results from this study can help in providing plans and policies that work as guide lines to other metropolitan areas similar to the study area. These metropolitan areas can use the generalized version of the results to lower the cost associated with urban problems.

### 1.3 Organization of the Dissertation

After the introduction chapter which includes a historical background and current status of the phenomenon, a second chapter examines important literature related to different aspects of the study is introduced. The third chapter describes the methodology and the theoretical perspective that the study adopts. It also describes the variables and defines the study area, the scope of the study, and the data. The fourth chapter is a descriptive analysis dedicated to the identification of subcenters, explaining the theoretical underpinning of the selected processes and the application results. Also, shows the growth rates and the change in size of different subcenters. Building on the results of chapter four, a multiple regression analysis is employed in the fifth chapter to examine the relationship between the explanatory variables and the growth rate of subcenters (the dependent variable). The results then are analyzed and appropriate statistical tests are performed. How the independent variables are measured, including

scaling techniques, are also discussed. Attention is given to analysis and statistical techniques, and test result for each hypothesis, along with the interpretation of the results. A policy implication of the findings that may impact planning at the regional and local levels is discussed in the sixth chapter. Moreover in this chapter, the conclusion of this dissertation including a summary of the main arguments, recounting the major findings, and exploring the theoretical and policy implications of the study. Also, further research will be suggested either in the form of new research questions raised by the study or in the form of methodological issues encountered in the study.

## CHAPTER 2

### THEORETICAL AND EMPIRICAL STUDIES OF EMPLOYMENT SUBCENTERS: A REVIEW OF LITERATURE

In order to understand the contemporary polycentric nature of the U.S. urban areas it is essential to review the history and understand the development of polycentricity in urban areas and the creation of employment subcenters. The monocentric city model represents the base that the polycentric city model was built on. The importance of the monocentric city model is twofold; its strength and simplicity in predicting the spatial arrangement of population density, employment density, income spatial patterns, etc. in urban areas as well as its effects on land use theory, housing and urban transport economics, and local public finance policies (previous major contributor in urban development). This model is still one of the most popular models used and was the cornerstone of urban economics in the 1970's, or what was then called the "New Urban Economics". The model was developed in the 20<sup>th</sup> century and was successfully used to explain land use patterns of the monocentric city. The determination of the spatial structure of cities was the main concern of the model. Its basic tool is based on the bid rent theory which represents the theoretical foundation of this dissertation and is discussed in the next section. At present, it's been argued that the model is out of date. It is no longer useful to describe or explain many emerging urban phenomena, for example: sprawl and multiple employment centers, of the contemporary urban areas.

Experts in the field suggest the use of a polycentric city model, which is an extension of the monocentric city model, as a better substitute to explain decentralized urban areas with multi-centers of the United States (Small & Song, 1994).

In spite of the ongoing decentralization process, some scholars still believe that the monocentric city model is a powerful tool that explains urban structure in some metropolitan areas in the United States. They show that the model predicts the spatial distribution of some present urban areas, such as, New York and Boston with satisfactory low error levels (McDonald & McMillen, 2007). Therefore, many scholars argue that the monocentric city model was and still is a cornerstone in urban economics and land use modeling development.

After reviewing the historical background and the theoretical framework, a more recent set of literature is presented through reviewing the work of McDonalds, McMillen and their joint work, Giuliano and Small, Song and Small, Borges and Ferry and others. Their work with employment subcenters provides very valuable sources to define, identify, analyze and understand employment subcenters in polycentric cities. In their work, they describe several statistical analysis techniques that this study finds very useful. In addition, they provide a wide range of measurements, in some cases precise figures, which enable researchers to carry out several quantitative analysis techniques, which were very useful for this study. Despite the valuable contributions of these studies there are many areas that could be improved. Suggested improvements as well as extracting key points, comparing and contrasting across these studies are contained in this review.

## 2.1 Bid Rent Theory and the Monocentric City Model

The theoretical foundation of this study is based on bid rent theory. Bid rent theory is a geographical theory that refers to how the price and demand on land changes as the distance from the Central Business District (CBD) increases. This theory is based upon the reasoning that the more accessible the area, the more profitable it is going to be. Firms in an urban area produce a particular product that is sold for export at the port in the center of the city or CBD. The shipping cost of this particular product to the port in the center of the city is lower when the firm is closer to that port. In this study, this particular reasoning leads to recognize accessibility as an important factor that contributes to the growth of subcenters.

The work of David Ricardo (1882), Von Thünen (1886), Alonso (1964), Mills (1967; 1972) and Muth (1969) considered to be a landmark in the developing process of the present monocentric city model. David Ricardo (1882) introduce valuable concept to the field, such as: the natural endowment of land, the scarcity of goods and perfect competition, while Von Thünen emphasis the importance of location in determining agriculture land use patterns and shipping cost as a result of distance from the market place. The concepts of Ricardo and Thünen are reflected in three sets of the independent variables tested in this study. The natural endowment of land concept introduces by Ricardo is reflected in the site-specific characteristics sets of variables, while accessibility and proximity sets of variables in this study reflects Thünen's concept. Alonso, Mills and Muth developed these original thoughts and expand them to apply to urban areas. Alonso introduces the Urban Land Market Theory, based on the bid rent



theory, where he assumes that the users have a perfect knowledge about the actual land rent structure and that there is a market clearing mechanism allowing the land to be occupied by the highest bidder. After that the model was broadened to include transportation, housing and production by Mills and Muth. Eventually, the model was incorporated into a cohesive framework. (Appendix A)

In recent years, the criticism of the monocentric city model focused on the fact that cities, at least since World War II, have been increasingly decentralized where employment in urban areas is either dispersed and/or clustered in subcenters. Accordingly, the new urban economics has been characterized as providing analysis to cities from another era. These cities do not exist anymore. Another criticism has concerned the theoretical incompleteness of the model. It fails to explain why cities exist and fails to explain the determinants of the pattern of agglomeration, because its focus is household location assuming a pre-specified firm location.

## 2.2 The Relation between Bid Rent and Employment Concentration

The Alonso-Muth-Mills urban land market models, which the literature frequently refers to all three as “the standard or the classical model” have common analysis basis (Miyao, 1986). They share the same theoretical basis and employ the same methodological framework of budget-constrained utility maximization to derive the relationships between land use and price of land. Moreover, they use the negative exponential function statistical analysis technique to arrive at similar bid rent functional forms. Finally, all three employ essentially the same mechanism for allocation of land to its users through the bidding process. (Briassoulis, 2000)

Bid rent is the concept that captures the essence of the bidding model of land market. It is a tool used to establish spatial equilibrium, in which firms and households are unresponsive to location difference, and consequently have no motivation to relocate. McDonald (1997) provides the following two examples to demonstrate the bid rent concept: “bid rent for a household for a particular urban site is the maximum rent per unit of land that the household can pay to reside at location  $x$  and maintain some given level of utility. Similarly, bid rent for a business is the maximum rent per unit of land that it can pay for a particular urban site and maintain a given profit level” (p. 86). In terms of employment subcenters, bid rent enables the comparison between land that is being used for employment subcenters, and land that is designated for other uses, and provides an explanation for such a variation in usage.

Alonso in the monocentric city model assumes a flat, continuous, monocentric and homogeneous urban area that is ready for use. The central business district (CBD) represents the city’s only center of employment in which households commute to work and shop and acts as an export point for industrial products. Land uses change only in reference to the CBD, as transportation costs and commuting time varies along an axis that radiate out of this CBD. The combination of housing, distance from the CBD and all other goods determine satisfaction or utility of the household, which in turn determine their location preference. Similarly, the combination of land input, the distance from the CBD, other inputs and outputs determine the utility of the firms, which in turn determine their location (Chapin & Kaiser, 1979; Romanos, 1976). These assumptions are needed to simplify the mathematical representation of the bid rent

theory, where analytical forms of bid rent and land use patterns can be derived. However, this only provides a general explanation of the urban form, thus, limiting its ability to predict the variation in land use of complex urban areas. Therefore, in order to study a complex phenomenon such as employment subcenters, this study certainly needs to relax or modify these assumptions.

This study is not the first to relax or modify the monocentric city model assumption. For example, the model assumes employment to be located entirely in a CBD. This assumption, considered not necessary in the work of several scholars. Instead, they assume that it is declining in density as a function of distance from the CBD similar to the population density but in a more centralized form (Hamilton, 1982; Kemper & Schmenner, 1974; Mills, 1972; White, 1988). This study focuses on employment subcenters which are concentrations of employment outside the CBD, therefore, will follow the concepts of such scholars about the distribution of employment instead of the traditional restricted assumption of the monocentric city model. While such restrictive assumptions about space in the monocentric city model are needed for an elegant analytical model, they are not necessary for the bid rent framework to work (Small & Song, 1994).

Therefore, based on the bid rent framework, several studies explain the phenomena of polycentricity and the creation of employment subcenters through the following logic:

Due to the cost associated with congestion, and due to the benefits associated with advances in transportation and communication technologies, firms start to rethink

their present location benefits and tend to relocate to locations that maximize their profit. The new location selection process, theoretically, is carried out through a bidding process, which is the essence of the bid rent theory. For example, a highly accessible location (i.e., a location well served by highways, rail lines, etc.) may attract many firms. If this location reaches both a high density and a high quantity of employment, then it will qualify to be an employment subcenter. This study will adopt this argument in developing arguments to explain the variation in the growth rate of employment subcenters (O'Sullivan, 2007; McDonald & McMillen, 1998).

Location preferences of firms across employment subcenters are multidimensional and differ from other land uses in the metropolitan area. Previous studies of employment subcenters have stressed the varying location preferences between employment subcenters and other land uses. They refer this variation in location preference to “attraction agglomeration economies”, which cause employment concentration. For example, employment subcenters outbid other land uses in locations that are highly accessible to highway interchanges, airports, public transportation, and in some cases the CBD. According to urban economic literature, the transformation in employment distribution in metropolitan areas is caused by such attraction agglomeration economies (O'Sullivan, 2007; McDonald & McMillen 1998).

Economic literature suggests that scale economies cause the concentration of employment. Scale economies have two primary types internal scale economies at a single location and agglomeration economies. Three types of economies are normally described as agglomeration economies in the literature; localization economies in urban

areas that are outside of firms and caused by the size of industries at a local level, as well as, urbanization economies in urban areas that are outside of industries at a local level, and caused by the size of the urban economy; and finally, inter-industry linkages, which emerge out of savings in transportation cost when purchasing intermediate inputs. Employment subcenters are not formed directly by internal scale economies although the latter can cause high employment density clusters in urban regions. The size of employment clusters lowers the cost of production for firms located within the cluster but not to others. (McDonald & McMillen, 1998) Although, agglomeration economies usually refer to economic forces that operate over an entire urban area; there are “attraction agglomeration economies” such as accessibility, proximity to other employment subcenters, site specific characteristics and certain local government policies that can generate employment subcenters at certain locations within an urban area (O’Sullivan, 2007; McDonald & McMillen, 1998).

### 2.3 The Polycentric City Model

The majority of leading edge studies in urban economic theory today deal with criticisms of the monocentric city model. One of the most important criticisms is that cities have become polycentric, which makes it natural to study the employment subcenters as contemporary phenomenon in the United States’ metropolitan areas. The polycentric city model is an important extension of the monocentric city model and is a substitute analytical tool to explain the employment subcenters in urban areas. The presence of employment subcenters in U.S. metropolitan areas was identified by Cervero (1989), Giuliano and Small (1991), Greene (1980), McDonald (1987) and their

theoretical basis was discussed in works of Helsley and Sullivan (1991), Papageorgiou (1971), Romanos (1977), Sasaki (1990), and White (1976). Recent research on employment subcenters in urban areas focused on several aspects regarding employment subcenters such as, the definition and the identification of employment subcenters (McMillen, 2003; McMillen, 2001; Craig & Ng, 2000; Giuliano & Small, 1991; McDonald, 1987); the effects of subcenters on land values or real estate values (McMillen, 2004; McMillen & McDonald, 1998; Barkley, Henry & Bao, 1996; Waddell, Berry & Hoch, 1993; Giuliano & Kenneth, 1990), and the effects of subcenters on the spatial distribution of employment and population in urban areas (McMillen, 2004; McMillen & McDonald, 1998; Small & Song, 1994).

Moreover, the factors that cause employment subcenters to exist in metropolitan areas and their effects on land values, population distribution, and travel patterns are described in a growing body of theoretical literature (Sasaki, 1990; Wieand, 1987; Kim, 1983; Fugita & Ogawa, 1982; Odland, 1978; Hartwick & Hartwick, 1974; White, 1976).

A review of three specific studies is important for this research, 1) Giuliano and Song (1991), 2) Small and Song (1994), and 3) McMillen and McDonald (1998). The first study provides a consistent subcenters definition and identification procedure, while the second presents techniques for estimating polycentric density functions for both employment and population. In addition, it gives a wide range of measurements to analyze employment subcenters. The last study offers alternative techniques for

estimating polycentric density functions for employment. Moreover, it delivers several variables that are believed to cause employment subcenters to exist and to grow.

### *2.3.1 Giuliano and Small (1991)*

One of the objectives of Giuliano and Small (1991) study was to provide a consistent subcenter definition and to develop a method for systematically identifying employment centers. They agree with McDonald (1987) in that the key to identify urban centers is employment and not population. They also agree with his definition of the employment subcenter as a zone whose measure of employment concentration is higher than all adjacent zones. Originally, their definition is a modification of McDonald's (1987) definition of employment subcenters.

Giuliano and Small (1991) define an employment subcenter as “a contiguous set of zones, each with density above some cutoff  $D$ , that together have at least  $E$  total employment and for which all the immediately adjacent zones outside the subcenter have density below  $D$ , and that in order to be classified as adjacent, the zones must have at least 0.25 miles of common boundary” (p. 167). According to this definition, all high-density zones in the region are classified as part of some center unless they are both small (less than  $E$  employment) and isolated (not part of a cluster of high-density zones with  $E$  employment in total). The highest-density zone of the center is called the “peak zone”.

This definition has so far proved to be the most popular among scholars in the field and have been used by McMillen (2003), Anderson and Bogart (2001), Bogart and Ferry (1999), McMillen and McDonald (1998), Cervero and Wu (1998, 1997),

Sivitanidou (1996), and Small and Song (1994). It will be used in this study but with modifications provided in Bogart and Ferry (1999) study.

Considering this definition, large values of  $D$  (density) and  $E$  (employment) produce a small set of subcenters in a metropolitan area, while small values of  $D$  and  $E$  produce a large set of subcenters (McMillen & McDonald, 1998). For example, Giuliano and Small (1991) used a density cutoff of 10 employees per acre, and a minimum total employment of 10,000 that was lowered to 7000 for some less dense counties in the Los Angeles metropolitan area. This assumption produced a total number of 28 employment subcenters using 1980 data. For the same metropolitan area, Small and Song (1994) assume a density cutoff of 20 employees per acre, and a minimum total employment of 20,000. These criteria identified a total number of 7 employment centers for the 1970 data and 10 employment subcenters for the 1980 data. Both studies had different goals and used the density and total employment cutoffs accordingly.

In addition to the definition, Giuliano and Small (1991) emphasize the importance of employment subcenters. They state that empirical analysis of such subcenters can identify economic forces that account for changing the urban structure. These forces create conflict between agglomeration economies (factors causing agglomeration economies are: reduction in shopping costs for customers, shared facilities, transportation cost savings in the purchase of intermediate inputs, and lower production costs by simplifying personal communication) and congestion (factors caused by congestion are: high land price leads to high rent, very long travel time,



costly travel, lack of parking spaces, higher density leads to higher cost of maintenance) Giuliano and Small (1991). According to the authors, sufficiently high congestion effects on central agglomeration can lead to decentralization of some firms and services. The authors explain that depending on the strength of agglomerative forces between these firms, different patterns of dispersal can emerge. If the agglomerative forces between these firms were weak, for example, it can cause them to decentralize to dispersed locations throughout the region, while on the other hand; strong agglomerative forces between these firms tend to result in concentrations of these firms and services in secondary clusters or nodes (subcenters). The degree of employment concentration in subcenters is an indication of a strong agglomeration economy (Giuliano & Small, 1991).

Giuliano and Small study was about employment subcenter in the Los Angeles region. The results of the study are that economic activity is heavily concentrated along a linear core area, especially around the Los Angeles central business district; and that the density and frequency of centers decline with distance from this core. Larger and more centrally located centers tend to have longer work trips, with workers in most centers experiencing longer commutes than those in comparable locations outside of centers. Overall, results suggest a highly complex space economy characterized by a system of specialized centers, distributed within a pattern of economic activity that is dispersed yet strongly influenced by the pull of the Los Angeles central area.

In summary, the study of Giuliano and Small (1991) is important because it introduces a constant definition to employment subcenters. Furthermore, it provides a

systematic procedure for identifying subcenters that has proven to be the most popular among scholars. Finally, it calls attention to the increasing role of subcenters in shaping the urban structure.

Bogart and Ferry (1999) introduced an extension to the Giuliano and Small (1991) methodology for identifying employment subcenters in a natural way to account for the way the data, taken from the Census Transportation Planning Package (CTPP), is collected. The modification was to add adjacent zones (analysis units) with employment densities less than the cutoff density to prospective employment subcenters, with the densest zones being added first. This process continued so long as the employment density for the entire group of zones was greater than the total employment cutoff. This modification will limit the incorrect omission of some zones from consideration despite their integral connection to an employment subcenter (Ferry, 1997). Both methodologies used the Transportation Analysis Zone (TAZ) as a unit of analysis.

### *2.3.2 Small and Song (1994)*

The second study is of Small and Song (1994), which examined spatial patterns and their change during the 1970s in the Los Angeles region by estimating monocentric and polycentric density functions for employment and population. Although it is another study of the Los Angeles area, the goals and techniques were different than that of Giuliano and Small (1991). They estimated polycentric density functions for both employment and population for 1970 and 1980 using a small-zone data for the Los Angeles region. All density functions were based on employment centers. Those

employment centers were predefined using Giuliano and Small 1991 procedure. This enables them to perform intensive hypothesis tests to verify the existence of polycentricity in the urban structure. Then, the polycentricity was tested to determine how its level changed over time. They also measured the impacts of employment subcenters on region-wide employment and population distributions, compared the polycentric and monocentric models, and examined change over time in the overall degree of dispersion.

The first step was the identification of employment subcenters using Giuliano and Small (1991) procedures. To have manageable number of subcenters they increased the density and total employment cutoffs, which decreased the number of subcenters. Then they defined the region's main center, which was different for 1970 and 1980 and fit the monocentric function (1) for both the population and the employment.

$$D_m = Ae^{-br_m}e^{u_m} \quad m = 1, 2, \dots, M, \quad (1)$$

“where  $D_m$  is the observed density of population or employment in zone  $m$ ;  $M$  is the total number of zones in a metropolitan area;  $r_m$  is the distance of zone  $m$  to the CBD;  $e^{u_m}$  is a multiplicative error term associated with zone  $m$ ; and  $A$  and  $b$  are parameters to be estimated.” (Small & Song, 1994, p.294)

Some assumptions of the standard monocentric model are that the urban area has a single employment center and that households are willing to trade off accessibility to this center against housing costs in order to maximize utility, resulting in residents

distributed in a circularly symmetric manner with density function  $fI$ , where  $r$  is the distance from the single center (Small & Song, 1994). However, the authors redefined the term *monocentric* to mean “any distribution which is circularly symmetric about a single center” (Small & Song, 1994, p. 294) because all employment may not necessarily be located in the CBD. Results of the estimated monocentric density function (1) showed that employment and population became more dispersed from 1970 to 1980, indicating that the model is less suitable for the Los Angeles area.

The natural extension of the monocentric model is to assume that urban residents and firms value access to all employment centers, so that employment and population densities are functions of distances to all these centers. They believed that the assumption that the sum of center-specific functions becomes a plausible specification, so they specify the polycentric density function to be additive. Applying these ideas to the negative-exponential functional form leads to the following generalization of the monocentric model:

$$D_m = \sum_{n=1}^N A_n e^{-b_n r_{mn}} + v_m \quad m = 1, 2 \dots M, \quad (2)$$

where  $N$  is the number of employment centers;  $r_{mn}$  is the distance between zone  $m$  and center  $n$ ;  $v_m$  is the error term of density associated with zone  $m$ ; and  $A_n$ ,  $b_n$  are parameters to be estimate for each center  $n$ . The first term on the right side of the equation is a vertical sum of negative-exponential density functions, each reflecting the influence of one center on that location. The error term is specified to be additive in order to permit estimation by nonlinear squares. (Small & Song, 1994, p. 295)

Then they estimated the polycentric density function (2) for population and employment separately for 1970 and 1980 in the Los Angeles area. The results show the polycentric density function (2) fits better than the monocentric one. Small and Song rejected the monocentric model in every case. In addition, they were able to measure the overall impact of each employment subcenter on region-wide employment and population distributions.

To facilitate the comparison between the two years, Small and Song showed results for 1980 estimates with only the 1970 centers. There was not overwhelming evidence that overall employment patterns are influenced by subcenters, referring instead to weak economies of agglomeration, so that only few centers act as attractors to other firms. Population densities, by contrast, were strongly influenced by employment centers; six of the eight 1980 centers had significant intercepts and gradients.

Finally, they examined the change in overall dispersion by computing the Gini coefficient of the distributions, which measures the degree of deviation of an actual density distribution from a uniform distribution. The coefficient is defined “as the fraction by which the area under the Lorenz curve exceeds what it would be if the Lorenz curves was a straight line” (Small & Song, 1994, p. 310). The results showed that the Gini coefficients for both the population and the employment distributions decreased between 1970 and 1980. This reinforces their earlier conclusion, based on monocentric density functions, that both population and employment became more dispersed.

### *2.3.3 McDonald and McMillen (1998)*

The third important article is McDonald and McMillen (1998) that identified employment subcenters and determined their influence on employment density. As a unique contribution to the field, this particular study derived an equation, using the bid rent theory, for determining the density function as well as the probability of a zone to have employment in the Chicago metropolitan area.

McDonald and McMillen (1998) discussed the causes and effects of suburban employment centers in the Chicago area. Their study had two parts: 1) the underlying reasons for the existence of employment subcenters were discussed, and 2) an econometric test is formulated and was used to distinguish between two types of agglomeration economies. First, the authors attribute the formation of subcenters and the spatial concentration of employment in general, to internal scale economies and agglomeration economies. Internal scale economies lead to large individual establishments, while agglomeration economies cause establishments to locate together. However, it was suggested that the internal scale economies do not lead to direct formation of subcenters; thus focusing their study on agglomeration economies.

Agglomeration economies can arise due to greater accessibility to an area, because it is well served by, for example, highways and rail lines, and/or due to proximity to other firms, which can lower production costs. They tested the effects of access to transportation on employment density and, separately, the effects of proximity to an existing employment subcenter. Their paper is unique, they claim, in providing a

detailed assessment of the nature of the agglomeration economies that cause employment concentration.

Second, a model of employment density is introduced that uses bid rent theory. The model explicitly includes a selection process that determines employment probability in a small zone located within the urban area. This modeling approach distinguishes between the probabilities that a zone contains any employment from the density of employment in those zones that do contain employment. They suggested that there are agglomeration economies that can generate concentrations of employment at certain locations within an urban area, and accessibility to an area rather than proximity to other firms is the initial reason for agglomeration. This line of reasoning suggests that a suburban subcenter may form near transportation centers, but accessibility rather than mutual attraction leads to the employment concentration. If such is the case, only the accessibility measures are statistically significant in an employment density regression that includes as explanatory variables both accessibility measures and a variable representing proximity to suburban subcenters.

The initial location of a suburban subcenter may be the result of access to the transportation network. However, proximity to other firms can result in lower production costs for firms through simplified communication, providing for an independent motivation for firm locations. If proximity to other firms lowers costs, then a firm may bid more for sites in suburban subcenters, independent of the other advantages the subcenter location offers. According to the above, their main concept is that the effect of suburban subcenters on employment density can be formalized using

bid rent functions. A bid rent function represents “the maximum amount a firm or an individual will pay for a unit of land as a function of the parcel’s characteristics” (McMillen & McDonald, 1998, p.160).

The primary equation their study is:

$$\ln R_1 = \beta' X + u_1,$$

where  $R_1$  represents bid rent for land use 1 (non-residential),  $X = A, S, C$  and  $\beta_1$  is a vector of coefficients, and  $u_1$  is a normally distributed error term.

$X$  = the parcel’s characteristics ( $A, S, C$ )

$A$ : access to expressway interchanges and other features of the transportation network.

$S$ : proximity to the employment subcenters, independent of the vector  $A$ .

$C$ : idiosyncratic characteristics (For example, some sites may be swampy and ill-suited for employment, while others are level and clear, reducing the costs of construction)

They create a similar equation which represents bid rent for land use 2 (residential). It is worth mentioning here that they considered land use as three portions in their equation: non-residential (zones that have employment), residential (usually zones with no employment), and spaces that have no development (open spaces, vacant land, parks, forests, swampy areas, forest preserves). Then they introduced density, which is the ratio of labor to land, in the equation. And since both are inputs to production, density becomes a function of “land rent, wages, other input prices, and output prices” (McMillen & McDonald, 1998, p. 161). However, density simplifies only to a function of land rent because output and input prices other than land are unlikely to vary greatly over urban areas.



Next, because data on land devoted purely to employment use are usually unavailable and often imprecise, they moved from an equation that uses net employment density to an equation that uses gross employment density. The equation that they created for density applies only for the minority of zones that have employment. In order to include the other zones, they created an equation that determines employment probability. Finally, they combined the two equations for density and probability into one maximum-likelihood estimation equation, which estimates both gross employment-density function and the probability that a site has employment. It should be noted that selection bias of sites by developers (they don't follow the logic of the theory in site selection) complicates the interpretation of employment-density function estimates.

The theory presented in their paper suggests that employment density and the probability of employment depend primarily on factors that influence bid rents. Their explanatory variables include standard measures of accessibility, with all distances measured in straight-line miles from the quarter-section midpoint. The explanatory variables are distance from: 1) the Chicago central business district; 2) O'Hare Airport; 3) the nearest commuter rail station; and 4) interchanges on expressways, tollways and major limited-access highways (all referred to as highways). Distances to commuter train stations and to highway interchanges are entered in inverse form because the effects of these sites are expected to decline quickly with distance.

The above mentioned four explanatory variables are distance measures. There are another set of variables that are concerned with what McMillen and McDonald

called “the idiosyncratic characteristics of the zone,” which, based on their reasoning, should be included in the model. Those are the proportion of the “quarter section”, the unit of analysis in their study, devoted to railroad rights of way (as a measure of accessibility), water (quarter sections with a greater proportion of water are unlikely to have much employment), parks and open spaces (Large proportions of parks and open reduce the probability of employment and lower gross employment density space) (see McDonald & McMillen, 1998, p. 165-166).

In the conclusion of their study, McDonald and McMillen (1998) accomplished two tasks. First, a bid rent model of employment location was formulated that makes the distinction between small zones that contain no employment and those that do contain employment. They showed that the method of maximum likelihood estimation can be used to estimate gross employment density and employment probability jointly. Second, they formulated an empirical test that distinguishes between two types of agglomeration economies that might be exhibited by an urban site. The first type of agglomeration economy is based on access to infrastructure shared by many firms. The second type of agglomeration economy stems from causes that are internal to the group of establishments, and may consist of information and communications exchange, or lowering shopping cost for customers.

Empirical results showed that the measures of access to the transportation systems are highly statistically significant determinants of both employment probability and employment density. The results also show that, holding access to transportation constant, proximity to an employment subcenter is a statistically significant variable in

both equations as well. These findings are general confirmation of the existence of both types of agglomeration economies as previously discussed.

The three above studies represent the spine for almost all employment subcenters literature. The Giuliano and Small (1991) study provide a consistent subcenter operational definition and develop a method for systematically empirically identifying employment centers that proves to be favored by scholars. Also, they provide a descriptive analysis of employment subcenters. Their study did not test any hypothesis but certainly is one of the most important in the field. Small and Song (1994) study provides a comprehensive density study, comparing the monocentric city model and the polycentric city model. Their dependent variable was the employment and the population densities separately, and their only independent variable was the distance from the peak zone of a subcenter. Their study was a model to other studies, where they use the same equations and only change the dependent variable from employment or population density to land values, income groups, race, etc. They also provide an equation to measure the overall impact of each employment subcenter on region-wide employment and population distributions. Even though, they explain the over all change in density between the years 1970 and 1980 they did not explain nor test the variables causing employment subcenters to have different growth rates. Finally, the McDonald and McMillen (1998) study introduces a unique contribution, not only to testing the effects of employment subcenters on over all density distribution, but also in measuring the probability of a zone to have employment. This particular study introduces variables that are used in this dissertation, with modifications, to explain the change in size of

employment subcenters. Yet, the study of McDonalds and McMillen (1998) fails to recognize an employment subcenter as a whole unit and analyze it on this base. Instead, their study pays attention to small zones covering all the metropolitan area. This dissertation, identifies employment subcenters using small zones, traffic survey zones (TSZs), as the unit of analysis but dissolve all the contiguous set of zones into one zone, composing an employment subcenter with defined boundary using GIS software and treat it as one entity for analysis purposes. In addition, the concern of this dissertation is the change in size and the growth rate of employment subcenters which makes it the only approach that counterparts the dynamic nature of urban areas.

The following are primary hypotheses, developed based on the literature review:

*Hypothesis 1: The greater the accessibility to an employment subcenter, the faster its growth rate.*

Accessibility to the transportation network is valued by business and workers and will be measured through variables such as the distance to highway interchanges, airports, and whether the subcenter is served by public transportation or not. It is expected to explain some of the variation in subcenters' growth rate.

*Hypothesis 2: The more suitable the site of an employment subcenter for construction of buildings and other infrastructure (relatively low construction cost), the faster its growth rate.*

There are other dimensions that explain growth rate variation, such as non-transportation characteristics. Non-transportation characteristics of a site or site-specific characteristics, such as the steepness of the slope or flood planes, directly affect the

construction cost at a site. Therefore, low construction cost resulting from the site being level and suitable for construction constitutes an attraction agglomeration economy, causing the growth rate of a subcenter to increase. The impact of such factors on employment subcenters is likely to have increased over time. The importance of such factors is increasing as a result of the improvement in overall accessibility and communication modes in metropolitan regions; partly due to major U.S. investments in highways and technological advances in communication. Observing that non-transportation factors do not necessarily eliminate the role of transportation in changing the size of subcenters, rather a combination of multiple factors can better explain the observed phenomenon.

*Hypothesis 3: The greater the accessibility of an employment subcenter to the traditional CBD and other employment subcenters, the faster its growth rate.*

At present, transportation influences on urban structure have become more sophisticated. This variable, which traditionally was the ideal measurement of transportation accessibility of a location, is now less important to employment subcenters than other accessibility measures, such as, the overall accessibility of the site to all the population and to all the employment. Moreover, the importance of such overall accessibility increased over time, while the impact of access to CBD decreased, and was not deemed to be significant in empirical studies, such as McDonalds and McMillen's (1998) study of the Chicago area.

The relationship between different employment subcenters matters in the growth of subcenters. For example, the importance of proximity to other subcenters was

significant in studies such as Small and Song (1994) and McDonald and McMillen (1998). However, there has never been a systematic exploration of such factors in relation to the change in size of subcenters. This study believes that they are an important determinant of the growth rate of employment subcenters because of positive externalities (Proximity to other firms may lower production costs by simplifying personal communication, sharing infrastructure or may help customers reduce their shopping costs, etc.) and negative externalities (congestion) between different subcenter activities.

*Hypothesis 4: The existence of local government policies that encourage businesses to locate in subcenters within their territory increases the growth rate of those subcenters.*

Land use regulations, taxation and capital investment are factors that influence the growth rate of employment subcenters. Land use regulations influence the type and intensity of development for a particular site, whereas taxation through local government incentive packages, and tax breaks represent an attraction factor for firms and businesses to locate in that site. On the other hand, capital investment in infrastructure and the adoption of economic development plans stimulates land conversion to urban use, which makes it a possible location for an employment subcenter.

## CHAPTER 3

### RESEARCH DESIGN AND METHODOLOGY

The hypothesis of this study is that there are factors such as accessibility measures, site-specific characteristic, proximity to other employment centers and local government policies that relate to the variation in growth rate of employment centers. Such factors cause some subcenters to grow faster than others, retain the same size, or even decline.

As was discussed in the examination of literature, there are several factors/variables that affect the growth rate of employment subcenters, which are the subject matter of this study. In order to empirically test the importance of individual factors, simplification is needed through a model that allows the link between the growth rate of employment subcenters and a number of measurable explanatory variables. This study will use a multiple regression model based on the bid rent theory, to explain the growth rate of employment subcenters. The model will be used to analyze the phenomenon in the DFW metropolitan area.

An employment subcenter is simply defined as “an area with both a high density and a high quantity of employment” (Bogart & Ferry, 1999, p. 2101). This area is usually a contiguous set of zones, where the peak of the center is defined as the highest-density zone (Giuliano & Small, 1991). The growth rate in this study will refer to the

growth rate of total employment in a subcenter over a specified time period (1995, 1999

and 2005, i.e.,  $\frac{E_{2005} - E_{1995}}{E_{1995}}$ ), where as change in size will refer to the change in total employment over a specified time period, i.e.,  $E_{2005} - E_{1995}$ .

### 3.1 Variables and Hypotheses

The concepts of bid rent theory are used in this study to derive a model that explains the determinants of employment subcenters' growth rate. This study, as with bid rent theory, assumes that land is allocated in a bidding process. The economic agent who bids the highest price for a site will occupy it. Employment subcenters take place through the functioning of the land market. Firms balance the tradeoffs between land prices/rent and location's amenities at each site and offer bids for land that vary across the city according to their amenities. They maximize their profit by weighing location advantages against land prices because of the additional revenues the site will draw or the cost savings it will bring. On the other side, land owners compare the bid rents offered by firms and other different users and sell the sites to the highest bidder.

A location's amenities cause attraction agglomeration economies that can generate concentrations of employment at certain locations within an urban area. According to urban economic literature, the transformation of employment distribution in metropolitan areas is caused by these agglomeration economies, or what some economic literature refer to as economic forces. For example, due to the cost associated with congestion and the advances in transportation and communication technologies, firms tend to relocate to locations that maximize their profit. The location selection



process, theoretically, is carried out through a bidding process, which is the essence of the bid rent theory.

As previously discussed, “attraction agglomeration economies” can generate employment concentration at certain locations within an urban area (O’Sullivan, 2007; McDonald & McMillen, 1998). For example, a highly accessible location that is well served by highways, rail lines, etc., and is level and ready for construction with low cost, attracts many firms. If this location reaches both a high density and a high quantity of employment, then it is referred to as an employment subcenter.

A location well served by highways, rail lines, etc. and has a low cost construction may attract many firms even when the firms have no interest in locating near one another. However, the initial location of a subcenter may be the result of access to the transportation network, but proximity to other subcenters may lower production costs by simplifying personal communication or may help customers reduce their shopping costs. This added agglomeration economy can provide an independent motivation for firms to locate near or in employment subcenters. Thus, firms may bid more for sites close to or in employment subcenters. In addition, local government policies promoting development is considered as attraction agglomeration economies as well.

From this line of reasoning and from the examination of literature the study identifies four factor, or general categories of independent variables:

1. Accessibility of an employment subcenter to the transportation network.
2. Proximity to other employment subcenters.

3. Site-specific characteristics, and
4. Local government policies.

All should correlate to the change in size of employment subcenters. The primary linear equation relating the dependent variable and the independent variable can be presented as follows:

$$\Delta Size \text{ or } growth \text{ rate} = f(x_1, x_2, x_3, \dots, x_i)$$

where  $\Delta Size$ , the change in size of employment subcenters, or growth rate is the dependent variable and is the function of several independent variables  $x_i$ .

The first category is accessibility measures. The purpose of the variables used in this category is to capture any potential accessibility affects on employment subcenters. Literature review suggests variables such as, distance to highway interchanges, distance to airports, distance to light rail stations, distance to subway stations, and other modes of public transportation. In this study, the accessibility variables that are believed to affect the change in size of employment subcenters in the DFW metropolitan area will include:

- *Distance to highway interchanges:* this variable will be measure by distance miles from the midpoint of a subcenter to all highway interchanges, identified as important, in the metropolitan area.
- *Distance to the DFW International Airport:* this variable will be measured by distance miles from the midpoint of a subcenter to the airport.

- *Distance to Love Field Domestic Airport*: this variable will be measured by distance miles from the midpoint of a subcenter to the airport.
- *Whether a subcenter is served with public transportation provided by DART (Dallas Area Rapid Transit) and the T (Fort Worth Public Transportation)*: this variable will be measured as a dummy variable, (1=Yes) the subcenter is served and (0=no) otherwise.

The study expects the estimated coefficients of the distance in miles to highway interchanges measure to be consistently negative. This means that the farther the distance of these points from a subcenter the lower the accessibility variables and the lower its growth rate, *ceteris paribus*. As for airports, firms tend to locate in nearby sites to regional, national, or international transportation facilities. The study expects the coefficient of distance to these facilities to also be consistently negative. Finally, access to the public transportation stations is expected to be consistently positive. Obviously, the improved highway network, and the high dependent on private vehicles for transportation in the DFW metropolitan area, decreased the importance of public transportation.

The second category of independent variables that affect the growth rate of employment subcenters is proximity to the CBD and other subcenters will also be measured by distance.

- *Distance to the Dallas traditional CBD*: this variable will be measured from the midpoint of a subcenter to the midpoint of the Dallas CBD.

- *Distance to the Fort Worth Traditional CBD:* this variable will be measured from midpoint of a subcenter to midpoint of the Fort Worth CBD.
- *Distance to all other subcenters:* this variable will be measured from the midpoint of a subcenter to midpoint of all other subcenters CBD.

This study expects the estimated coefficient of the distance to the Dallas traditional CBD, to the Fort Worth Traditional CBD, and from a subcenter to all other subcenters to be significant and consistently negative.

The third category of independent variables that is believed to affect the change in size of subcenters is site-specific characteristics. This category includes both a site's degree of slope and whether it's located in floodplain or not. For example, some sites maybe swampy and ill-suited for employment, increasing the cost of construction, while others are level and clear, reducing the costs of construction. Possible examples could include:

- The slope in percentage within a subcenter, where higher percentage is expected to cause higher construction cost, which negatively influences the decision to locate in subcenters with high slope percentage, consequently, negatively affects the growth rate of that subcenter.
- If a large proportion of the subcenter is located in a floodplain, then the site considered ill-suited for construction and development and will negatively affect the growth rate of a subcenter.

The fourth category is local government policies such as, tax incentives, relaxing development restrictions, and whether the local government has economic development plans or not. Such variables can be included as dummy variables. Possible examples could include:

- If a subcenter is located within the boundary of a local government that offers tax incentives to firms, then the growth rate will be affected positively.
- If a subcenter is located within the boundary of a local government that relaxes development restrictions, then the growth rate will be affected positively.
- If the local government has economic development plans that facilitate the development of firms or attract them, then the growth rate will be affected positively.

The first two categories include variables that are measured using the distance miles. It is believed that a major part of the variation in the dependent variable is explained by such variables. Therefore, measuring the distance miles is given a special attention in this study and is measured using two techniques. The first is a straight line technique between two points, a conventional technique presented in the literature review; and the second is a shortest route technique, which refers to the shortest distance between two points following the transportation network. Both techniques are tested statistically and compared for better fit of the data in the DFW metropolitan area. Nevertheless, the second is believed to be a more accurate measure and hypothesized to

better explain the variation of the dependent variables, the change in size of employment subcenters. The real route technique is a unique contribution of this study and has not been used in such context in similar studies. As such, this is believed to be an important contribution.

### 3.2 Data and Units for Analysis

The geographical unit of analysis used in this study to identify and analyze employment subcenters is Traffic Survey Zone (TSZ). It is generally aggregation of census block groups and is the finest grain available zone with the required information to adequately identify employment subcenters. There are over six thousand TSZs in the DFW metropolitan region. Spatial raw data sets at a TSZ level covering the DFW metropolitan area was obtained from the North Central Texas Council of Governments (NCTCOG) for three available points of time (1995, 1999 and 2005) and was used to analyze the variation in growth rates of employment subcenters. Employment gross density is used to measure the concentration of employment in these zones.

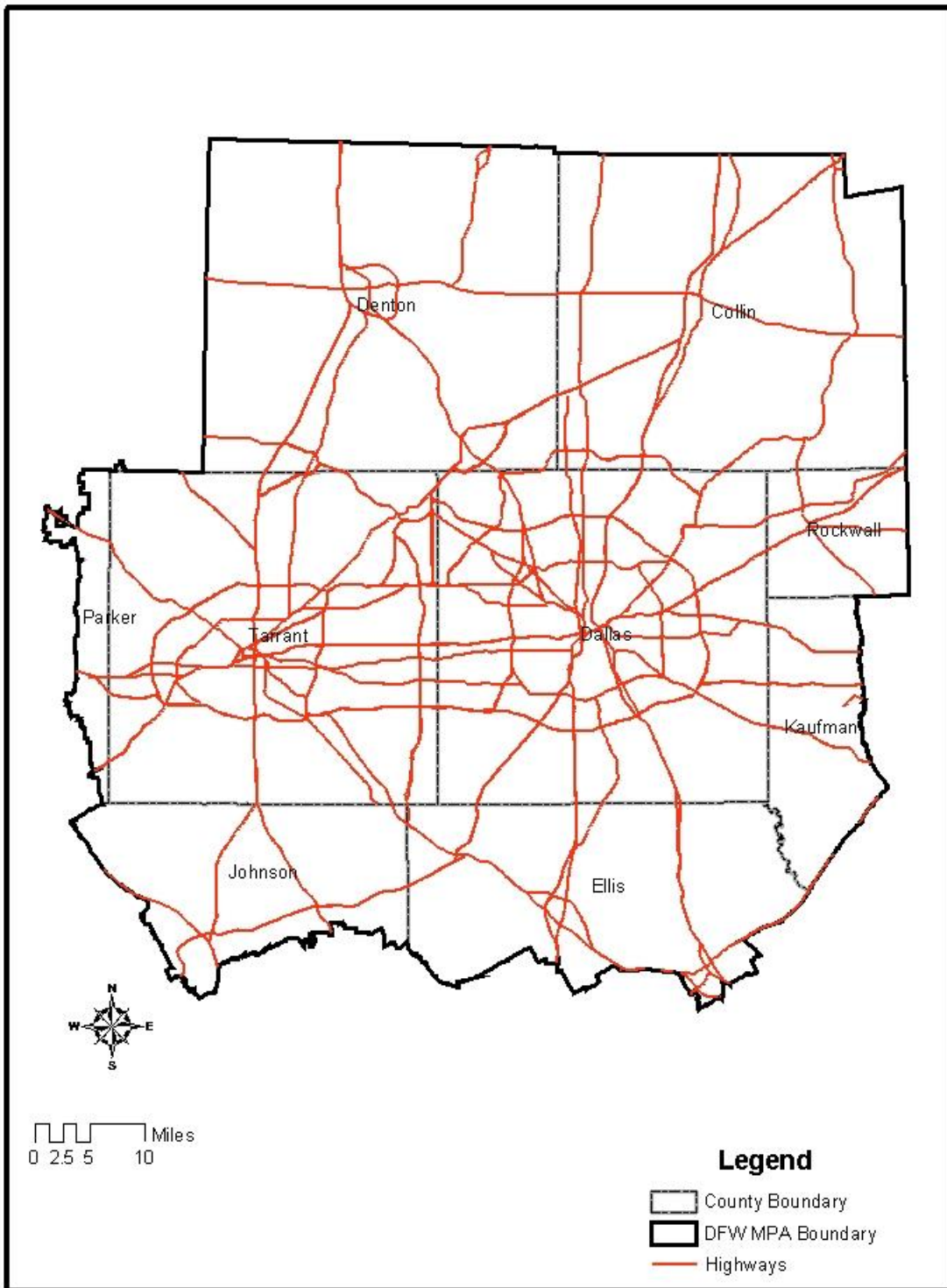
All base maps and deferent data layers including Metropolitan Planning Area (MPA) boundary, county boundary, city boundary, highways, airports, floodplain maps, and most important the base map dividing the Metroplex into TSZs for the years 1995, 1999, and 2005, are all obtained from the North Central Texas Council of Government (NCTCOG) as shape files compatible with ArcGIS software. Topographical maps for the purpose of slope calculations were obtained from the Texas Natural Resources Information System (TNRIS). The data, then, was analyzed using ArcGIS to get employment densities and identify employment subcenters.

### 3.3 The Study Area

The DFW metropolitan planning area (MPA) is currently the fastest growing major metropolitan area in the nation, with a population growth rate of 29 percent between 1990 and 2000, which is twice the national average (NCTCOG, 2005). Its size moved up in rank from number 9 in 1990 to number 4 in 2006 among United States metropolitan areas, with total population of 6,003,967 according to July 2006 estimates (U.S. Census Bureau, 2006), and according to NCTCOG estimates of 2007 its current total employment is about 3.6 million.

Rapid employment and population growth are expected to continue, with more than 9 million residents and 5.4 million jobs expected by the year 2030 (NCTCOG, 2007). However, the effects of such fast growth on its spatial urban structure, including population and employment distribution and existing and newly emerged employment subcenters remains uninvestigated. This empirical research will investigate the change in size of employment subcenters, and the factors contributing to this change.

Map 3.1 shows the boundary of the DFW MPA, also, shows that it consists of nine counties: Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, and Tarrant (NCTCOG, 2005). A distinct character of the DFW urban area is that it has a fast growth rate. Moreover, it has two major downtown areas, the city of Dallas downtown and the city of Fort Worth downtown, which makes the metropolitan area a unique case study.



Map 3.1 DFW Metropolitan Planning Area



A distinct character of the area is its transportation network. While Los Angeles metropolitan area has grid type highway network, Dallas-Fort Worth metropolitan area has hub-and-spoke type of highway network which provides a unique configuration to this urban area, considering its two main centers (Map 3.1). Furthermore, in contrast to metropolitan areas, such as Chicago, it depends heavily on highways and less on public transportation.

### 3.4 The identification of employment subcenters

The first step identifies employment subcenters, using the systematic identification procedure of employment subcenters introduced by Giuliano and Small (1991), later modified by Bogart and Ferry (1999). The algorithms used by both are summarized in the following two tables respectively.

Table 3.1 Identifying employment centers: Giuliano and Small (1991)

1.	Choose density and employment minima. These are referred to as $\Phi$ and $\xi$ respectively.
2.	Identify all TAZs that equal or exceed employment density $\Phi$ .
3.	All TAZs identified in step 2 that are adjacent are combined.
4.	Gross employment for the multiple-TAZ groups and for the single-TAZ groups identified in step 2 are totaled. Groups of TAZs or single TAZs that have total employment equaling or exceeding $\xi$ are considered “employment centers”.

Table 3.2 Identifying employment centers: Bogart and Ferry (1999)

1.	Choose density and employment minima. These are referred to as $\Phi$ and $\xi$ respectively.
2.	Identify all TAZs that equal or exceed employment density $\Phi$ .
3.	All TAZs identified in step 2 that are adjacent are combined.
4.	TAZs that are adjacent to the TAZ groups identified in step 3 are combined to the groups in order of decreasing density so long as the employment density for the entire TAZ group remains greater than or equal to $\Phi$ .
5.	Gross employment for the multiple-TAZ groups and for the single-TAZ groups identified in step 2 are totaled. Groups of TAZs or single TAZs that have total employment equaling or exceeding $\xi$ are considered “employment centers”.

However, the algorithm used by Bogart and Ferry (1999) is employed in this study but with modified parameters to suite the Metroplex (Table 3.2). The parameters for total employment used by Giuliano and Small (1991) are a minimum total employment of 10,000 in Los Angeles County and lowered the cutoff to 7000 employees in surrounding counties. For the density cutoff the Bogart and Ferry (1999) used 8 employees per acre because they covered an area that had a total employment and an overall employment density less than the Los Angeles area. This study uses this lower employment density cutoff because it identifies more prospective employment subcenters in the Metroplex. Therefore, employment subcenters in the DFW area will be defined as: a contiguous set of zones, each with density equal or above 8 employees per acre that together have at least 7,000 total employments for areas out side the central core (less dense areas far from the traditional downtowns of Dallas and Fort Worth). On the other hand, a 20,000 total employment with density equal or above 20 employees per acre will be the parameters for the more dense areas at and around the central areas, including the two traditional downtowns of the area. A similar approach was used by McDonald and McMillen (1998) to identify subcenters in the more dense areas of the Chicago region.

The procedure used to identify subcenters in this study is as follows:

1. Choose density and employment minimums. These are 8 employees per acre and minimum total employment of 7,000 for less dense areas and 20 employees per acre and minimum total employment of 20,000 for the more dense area.
2. Identify all TSZs that equal or exceed employment density 8.

3. All TSZs identified in step 2 that are adjacent are combined.
4. TSZs that are adjacent to the TSZ groups identified in step 3 are combined to the groups in order of decreasing density so long as the employment density for the entire TSZ group remains greater than or equal to 8.
5. Gross employment for the multiple-TSZ groups formed in step 4 and for the single-TSZ groups identified in step 2 are totaled. Groups of TSZs (or single TSZ) that have total employment equaling or exceeding 7,000 are considered “employment subcenters”.

The above procedure produced giant continues subcenters in the high density areas, such as the Dallas downtown area and the city to the north of Dallas, such as Plano, Richardson, also, Irving and Farmers Branch. Therefore, the density for only those giant subcenters where raised to identify subcenters within these giant concentrations. The same procedure from step 2 onward will be repeated for these subcenters. The final result is identifying prospective employment subcenters in the DFW MPA.

## CHAPTER 4

### EMPLOYMENT SUBCENTERS IN THE DFW METROPOLITAN AREA: A DESCRIPTIVE ANALYSIS

This chapter is a descriptive analysis of employment subcenters in the DFW metropolitan area. It shows the number, location, total employment, density distribution and the rank order by total employment of employment subcenters. It also shows the portions of employment subcenters located in different counties and cities of the Metroplex. The chapter then characterizes the size distribution of employment subcenters using a Pareto distribution. Also, the distribution of total employment by location is considered using the Spearman rank correlation between size and proximity to the Dallas downtown. Finally, this chapter will describe the growth rates of different employment subcenters and their change in size between the years 1995, 1999, and 2005, since this is the main topic of this dissertation.

#### 4.1 Subcenters' Characteristics

The study identifies 39 employment subcenters using the procedure of Bogart and Ferry (1999) (Table 3.2). The parameters of their algorithm for gross employment density and total employment were adjusted. A minimum cutoff density of 8 employees per acre and a minimum cutoff total employment of 7,000 were primarily used to identify all possible employment subcenters. This low density cutoff produced several reasonable employment subcenters in the suburbs and areas outside the central areas of

Dallas and Tarrant Counties. However, it produced huge employment subcenters in the central area, in particular the Dallas downtown area, where the employment density is the highest in the region. For such areas, the minimum cutoff density was increased to 20 employees per acre and the minimum cutoff total employment was increased to 20,000. These parameters produced several employment subcenters rather than one huge subcenter in the Dallas downtown area (Map 4.1). This methodology was used in McDonald and McMillen (1998) study of the Chicago area. The unit of analysis used in this study to identify employment subcenters is the Traffic Survey Zone (TSZ) with 2005 employment data obtained from NCTCOG. GIS software was utilized to accomplish the identification process.

The identified 39 employment subcenters are listed in Table 4.1. They are ranked according to their total employment and named either according to their location, major mall or major employer in the subcenter. Their location is illustrated in Map 4.1. The study also provides summary statistics in Tables 4.1 and 4.2.

Table 4.1 Subcenters by Rank Order According to Total Employment in 2005

Rank	Subcenter Name	County	City	Employment	Employment Density / acre	Area / Acres
1.	Dallas Galleria Area	Dallas	Addison, Dallas, Farmers Branch, Carrollton	165,201	24	9501.39
2.	Las Colinas Area	Dallas	Irving, Coppell	139,272	23	9483.54
3.	Dallas West	Dallas	Dallas	131,864	22	7025.70
4.	Dallas Downtown	Dallas	Dallas	130,708	152	1518.28
5.	Dallas, Farmers Branch, Carrollton	Dallas	Dallas, Farmers Branch, Carrollton	96,415	11	8916.43

Table 4.1 continued

6.	Ft Worth Downtown	Tarrant	Fort Worth	83,708	106	2791.76
7.	Dallas NE	Dallas	Dallas, Richardson	69,404	20	4196.60
8.	Richardson UTD	Dallas	Richardson	57,855	26	2331.28
9.	GM Factory and Six Flags	Tarrant	Arlington, Grand Prairie	55,549	8	7031.55
10	Plano Eds	Collin	Plano, Carrollton	52,023	9	6072.06
11	Garland	Dallas	Garland, Dallas	44,819	10	4389.46
12	Dallas 75	Dallas	Dallas	42,625	21	2100.61
13	Plano2	Collin	Plano, Richardson	35,540	8	4593.83
14	Dallas Downtown N	Dallas	Dallas	34,048	25	1280.27
15	DFW	Tarrant	Eules, Grapevine, Irving	31,712	31	1567.88
16	Plano1	Collin	Plano	29,822	8	4673.86
17	Denton Downtown	Denton	Denton	28,683	8	3352.00
18	AA Training Center	Tarrant	Fort Worth	26,611	10	2250.59
19	The Parks Mall	Tarrant	Arlington	24,002	8	4003.01
20	Ft Worth NAS Base	Tarrant	Fort Worth	23,123	19	1946.01
21	Ft Worth Hulen Mall	Tarrant	Fort Worth, Benbrook	18,426	8	2433.65
22	Irving S	Dallas	Irving	18,292	8	2264.55
23	Melody Hills	Tarrant	Fort Worth, Haltom City	18,260	6	2730.30
24	UTA		Arlington	18,251	14	1986.06
25	North East Mall	Tarrant	Hurst, Richland Hills, North Richland Hills	15,920	7	2382.25
26	Dallas SW	Dallas	Dallas	15,852	10	1620.98
27	Vista Ridge Mall	Denton	Lewisville	14,700	8	1950.46
28	McKinney Downtown	Collin	McKinney	14,645	7	3419.97
29	Dallas Downtown E	Dallas	Dallas	14,210	44	235.53
30	Grapevine Mills Mall	Dallas / Tarrant	Grapevine	13,313	6	1789.25

Table 4.1 continued

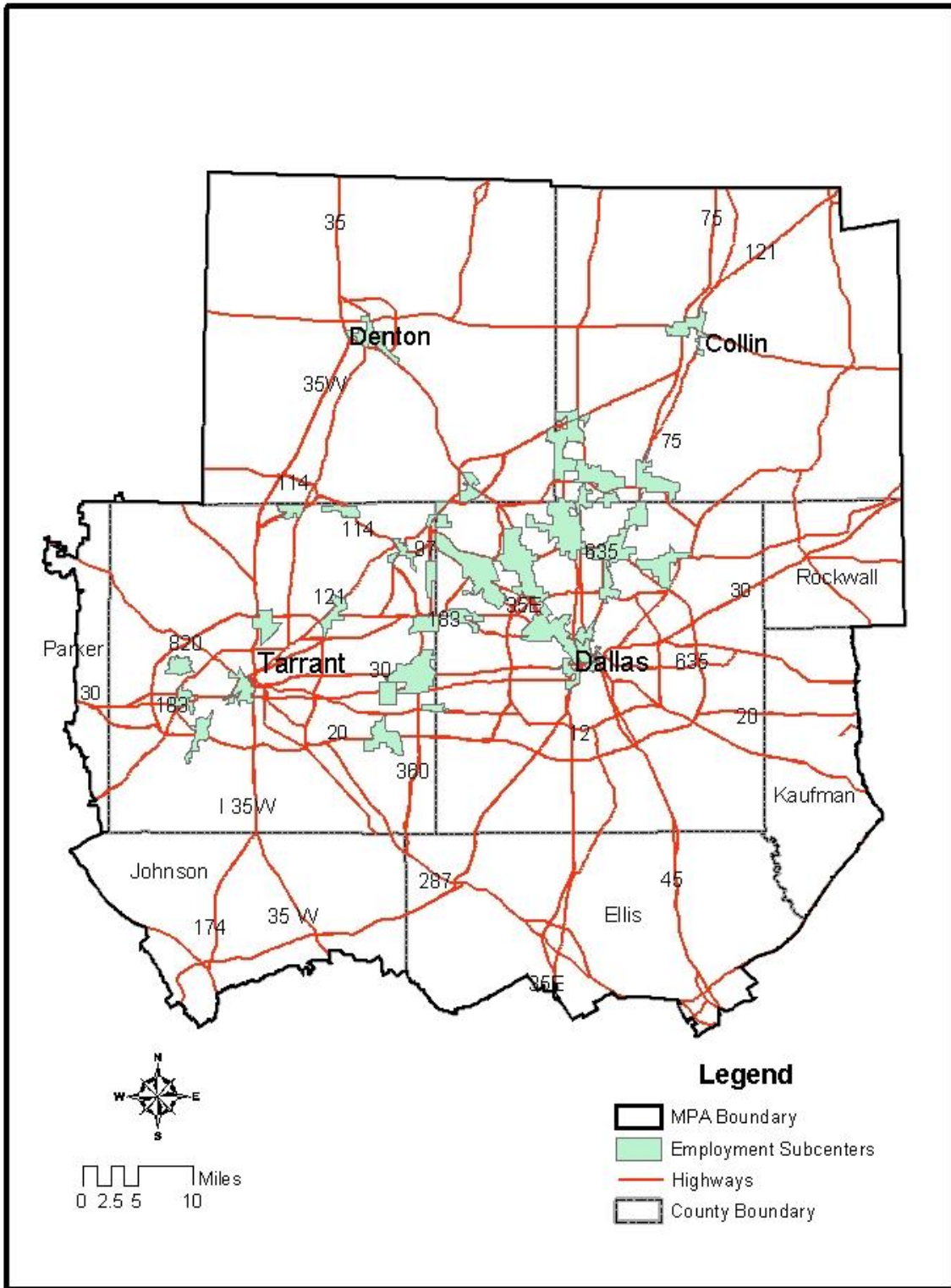
31	South Lake, West Lake	Tarrant	South Lake, West Lake	13,221	8	1639.04
32	Ridgmar Mall	Tarrant	Fort Worth	10,948	8	1713.41
33	Grapevine	Tarrant	Grapevine	10,904	6	1590.38
34	Dallas N	Collin / Dallas	Dallas	10,080	8	1369.43
35	Dallas, Richardson	Collin / Dallas	Dallas, Richardson	9,200	8	1042.67
36	Dallas Downtown S	Dallas	Dallas	8,602	16	507.13
37	Frisco	Collin	Frisco	8,547	8	1097.79
38	Ft Worth Alliance	Tarrant	Fort Worth	8,067	7	1385.21
39	Grand Prairie, Arlington	Dallas / Tarrant	Grand Prairie, Arlington	7,186	8	859.58

In 2005, the 39 employment subcenters are composed of 1,115 TSZs with a total area of 121,043.75 acre (189.13 Sq-mile) and a total employment of 1,551,608. Their area is about 4 percent of the total Metroplex, containing about half of its total employment. In 1995 and 1999 the ratio of employment in subcenters to the total employment in the Metroplex was not too far below that of 2005 (Table 4.2).

Table 4.2 Aggregate Employment and Density Within and out of Subcenters

	Employment 2005	Employment 1999	Employment 1995	Empl. Dens/Sq-Mil 2005	Empl. Dens/Sq-Mil 1999	Empl. Dens/Sq-Mil 1995
Total in Subcenter	1,551,608	1,474,698	1,276,187	8,210	7,803	6,752
Total not in Subcenters	1,620,595	1,591,109	1,361,668	339	333	285
All Zones	3,172,203	3,065,807	2,637,855	638	617	531

The total employment in subcenters increases about 18 percent from 1995 to 2005 and about 16 percent outside subcenters. This indicates that the Metroplex tends to add more employment to its subcenters. However, when the 1999 data was used, the



Map 4.1 Locations of Employment Subcenters in the DFW Area

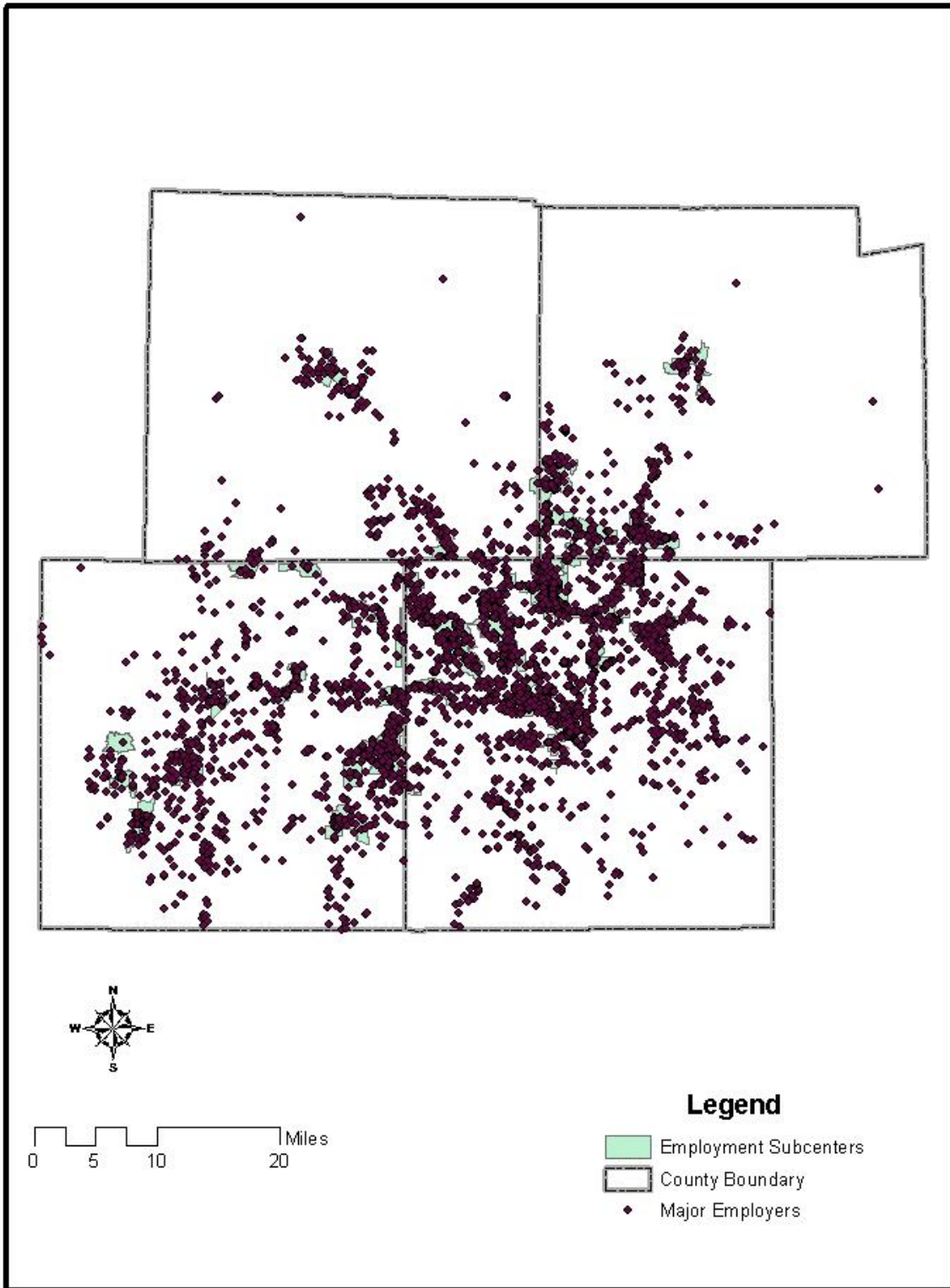


results vary. From 1995 to 1999 the growth rate of employment in subcenters was 14 percent and was about the same for areas outside subcenters. In the later period of 1999 to 2005 the growth in employment was only 5 percent, whereas for areas not in subcenters, employment increased by only 2 percent, indicating that the fast employment growth of the Metroplex is slowing down dramatically. Moreover, during this slow growth, subcenters attract more than double the employment that areas outside subcenters attract in the Metroplex. The total density inside subcenters increased about 18 percent from 1995 to 2005 and about 16 percent outside subcenters (Table 4.2).

Map 4.2 shows the distribution of major employers in the Metroplex along with the distribution of employment subcenters. It shows that the concentration of major employers closely overlaps with employment subcenters identified by the study. About 2465 out of 4535 major employers in the region, or about 54 percent of total major employers, are located within employment subcenters. This result adds credibility to the procedure used in this study to identify employment subcenters in the DFW area.

#### 4.2 Employment Subcenters in the Metroplex (Counties and Cities)

The employment subcenters are located in just four of the nine counties making up the Metroplex. The counties are Dallas, Tarrant, Collin, and Denton counties (Map 4.1). Figure 4.1 shows that Dallas County has a major share of employment subcenters, where 649 TSZs out of the 1,115 TSZs composing all employment subcenters in the Metroplex are located within its boundary. Consequently, the county has a total employment of 985,480 which is about two thirds of the overall total employment for all subcenters, and an overall density of 65 employees per acre. Tarrant County comes



Map 4.2 The Distribution of Major Employers in the Metroplex

second with a total of 343 TSZs, about half of what Dallas County has, while Collin County has only 92 TSZs. The fourth county, Denton, has only two employment subcenters and a small part of the “Plano Eds” employment subcenter all of which are composed of only 30 TSZs with a total employment of 45537, the lowest of all four counties.

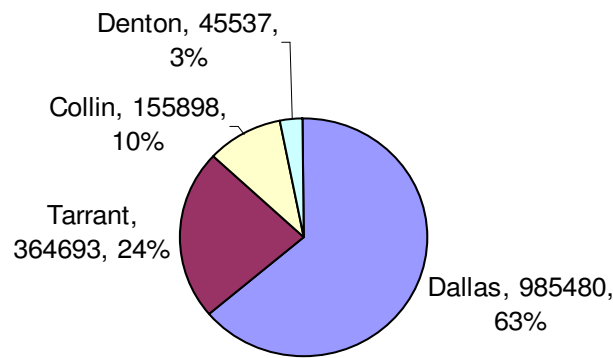


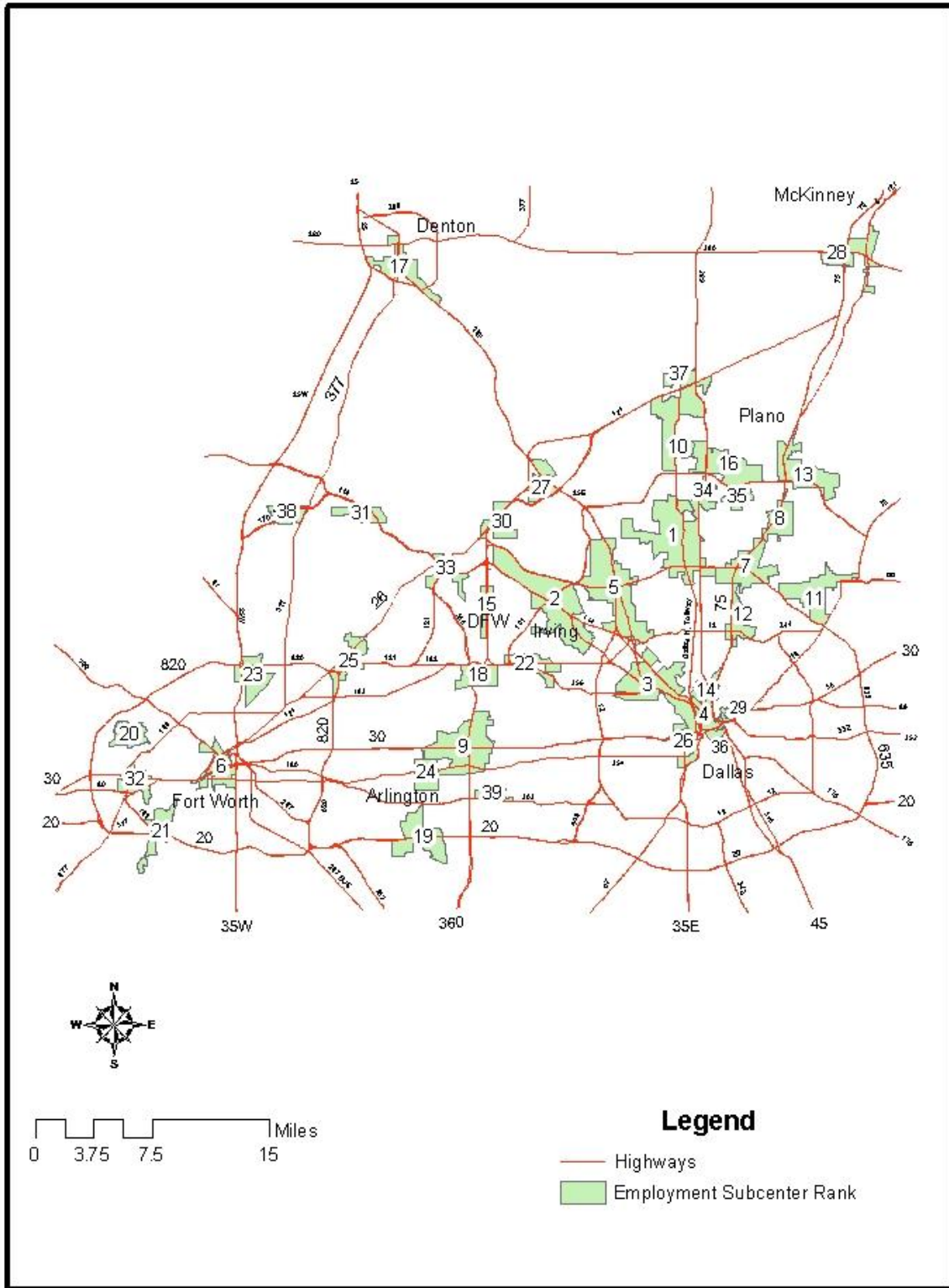
Figure 4.1 Total Subcenter Employments per County

Within the four counties, employment subcenters are located in 26 cities. A distinct character of employment subcenters, which was pointed out in the literature, is that they don’t follow political boundaries. Rather, they cluster in locations where the “attraction agglomeration economies” are strong, and in general have less concern for political boundaries between cities or counties. The results of this chapter confirm this characteristic of employment subcenters. For example, the largest subcenter is “the Dallas Galleria Area” employment subcenter with approximately 165 thousands total employment and employment density of 24 employees per acre. The subcenter is

divided between the cities of Addison, Dallas, Farmers Branch and Carrollton. Addison is completely contained by the giant subcenter while half of its area is located in the City of Dallas.

The second largest employment subcenter identified was the Las Colinas Area subcenter with a total employment of about 139 thousands and a density of 23 employees per acre. The majority of this subcenter's area is located within the city of Irving and a small part is located in the city of Coppell. The third and fourth largest subcenters, "Dallas West" and "Dallas Downtown", are completely located in the city of Dallas. Employment subcenters ranked top five by total employment tend to be located along major highways leading toward the DFW airport and the city of Dallas traditional CBD. Map 4.3 shows employment subcenters with their respective ranking numbers along with major highways in the area.

The city of Dallas not only contains the third and fourth largest employment subcenters, but it also contains approximately half of the first and the fifth largest subcenters, and completely contains seven other subcenters. The seven subcenters are "the Dallas 75" ranked 12<sup>th</sup>, "Dallas Downtown North" ranked 14<sup>th</sup>, "Dallas South West" ranked 26<sup>th</sup>, "Dallas Downtown East" ranked 29<sup>th</sup>, "Dallas North" ranked 34<sup>th</sup>, and "Dallas Downtown South" ranked 36<sup>th</sup> among employment subcenters. The city's total share of TSZs, that were part of the subcenters, is 471 TSZs with a total employment of 577,115 and an overall density of 83 employees per acre (Figure 4.2). Emphasizing its dominance, the city also includes the highest density employment subcenter in the region, the "Dallas Downtown Area" employment subcenter with a



Map 4.3 Employment Subcenter Ranked by Total Employment

density of 152 employees per acre, as well as the third highest, the “Dallas Downtown East” with a density of 44 employees per acre (Table 4.1).

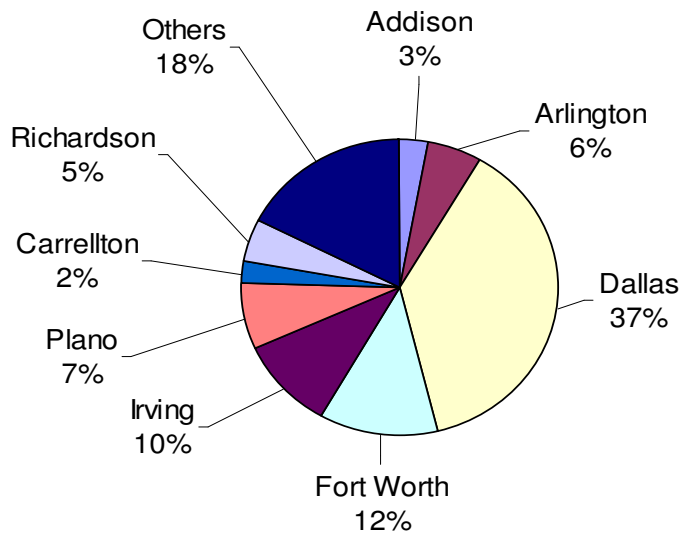


Figure 4.2 Total Subcenter Employments per City

All of the subcenters in the city of Dallas, with the exception of “Dallas 75” subcenter, tend to grow out from their central areas along highways and major arterials. The mass portion of this growth is northwest toward the Las Colinas Area and the DFW international airport employment subcenters. The growth is mainly along the primary highways of interstate 35E and central expressway and along the major arterials of 354 and 289 (Map 4.3).

The second densest and the sixth largest employment subcenter is the “Fort Worth Downtown” employment subcenter (Table 4.1). The city’s total share of TSZs that was identified as part of subcenters is 225 TSZs with a total employment of 181,276 and an overall density of 83 employees per acre (Figure 4.2). This is less than

half the number of the subcenters TSZs in the city of Dallas and about one third of its subcenter total employment. Irving contains the second largest employment subcenter, the “Las Colinas Area” and has 158,206 of the total employment of subcenters and 19 employees per acre density, comes in third place after the city of Dallas and the city of Fort Worth. Plano, Arlington, and Richardson, comes next containing 111,688, 87,533, and 73,744 of the total subcenter employment respectively.

The study characterizes the size distribution of employment subcenters in the Metroplex by fitting the following Pareto distribution, which estimates a regression relating the natural logarithm of the rank of a subcenter in terms of its total employment [ $\ln(rank)$ ] and the natural logarithm of its total employment [ $\ln(employment)$ ]:

$$\ln(rank) = 12.397 - .966 \ln(employment), R\ Square=0.933$$

Table 5.3 (0.042)

This equation shows that 93 percent of the variance in [ $\ln(rank)$ ] is explained by the size of employment in subcenters. The standard errors are given in parentheses. The correlation is significant at the 0.01 level, suggesting that the well-known rank-size rule (which asserts that rank times size is constant through the distribution) holds to a remarkably close approximation.

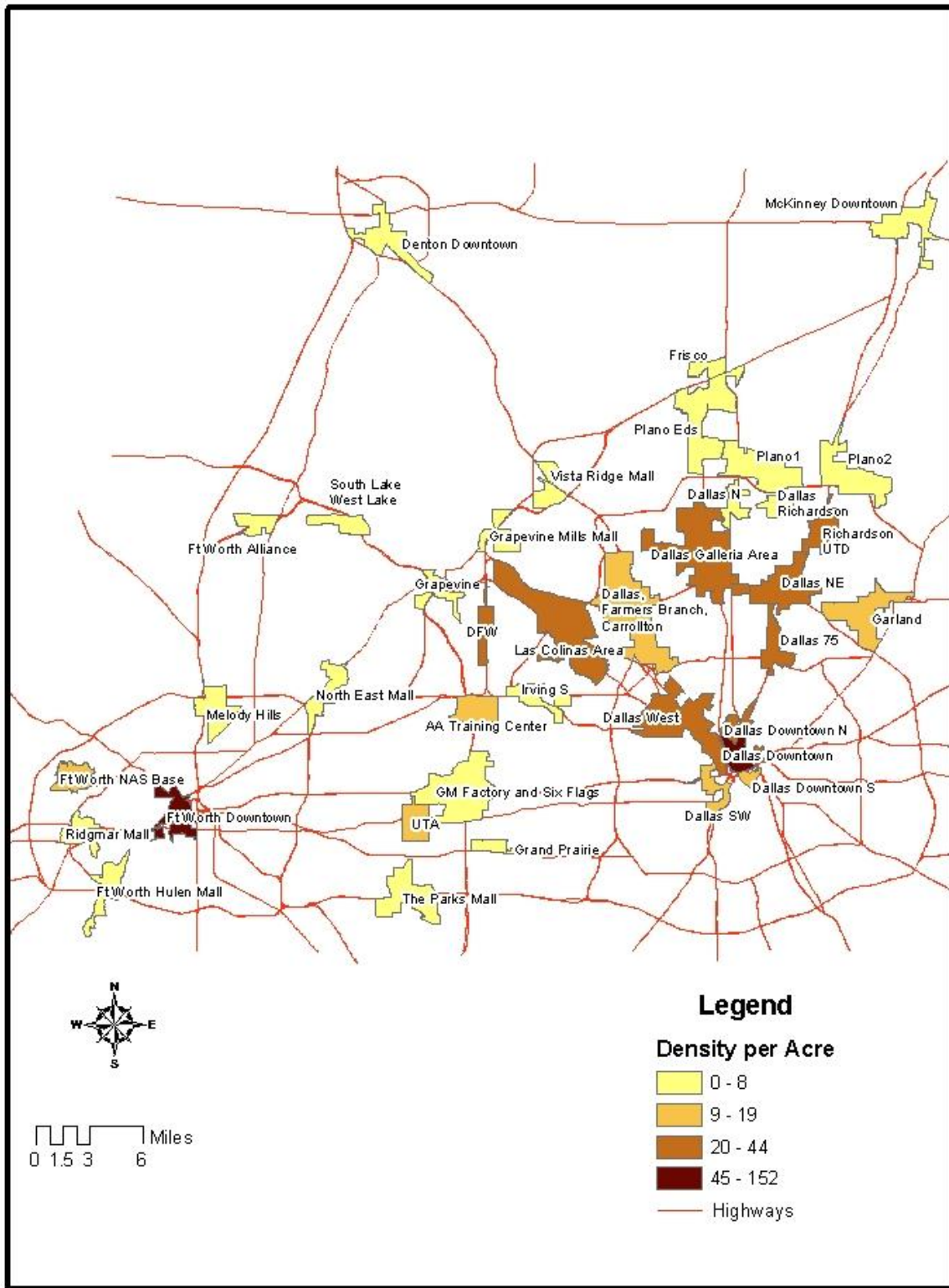
There is only a slight tendency for larger subcenters to be located close to downtown Dallas. The study uses the Spearman’s rank correlation between size and distance to the Dallas downtown, measured by highway network distance. The Spearman rank correlation coefficient is 0.30, which shows some relation but very weak. Also, it is insignificantly different from zero at a 5 percent level.

The overall density distribution of employment subcenter in the Metroplex is shown in Map 4.4. The map shows clearly, that the closer to the Dallas downtown, the higher the density. Also, it shows very high density for the two traditional CBDs in the Dallas and Fort Worth downtown areas, the first and the second highest density subcenters in the Metroplex.

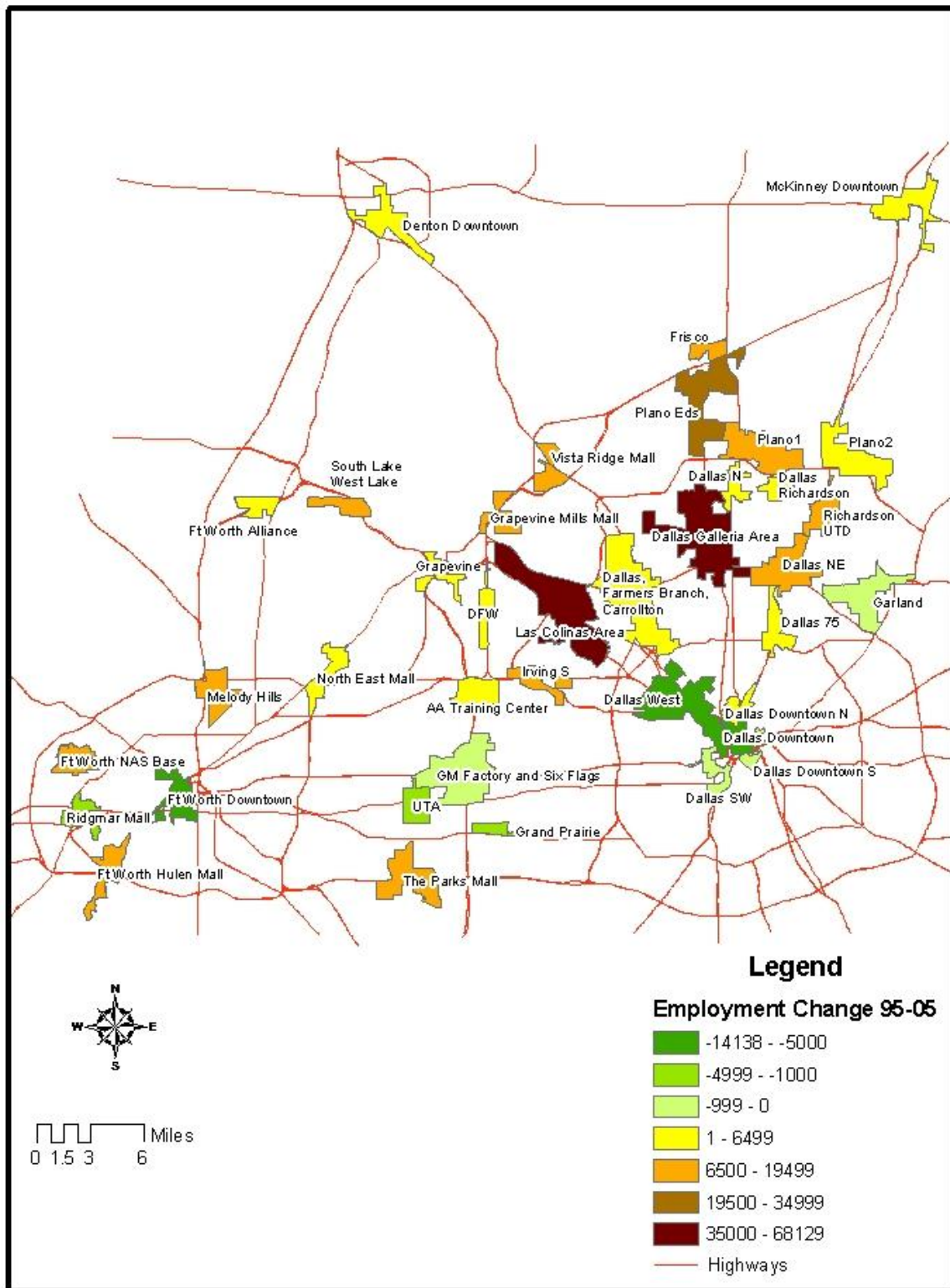
#### 4.3 The Change in Size and Growth Rate of Employment Subcenters

The change in size of employment subcenters from the years 1995 to 2005 is shown in Map 4.5. The shades of green represent the negative change or the decrease in employment, and the shades of yellow represent the increase in employment. An interesting observation is that subcenters which experience a decrease in employment are located on a long East-West axis (along interstate highway 30) from the Dallas downtown areas passing through the Arlington/UTA downtown area and the Fort Worth Downtown area ending at the Ridgmar Mall subcenter. An exception is the Garland employment subcenter, which is not too far from the Dallas downtown area. All the subcenters that experienced an increase in their total employment are located north of this axis except two mall employment subcenters, the Fort Worth Hulen Mall and the Arlington Parks Mall employment subcenters. Both are located on Interstate highway 20 south of the observed axis and away from downtown areas. The maximum decrease of employment is noticed in the Dallas West subcenter, followed by the two traditional downtown areas of Dallas and Fort Worth. In contrast, the maximum increase in employment is noticed in the Irving Las Colinas area and the Dallas Galleria area





Map 4.4 Density Distributions of Employment Subcenters



Map 4.5 Changes in Size of Employment Subcenters (1995-2005)

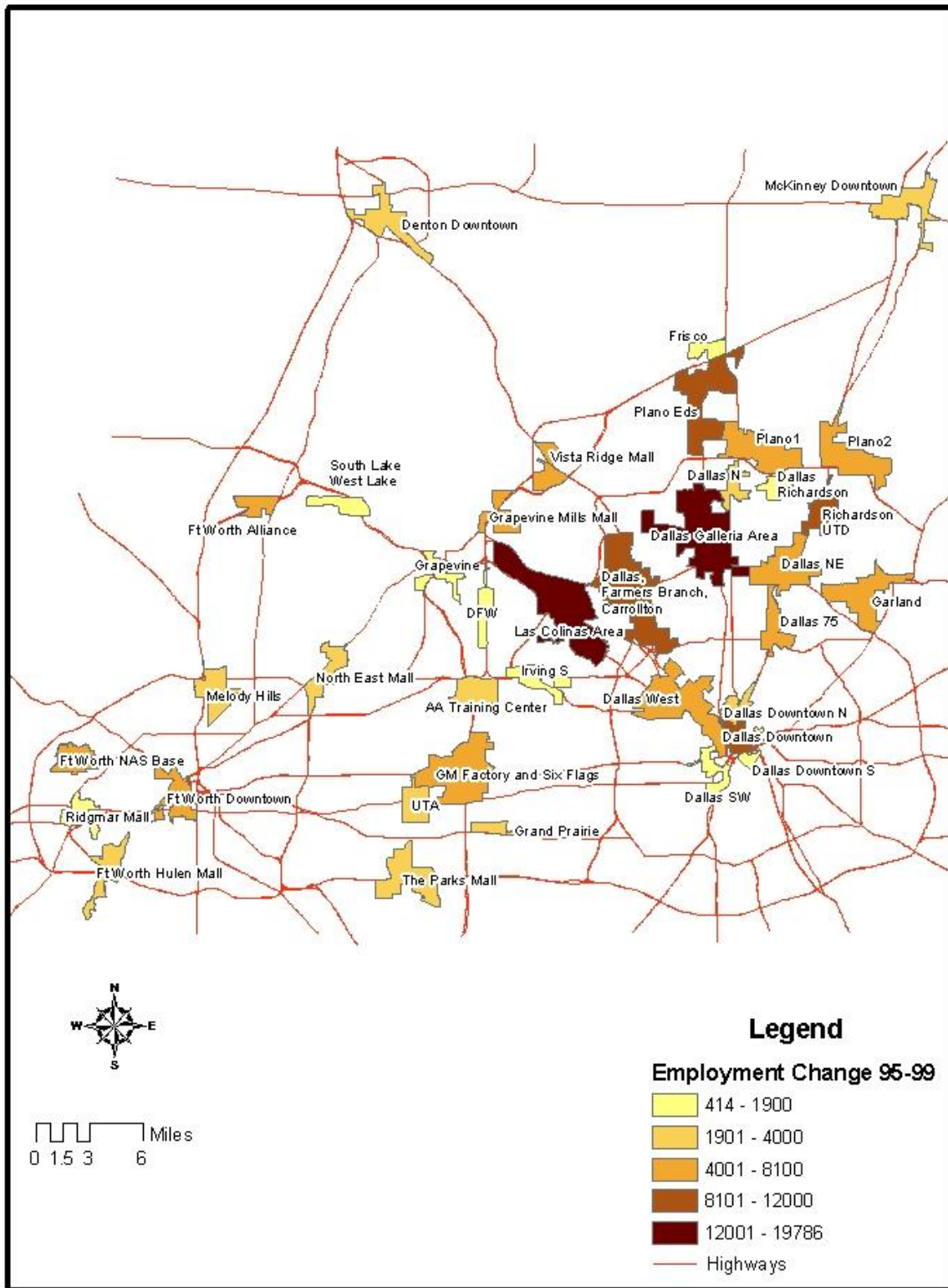
subcenters. Expectedly, these two subcenters are ranked number one and two according to their size in 2005 (Table 4.1).

The above results are observed on a 10 years period from 1995 to 2005. Using a 1999 data, this study will test to see if the same results hold true. Map 4.6 shows the change in size of subcenters from 1995 to 1999. The most striking observation is that employment increase in all subcenters in the region, even the two densest downtowns of Dallas and Fort Worth employment subcenters. The decentralization trends of metropolitan areas around the United States suggests that downtown areas losing employment constantly. Yet, during this 4 years period the Metroplex did not show negative growth for any of its subcenters, including its two downtowns.

The growth rates, on the other hand, vary among its different employment subcenters. The highest gains in employment are, once again, in the highest two ranked subcenters. The Las Colinas area and the Dallas Galleria area employment subcenters show an increase of more than 18 thousands employees between the years 1995 and 1999, about 7000 employees higher than the Richardson UTD employment subcenter the third highest subcenter regarding employment gain. The lowest gain of employment is noticed in central areas around downtown Dallas and areas to the northwest forming a corridor from these areas going through the DFW airport to the South Lake and West Lake employment subcenter. The Frisco, Ridgmar Mall, and the Dallas/Richardson employment subcenters also experience low gains of employment. They are scattered over the Metroplex and far from the observed northwest corridor.

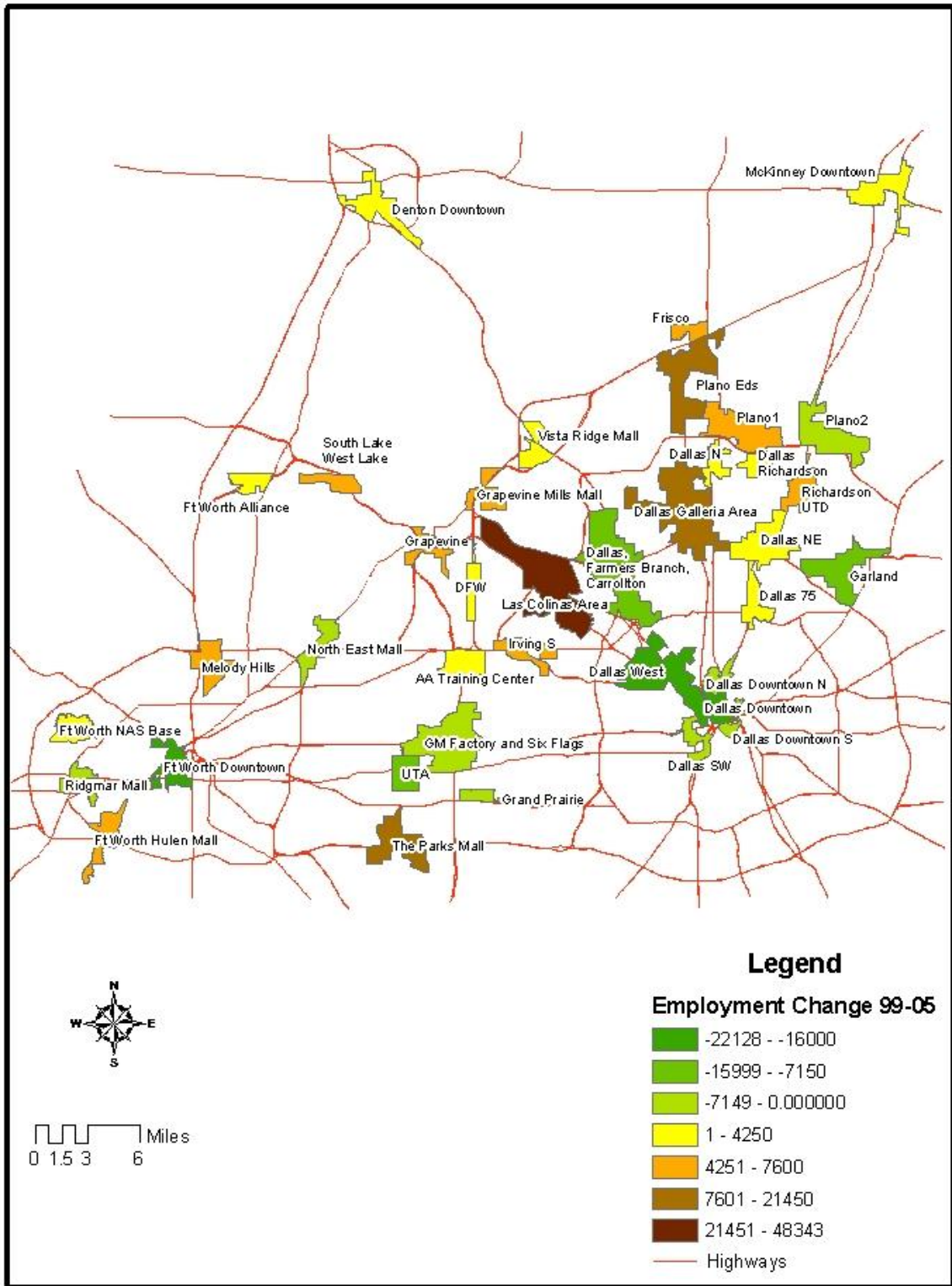
A more surprising finding is that a sharp decline in the size of many subcenters occurred during the period from 1999 to 2005. While the first half of the 10 years period from 1995 to 1999 shows a growth in the size of all subcenters, the second half shows the contrary. Map 4.7 shows the employment growth/decline in subcenters during the second period from 1999 to 2005. Similar to the legend used in Map 4.5, the green color and its shades in the legend of Map 4.7 show the decline, while the yellow and its shades show the growth in size of employment subcenters.

Predictably, the same east-west axis (along interstate highway 30) of subcenters that experience a decrease in employment in Map 4.5 appear again in Map 4.7. It is expected though, that the subcenters which experienced a decrease in employment during the 10 years period of 1995 to 2005, will appear in the period of 1999 to 2005, for the simple reason that this period is the only period in which subcenters start losing employment. The Dallas West, the Dallas and Fort Worth downtown areas are again the most subcenters to lose employment. Nonetheless, other large subcenters lose a substantial amount of employment during this period. The Dallas, Farmers Branch, Carrollton employment subcenter, which ranked fifth in total employment, the Garland employment subcenter, which ranked 11<sup>th</sup>, and the Arlington/UTA employment subcenter which ranked 24<sup>th</sup>, all lost 7 to 11 thousand employees.



Map 4.6 Changes in Size of Employment Subcenters (1995-1999)





Map 4.7 Changes in Size of Employment Subcenters (1999-2005)

#### 4.4 Summary of the Results

In summary, the descriptive analysis of employment subcenters in the DFW metropolitan area shows several interesting results. Nearly half of the region's employment occurs in subcenters that occupies only 4 percent of its total land area. This calls attention to the observation that the clustering of employment into subcenters is important to the Metroplex. The increase of total employment within employment subcenters of the Metroplex is higher than the increase of employment outside, which means that employment subcenters offer some attraction to businesses. The growth of employment subcenters is mainly towards the north and the northwest of the Dallas downtown area, along major highways and main arterials. The dominance of the city of Dallas is evident. Regardless of decreases in employment within its employment subcenters, the city still has a major share of employment in the region. Moreover, it contains the densest employment subcenter located at its traditional downtown area.

The patterns of growth and decline in a subcenter's employment are very interesting as well. When considering the period of 1995 to 2005 a decline was observed in employment subcenters along an axis from Dallas downtown to Fort Worth downtown passing through Arlington. The same axis exists when examining the period from 1999 to 2005. The decline is only shown in these two periods while the period of 1995 to 1999 shows a constant growth in all subcenters. This means that the decline in employment of subcenters only occurred during the 1999 to 2005 period.

In addition, different employment subcenters located within the same city experience completely different growth rates during the same period of time, some are

negative and others are positive. This means that while some subcenters are gaining employment, others located in the same city are losing employment. Plano, Arlington, and Fort Worth are very good examples of this (Map 4.7). The top two ranked employment subcenters in Table 4.1, the Dallas Galleria Area and the Irving Las Colinas Area, continue to have the highest growth rates in all the three periods the study considered. This is an indicator that the economic forces or the attraction agglomeration economies that these two sites offer are very strong. In contrast, The Dallas West, the Dallas downtown areas and the Fort Worth Downtown area have the sharpest decline in their total employment. Those areas are located in the densest, most crowded areas of the Metroplex, the downtown areas.



## CHAPTER 5

### EMPLOYMENT SUBCENTERS GROWTH RATE/CHANGE IN SIZE MODELS: ESTIMATES AND SIGNIFICANCE

This chapter provides information about the dependent and independent variables and estimates the significance of the explanatory variables contributing to the variation in the growth of employment subcenters.

#### 5.1 Dependent Variables

The growth is expressed either through the growth rate or the change in size of employment subcenter. The growth rates of employment subcenters are estimated separately in a multiple regression model for the periods between the years 1995 to 1999, 1999 to 2005, and 1995 to 2005. The growth rates and the change in size for employment subcenters are the dependent variables in this dissertation. The growth rate is the difference in employment from the initial year to the end year all divided by the employment in the initial year (i.e.:  $Growth\_Rate_{(1995-2005)} = \frac{E_{2005} - E_{1995}}{E_{1995}}$ ), whereas change in size is the difference in employment from the initial year to the end year (i.e.:  $E_{2005} - E_{1995}$ ). Table 5.1 shows growth rates and change in size of employment of the subcenters for the three periods under investigation.

Table 5.1 Growth Rates and Change in Size of Employment Subcenters

SUBCENTER	CH95_99	CH99_05	CH95_05	GR95_99	GR99_05	GR95_05
AA Training Center	2951	2251	5202	0.14	0.09	0.24
GM Factory and Six Flags	7060	-7140	-80	0.13	-0.11	0.00
UTA	2648	-7214	-4566	0.12	-0.28	-0.20
The Parks Mall	2108	12521	14629	0.22	1.09	1.56
DFW	1877	670	2547	0.06	0.02	0.09
Dallas 75	4010	2408	6418	0.11	0.06	0.18
Dallas N	3547	2110	5657	0.80	0.26	1.28
Dallas NE	4864	4221	9085	0.08	0.06	0.15
Dallas Galleria Area	18313	16796	35109	0.14	0.11	0.27
Dallas SW	1113	-1198	-85	0.07	-0.07	-0.01
Dallas West	7990	-22128	-14138	0.05	-0.14	-0.10
Dallas Downtown	9925	-20795	-10870	0.07	-0.14	-0.08
Dallas Downtown E	414	-702	-288	0.03	-0.05	-0.02
Dallas Downtown N	2281	-2194	87	0.07	-0.06	0.00
Dallas Downtown S	628	-1289	-661	0.07	-0.13	-0.07
Dallas, Farmers Branch, Carrollton	11245	-10247	998	0.12	-0.10	0.01
Dallas, Richardson	1626	2604	4230	0.33	0.39	0.85
Denton Downtown	2496	2594	5090	0.11	0.10	0.22
<b>Frisco</b>	<b>1508</b>	<b>6964</b>	<b>8472</b>	<b>20.11</b>	<b>4.40</b>	<b>112.96</b>
<b>Ft Worth Alliance</b>	<b>5526</b>	<b>961</b>	<b>6487</b>	<b>3.50</b>	<b>0.14</b>	<b>4.11</b>
Ft Worth Hulen Mall	2577	6077	8654	0.26	0.49	0.89
Ft Worth NAS Base	8071	1252	9323	0.58	0.06	0.68
Ridgmar Mall	1774	-3851	-2077	0.14	-0.26	-0.16
Ft Worth Downtown	5678	-16060	-10382	0.06	-0.16	-0.11
Grand Prairie, Arlington	2145	-4073	-1928	0.24	-0.36	-0.21
Grapevine	935	5015	5950	0.19	0.85	1.20
<b>Grapevine Mills Mall</b>	<b>4886</b>	<b>7111</b>	<b>11997</b>	<b>3.71</b>	<b>1.15</b>	<b>9.12</b>
Garland	6951	-7174	-223	0.15	-0.14	0.00
Las Colinas Area	19786	48343	68129	0.28	0.53	0.96
Irving S	1304	6956	8260	0.13	0.61	0.82
Vista Ridge Mall	7220	3568	10788	1.85	0.32	2.76
McKinney Downtown	2211	1806	4017	0.21	0.14	0.38

Table 5.1 Continued

Melody Hills	3946	5072	9018	0.43	0.38	0.98
Plano1	5804	6622	12426	0.33	0.29	0.71
Plano2	7374	-1163	6211	0.25	-0.03	0.21
Plano Eds	9909	21413	31322	0.48	0.70	1.51
Richardson UTD	11898	7407	19305	0.31	0.15	0.50
South Lake, West Lake	1484	7580	9064	0.36	1.34	2.18
North East Mall	2428	-184	2244	0.18	-0.01	0.16

The emboldened rows in Table 5.1 show subcenters that experience very high growth rates. Frisco employment subcenter have extremely high growth rate of 11296 percent, followed by Grapevine Mills Mall with 912 percent and the Fort Worth Alliance with 411 percent. The results, although seem surprising when first observed, are nevertheless reasonable. That is because those three did not exist as employment subcenters in the initial year 1995, but emerged before the end year 2005, the year that subcenters were identified. In the year 1995, Frisco had only 75 total employment in the area identified as subcenter in the year 2005, while Grapevine Mills Mall had 1316 and Fort Worth Alliance had 1580 total employment. This explains the extremely high growth rates of those subcenters from 1995 to 2005.

### 5.2 Variables' Explanation and Statistics

A descriptive analysis of the dependent variables and the independent variables are shown in Table 5.2. The table shows that the growth rate between the years 1995 and 1999 is about 3 times the growth rate between 1999 and 2005. This is Similar to the change in size of employment subcenters for the same time period. The maximum growth rate was about 11296 percent at the Frisco employment center between the years 1995 and 2005, while the minimum growth rate decreased by about 36 percent at the

Grand Prairie-Arlington employment subcenter between the years 1999 and 2005. Table 5.2 also shows statistics about the explanatory variables.

Table 5.2 Statistics for Each Dependent and Independent Variable

<b>Dependent Variable</b>	Mean	Minimum	Maximum	Standard Deviation	N
Growth Rate 95-99	0.935	0.029	20.107	3.211	39
Growth Rate 99-05	0.300	-0.362	4.399	0.774	39
Growth Rate 95-05	3.693	-0.212	112.96	17.798	39
Change in Size 95-99	5090.026	414	19786	4457.193	39
Change in Size 99-05	1972.051	-22128	48343	11345.932	39
Change in Size 95-05	7062.077	-14138	68129	13590.652	39
<b>Independent Variables</b>					
Inv_Dist_Hgwy	4.286	1.399	8.206	1.790	39
Inv_Dist_Hgwy_Real	4.844	1.633	9.765	1.873	39
Dist_DFW	14.789	3.215	32.406	7.640	38
Dist_DFW_Real	18.529	4.745	37.289	9.022	38
Dist_LFD	15.128	2.244	34.867	9.611	39
Public_Trans	Dummy Variable				39
Dist_DAL_CBD	17.115	1.147	37.071	10.871	38
Dist_DAL_CBD_Real	18.661	1.515	43.420	12.070	38
Dist_FTW_CBD	47.676	4.534	188.525	53.823	38
Dist_FTW_CBD_Real	28.959	5.528	57.985	14.713	38
Inv_Dist_Sub	2.979	1.361	4.779	0.865	38
Inv_Dist_Sub_Real	2.480	1.178	4.307	0.795	38
Dist_Nearest_Sub	3.995	1.147	16.453	3.402	39
Dist_Nearest_Sub_Real	4.899	0.857	18.134	3.840	39
Mean_Slope %	2.254	0.931	4.519	0.932	39
Max_Slope %	15.855	3.303	36.664	7.571	39
Flood_Por	0.104	0.000	0.658	0.155	39

The variables will be briefly discussed in this section. The next few paragraphs provide an explanation of how these independent variables are measured. The variables are divided into three categories, accessibility variables, proximity variables, and site-specific characteristic variables. Table 5.3 is as a quick reference that highlights all the variables, including their description.

Table 5.3 Summary Information for Explanatory Variables

Variable Abbreviation	Description
<b>Accessibility Variables</b>	
Inv_Dist_Hgwy	Inverse distance to highway interchanges

Table 5.3 Continued

Inv_Dist_Hgwy_Real	Inverse distance to highway interchanges following highway network
Dist_DFW	Distance to the DFW international airport
Dist_DFW_Real	Distance to the DFW international airport following highway network
Dist_LFD	Distance to Dallas Love Field Domestic Airport
Public_Trans	Whether a subcenter is served with public transportation
<b>Proximity Variables</b>	
Dist_DAL_CBD	Distance to the Dallas traditional CBD
Dist_DAL_CBD_Real	Distance to the Dallas traditional CBD following highway network
Dist_FTW_CBD	Distance to the Fort Worth traditional CBD
Dist_FTW_CBD_Real	Distance to the Fort Worth traditional CBD following highway network
Inv_Dist_Sub	Inverse distance to all other subcenters
Inv_Dist_Sub_Real	Inverse distance to all other subcenters following highway network
Dist_Nearest_Sub	Distance to the nearest subcenters
Dist_Nearest_Sub_Real	Distance to the nearest subcenters following highway network
<b>Site-Specific Characteristics</b>	
Mean_Slope %	The mean of the slope percent in subcenter
Flood_Por	The proportion of subcenter in a floodplain

DFW metropolitan area has an extensive highway system, and access to highways is valued by both business and homeowners. Thus, to measure the effect of access to highways, the sum of the inverse distance in miles from the midpoint of a subcenter to all highway interchanges is included as an explanatory variable. Distances are entered in inverse form because the effects of these interchanges are expected to decline quickly with distance. For each of the subcenters, the value entered is  $(d_{Highway} = \sum 1/d_{highway})$ . This research follows similar studies in this regard, such as McDonald and McMillen (1998).

Another accessibility variable of a subcenter in the Metroplex is its distances from the DFW international airport and the Dallas Love Field domestic airport. According to literature, statistical tests suggest that higher order terms are unnecessary for this variable (McDonald & McMillen, 1998). The variable is simply entered as distance in miles from the midpoint of the employment subcenter to the midpoint of the airport.

The last accessibility variable is measured through access to public transportation (e.g.: bus routes, light rail, subways, etc.). The Metroplex has buses and light rail modes of public transportation and access to these facilities is valued by both businesses and workers. The variable is entered as a dummy variable coded 1 if the subcenter is served by any mode of public transportation and coded 0 if not served.

The second group of variables is categorized as proximity variables. The effects of proximity to other subcenters, as an explanatory variable, are measured by distance. Similar to highway interchanges, the sum of distance in miles from the midpoint of a subcenter to the midpoints of all other subcenters is entered in inverse form because their effect is expected to decline quickly with distance. Two approaches were taken to measure the effects of subcenters' proximity. The first, similar to measuring the highway interchanges effects, is ( $d_{Subcenter} = \sum 1/d_{subcenter}$ ). The second is entered as the distance in miles from the midpoint of a subcenter to the midpoint of the nearest subcenter. The use of inverse form here is unnecessary because the distance is measured only to one subcenter, the nearest employment subcenter.

The central core of the city of Dallas shows dominance over the metropolitan area, as shown in the results of chapter four. Dallas and Fort Worth CBD areas are both the highest density employment subcenters in the area. Their effect is evident in the overall urban form of the Metroplex where highway spoke and hub distribution surrounds these two cores. In urban economic literature, a third order term proved necessary to suitably account for the effects of CBDs on employment density in U.S. metropolitan areas. In this study a third order term is unnecessary because the study is not measuring density that declines fast with distance, instead it is concerned with the growth rates of subcenters. Therefore, the distance in miles to the Dallas and Fort Worth CBDs is entered in the model as distance miles without multiplication.

Due to the intensive use of distance as explanatory variables in this study, two approaches are taken in modeling the effects of distances for the accessibility and the proximity variables. The first approach is a straight line measurement and the second is the shortest route approach, which refers to the shortest distance between two points following the transportation network. The latter is believed to give a more accurate measure for variables including distance measurements.

The site-specific characteristic effect is measured using two variables. The first variable is the steepness of slope and is entered as the subcenter's average slope in percent. As an alternative approach, the subcenter's maximum slope in percent is also entered since averaging slope will mask the steep areas. The slope information was obtained from TNRIS web site. Data files are available for download as elevation contours. Several files at a 30 square-meter accuracy level are needed to cover the

Metroplex. Using ArcGIS the files were converted to Grid and joined together to give slope information in percent for the entire metropolitan area. Then, the employment subcenters' layer was imported to ArcGIS. The slope layer then was overlaid on top of the subcenters' layer to begin the process of extracting slopes information for each subcenter. Then the zonal statistics command was used for the extraction of slopes' information, under the spatial analyst tool in ArcGIS. This resulted in slope information for every 30 square-meter zone within each employment subcenter. The output table gives statistics such as average, minimum, maximum, and standard deviation of slopes in percent for all the 30 square-meter zones (about 30 square yards) within each employment subcenter. This study used the average and the maximum slope percent in particular as explanatory variables.

The second variable in this category is entered as a proportion of a subcenter area that overlaps a designated floodplain area. The hypothesis suggests that the higher the proportion of a subcenter that overlaps a floodplain, the lower its growth rate. Maps that show floodplain designated areas in the Metroplex are available at the NCTCOG web site as shape files that can be imported directly into ArcGIS. The floodplain map then was overlaid on top of the subcenters' map in ArcGIS. Using the clip tool in ArcGIS the proportion of subcenter in floodplain was determined and is used as an explanatory variable in this study.

The fourth category, which is local government policies, is not included in the models as explanatory variables, because all of the identified subcenters are located in cities that provide tax incentives and promotional packages for attracting new



businesses. This is according to the official office of economic development’s web page. In addition to the above, the results of chapter four show that there are subcenters located within the same city that experience different growth rates. Some were negative while others were positive. Such variables need to be investigated at micro level of detail and should focus on the techniques these cities use to attract businesses.

### 5.3 The Models

Based on the above analysis of dependent and explanatory variables the study decides that the three employment subcenters, Frisco, Grapevine Mills Mall and Fort Worth Alliance are outliers, particularly Frisco. They have growth rates far above the average growth rate of the rest of the employment subcenters in the Metroplex, as was indicated in Table 5.1. All are good candidates for removal from the model for the purpose of improving overall goodness of fit.

#### *5.3.1 Regression model for Period From 1995 and 2005*

The first model run by the study uses SPSS and includes the change in size of employment subcenters from the years 1995 to 2005 as a dependent variable. Table 5.4 lists all the independent variables as well as the results.

Table 5.4 Model 1 (1995-2005) Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	5698.448	34230.445		0.166	0.869
Inv_Dist_Hgwy	-34.481	2060.091	-0.005	-0.017	0.987
Dist_DFW	-216.304	937.473	-0.107	-0.231	0.819
Dist_LFD	-2972.968	2435.287	-1.983	-1.221	0.233
Public_Trans	4549.014	6189.771	0.151	0.735	0.469
Dist_DAL_CBD	2566.256	1625.819	1.918	1.578	0.127
Dist_FTW_CBD	47.508	424.822	0.043	0.112	0.912

Table 5.4 Continued

Inv_Dist_Sub	-663.731	7647.801	-0.037	-0.087	0.932
Mean_Slope %	3300.230	2640.659	0.214	1.250	0.223
Flood_Por	-33119.085	21961.755	-0.329	-1.508	0.144
Dependent Variable: CH95_05					
N=39	R Sq = 0.34	F = 1.518	p-value = 0.194		

The analysis of variance shows that the p-value associated with the F value is greater than 0.05 and 0.10. This means that the group of independent variables does not show a statistically significant relationship with the dependent variable, and does not reliably predict it.

As was discussed in the preliminary analysis stage of this chapter, one of the subcenters, Frisco, was identified as having extremely high growth rate as an outlier. Therefore, it was decided to remove this subcenter from the analysis and rerun the model with the same variables as the first model. While the results did not improve when using the change in size as a dependent variable, the results did improve dramatically when using the growth rate as a dependent variable. Table 5.5 shows the results of this second model using the growth rate.

5.5 Model 2 (1995-2005) Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-2.751	3.686		-.746	.462
Inv_Dist_Hgwy	-.596***	.221	-.640	-2.694	.012
Dist_DFW	-.410***	.101	-1.646	-4.042	.000
Dist_LFD	.645**	.264	3.500	2.441	.022
Public_Trans	1.707**	.686	.445	2.489	.020
Dist_DAL_CBD	-.310*	.177	-1.883	-1.757	.091
Dist_FTW_CBD	.123***	.046	.884	2.704	.012
Inv_Dist_Sub	1.101	.823	.498	1.338	.193
Mean_Slope %	-.155	.283	-.082	-.547	.589

Table 5.5 Continued

Flood_Por	4.295*	2.379	.347	1.806	.083
Dependent Variable: GR95_05					
N=38	R Sq = 0.52	F = 3.000	p-value = 0.014		
*** Coefficient is significant at the 0.01 level (2-tailed).					
** Coefficient is significant at the 0.05 level (2-tailed).					
* Coefficient is significant at the 0.10 level (2-tailed).					

R-Square value indicates that 52 percent of the variance in the growth rate can be explained by the independent variables in the model. The analysis of variance shows that the p-value associated with the F value is (0.014) and less than (0.05), which means that the group of independent variables does show a statistically significant relationship with the dependent variable. Therefore, the group of independent variables does reliably predict the variation in growth rate between the years 1995 and 2005.

The regression equation for predicting the growth rate of employment subcenters during the period from 1995 to 2005 is expressed in terms of the independent variables used in Model 2 as follows:

$$\begin{aligned} \text{Predicted Growth Rate}_{(1995-2005)} = & -2.751 + (-.596)\text{Inv\_Dist\_Hgwpy} + (-.410)\text{Dist\_DFW} \\ & + (.645)\text{Dist\_LFD} + (1.707)\text{Public\_Trans} + (-.310)\text{Dist\_DAL\_CBD} + \\ & (.123)\text{Dist\_FTW\_CBD} + (1.101)\text{Inv\_Dist\_Sub} + (-.155)\text{Mean\_Slope \%} + (4.295) \\ & \text{Flood\_Por} \end{aligned}$$

The significant variables in model 2 are: Inv\_Dist\_Hgwpy, Dist\_DFW, Dist\_LFD, Public\_Trans, Dist\_DAL\_CBD, and Flood\_Por. All are significantly different from 0 at the 0.05 level, except Dist\_DAL\_CBD and Flood\_Por, which are significant at the 0.10 level. The coefficients show the amount of change in the growth

rates of employment subcenters, as the independent variable changes by one unit during the period from 1995 to 2005. The interpretation of the first significant variable, inverse distance from highways interchanges in miles (Inv\_Dist\_Hgwy) indicates that for every one mile increase in the inverse distance from highway interchanges the growth rate of employment subcenters decrease by 0.596, holding all other variables constant. This result is reasonable since the accessibility to highway interchanges is valued by businesses.

The interpretation of the second significant variable shows that one mile increase in the distance to the DFW airport will decrease the growth rate of employment subcenters by 0.410. Dist\_DAL\_CBD has a similar effect on the growth rate, where one mile increase in the distance to the Dallas CBD will decrease the Growth rate by 0.310. The interpretation of these two variables suggests that the closer an employment subcenter is to the DFW international airport and to the Dallas CBD, the higher its growth rate. In contrast, distance to the Fort Worth traditional CBD and distance to Dallas Love Field Airport seem to have an opposite effect on growth rate during the same period. One mile increase in the distance from the Fort Worth traditional CBD will increase the growth rate by 0.031 and one mile increase in the distance from Dallas Love Field Airport will increase the growth rate by 0.645.

Public transit and the proportion of subcenters located in floodplains have positive effect on the growth of employment subcenters during the period from 1995 to 2005. Interpretation of public transit variable, which is a dummy variable, shows that if the subcenter is served by public transit then the growth rate will increase by 1.707. The

findings regarding public transit are compatible with the literature review in this dissertation. However, while the study expected a negative effect for the Flood\_Por variable, instead it showed a positive effect. The direction of this variable shows that an increase in the proportion of a subcenter in a floodplain increases the growth rate.

A couple of different attempts were also made to further improve the model. At first, the study introduces the initial size of subcenters in 1995 as a new explanatory variable. The results show that the variable is not significant. Second, the mean slope in percent of a subcenter was substituted with the maximum slope in percent; again, the results show insignificance. Third, the inverse distance to other subcenters was substituted with the distance to the nearest subcenter, the result of which is also insignificant. Finally, when the mean slope in percent was removed from the model, the overall significance improved and the significance of individual explanatory variables improved slightly.

### 5.3.2 Regression model for Period From 1995 to 1999 and 1999 to 2005

Given the above results, the study decided to use the set of explanatory variables in model 2 to predict the growth rate of subcenters for the periods 1995 to 1999 and 1999 to 2005. The study also decided to keep the Frisco employment subcenter out of the prediction model, for the reasons given in the section of Model 2. Table 5.6 shows the result in a third model for the period from 1995 to 1999.

Table 5.6 Model 3 (1995-1999) Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-1.121	1.927		-.582	.566

Table 5.6 Continued

Inv_Dist_Hgwy	-.308***	.116	-.664	-2.667	.013
Dist_DFW	-.190***	.053	-1.533	-3.591	.001
Dist_LFD	.327**	.138	3.557	2.366	.026
Public_Trans	.927***	.359	.485	2.584	.016
Dist_DAL_CBD	-.164*	.092	-1.995	-1.776	.088
Dist_FTW_CBD	.058**	.024	.828	2.417	.023
Inv_Dist_Sub	.490	.430	.445	1.139	.266
Mean_Slope %	-.136	.148	-.144	-.916	.368
Flood_Por	2.508**	1.243	.406	2.017	.055
Dependent Variable: GR95_99					
N=38	R Sq = 0.47	F = 2.5	p-value = 0.035		
*** Coefficient is significant at the 0.01 level (2-tailed).					
** Coefficient is significant at the 0.05 level (2-tailed).					
* Coefficient is significant at the 0.10 level (2-tailed).					

The value of R-Square indicates that 47 percent of the variance in the growth rate (less than in Model 2 for the period 1995-2005) can be predicted from the group of independent variables used in the model. The analysis of variance shows that the p-value associated with the F value is 0.035 and less than 0.05. This means that the group of independent variables shows a statistically significant relationship with the dependent variable and reliably predicts the variation in growth rate between the years 1995 and 1999.

The same group of explanatory variables that was significant in Model 2 for the period 1995-2005 is also significant in Model 3 in that they all have the same direction affect. Proximity to highway interchanges, DFW Airport, and Dallas CBD as well as the two variables, Public\_Trans and Flood\_Por all have a positive affect on the growth rate of employment subcenters from the year 1995 to 1999. Conversely, distance to the

Dallas Love Field airport, inverse distance to other subcenters and distance to the Fort Worth CBD all have negative effects on growth rates between the years 1995 and 1999.

The regression equation for predicting the growth rate of employment subcenters during the period from 1995 to 1999, expressed in terms of the independent variables used in Model 3 is:

$$\begin{aligned} \text{Predicted Growth Rate}_{(1995-1999)} = & -1.121 + (-.308)\text{Inv\_Dist\_Hwy} + (-.190)\text{Dist\_DFW} \\ & + (.327)\text{Dist\_LFD} + (.927)\text{Public\_Trans} + (-.164)\text{Dist\_DAL\_CBD} + \\ & (.058)\text{Dist\_FTW\_CBD} + (.490)\text{Inv\_Dist\_Sub} + (-.136)\text{Mean\_Slope \%} + \\ & (2.508)\text{Flood\_Por} \end{aligned}$$

The same set of explanatory variables that was used in the two models 2 and 3 is used in a fourth model to predict the growth of subcenters for the periods 1999 to 2005.

The results of the fourth model are shown in Table 5.7.

Table 5.7 Model 4 (1999-2005) Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-.459	1.001		-.459	.650
Inv_Dist_Hwy	-.074	.060	-.325	-1.228	.231
Dist_DFW	-.067	.028	-1.104	-2.429	.023
Dist_LFD	.063	.072	1.398	.873	.391
Public_Trans	.160	.186	.171	.856	.400
Dist_DAL_CBD	-.014	.048	-.346	-.289	.775
Dist_FTW_CBD	.019	.012	.562	1.540	.136
Inv_Dist_Sub	.180	.223	.335	.805	.429
Mean_Slope %	.055	.077	.120	.720	.478
Flood_Por	.008	.646	.003	.013	.990
Dependent Variable: GR99_05					
N=38	R Sq = 0.40	F = 1.86	p-value = 0.107		
*** Coefficient is significant at the 0.01 level (2-tailed).					
** Coefficient is significant at the 0.05 level (2-tailed).					
* Coefficient is significant at the 0.10 level (2-tailed).					

The goodness of fit test of Model 4 was not significant when predicting growth rate during the period 1999 to 2005 of at the 0.05 level. It shows only one significant variable, which is the distance to the DFW airport. The approach used in the previous two models where the Frisco employment subcenter was removed in order to improve the models' significance, did not work in this model. It is worth mentioning here that the growth rates of employment subcenters during this specific period experienced a sharper decline in subcenters' employment than the previous two periods tested. This finding is shown in chapter 4.



## CHAPTER 6

### FINDINGS AND CONCLUSIONS

The growth or decline of employment subcenters in the DFW metropolitan area was discussed and analyzed thoroughly in the previous two chapters. The results of these two chapters help in solving some of the mysteries about the growth of employment subcenters. To summarize the results, the original research question will be addressed: what factors/variables contribute to employment subcenters' change in size over a specified period of time in fast growing metropolitan areas? In other words, what variables relate to the variation in growth rates of employment subcenters?

The next few sections will provide a discussion of those variables found significant in the previous chapter. Their policy and planning implications are also discussed, in addition to a summary of major findings and conclusions.

#### 6.1 Significant Variables

Explanatory variables that are proven to be statistically significant in affecting the growth rate of subcenters in the DFW metropolitan area are listed in Table 6.1 It shows the variables' abbreviation and description. The table ranks the variables according to the level of significance expressed by their correspondent p-value in Model 2, the 10 years period model.

Table 6.1 Significant Variables

Variable Abbreviation	Description	p-value
Dist_DFW	Distance to the DFW international airport	.000
Inv_Dist_Hgwy	Inverse distance to highway interchanges	.012
Public_Trans	Whether a subcenter is served with public transportation	.020
Dist_LFD	Distance to Dallas Love Field Domestic Airport	.022
Flood_Por	The proportion of subcenter in a floodplain	.083
Dist_DAL_CBD	Distance to the Dallas traditional CBD	.091

As shown in Table 6.1 one of the variable affecting the growth rates of employment subcenters in the DFW metropolitan area is the distance from the DFW International airport. The DFW international Airport affects the growth rates of employment subcenters in the area as well as the overall urban form. As shown in chapter four, the largest employment subcenters tend to be developing along major highways leading toward this airport. The Dallas Galleria and the Las Colinas Area employment subcenters, ranked first and second according to their total employment, are good examples (see Map 4.1). The distance from the DFW airport has a positive effect on the growth rate of employment subcenters indicating that the closer a subcenter is to the DFW airport, the higher its growth rate. This variable is significant at the 0.01 level. The result is compatible with the literature in this regard. Studies of other metropolitan areas, such as Los Angeles and Chicago, show the effect of major airports on employment subcenters, and their effect on urban form in polycentric metropolitan areas.

The second significant variable is the inverse distance to highway interchanges. This variable has a positive affect on the growth rate of an employment subcenter and is

significant at the 0.05 level. This means that the closer a subcenter is to highway interchanges, the higher its growth rate. Accessibility to highway interchanges is valued by both businesses and workers. This result is confirmed by other studies in the literature review.

The third variable is a dummy variable that indicated whether the subcenter is served with public transportation or not. This variable also has similar positive effect as the previous two variables and is significant at the 0.05 level. It shows that if an employment subcenter is served with public transportation then its growth rate will increase. In addition to the DFW airport and highway system, public transportation is yet another accessibility variable in the Metroplex. It increases accessibility for workers and customers of employment subcenters. Again, this is confirmed by other studies in the literature review of this dissertation.

The fourth variable in Table 6.1 is the distance to the Dallas Love Field Domestic airport. The distance to the Dallas Love Field airport has a negative effect on the growth rate of employment subcenters and is significant at the 0.05 level. In contrast, the DFW airport has a positive effect, even though they serve the same function. A major difference between the two is that the DFW airport is well served by a highway system, while the Dallas Love Field airport is not. There is also a difference in size between the two airports, Dallas Love Field airport being the smaller of the two. This might explain why the two airports have different directions in their effect on the growth rate of employment subcenters in the metropolitan area.

The proportion of subcenters in a floodplain is the fifth explanatory variable in Table 6.1, and is significant at the 0.10 level. This variable, strangely enough, has a positive affect on the growth rate of employment subcenters in the area. The hypothesis regarding this variable in this study points out that if a large proportion of the subcenter is located in a floodplain, then its growth rate will be lower. The reason for this is that the site is considered risky and needs special consideration during construction to avoid flooding, which would increase the cost of construction. This will affect the growth rate of a subcenter negatively. Yet, the variable in Model 2 shows a positive affect on the growth rate of subcenters.

The last significant variable in Table 6.1 is the distance to the Dallas CBD. This variable has a positive effect on the growth rates of subcenters and is significant at the 0.10 level. The literature agrees with this result, where urban economic literature suggests that proximity to the traditional CBD in urban areas is part of the attraction agglomeration economies. It positively affects the growth rate of employment subcenters (Small and Song, 1994).

## 6.2 Policy and Planning Implications

Improving subcenters' accessibility to highways, to the DFW airport, and to the Dallas CBD is necessary to increase the growth rate of employment subcenters. This can be achieved through policies that aim to improve the highway network connecting subcenters, the DFW airport, and the Dallas CBD.

In addition, the public transit system is important for increasing the growth rates of subcenters. Also, as an accessibility variable, public transit has a positive effect on

the growth of employment subcenters. Policies to improve and expand the public transportation system in the region will also help to improve the growth rates of subcenters.

The finding that faster and more efficient travel within the urban area has a positive impact on the growth rates of subcenter which in turn has important implications for future transportation policies. Policies which aim to improve the transportation network through comprehensive planning are certainly needed in U.S. metropolitan areas.

### 6.3 Other Findings

The comparison between the straight line technique and the shortest route technique, which this study used in measuring distances, did not show a large difference in explaining the growth rate of subcenters. The hypothesis regarding using the shortest route technique was that it would yield a more accurate measure which in turn increases significance. However, the results of this study show that the straight line technique does add significance to the distance variables, while using the shortest route technique does not. This might be due to the scale of the study covering the whole metropolitan area.

Also, it was observed that when comparing the results of predicting the growth rate of employment subcenters using multiple regression model for the 3 periods, the period from 1999 to 2005 did not show significant results. This period in particular experienced a sharp decline in employment for several employment subcenters, This is specially true for the two traditional CBDs of the metropolitan area, the Dallas and Fort

Worth CBDs. This implies that during a sharp decline in the growth rates of employment subcenters other factors may have played a role which has not been considered in this study.

In addition to the above, this study also contributes to the understanding of employment subcenters in a number of other aspects.

First, this study provides a descriptive analysis of employment subcenters' growth and decline for the DFW metropolitan region, based on data obtained from NCTCOG for the Metroplex. The analysis in chapter 4 provides information on the change in size of employment subcenters in the metropolitan region over a 10 year period. The descriptive analysis also provides a spatial perspective of employment subcenters in the Metroplex.

Second, this study bases its empirical structure on the bid rent model, which is a theoretical framework consistent with the traditional urban economic framework. It shows how a multiple regression model can be linked to the bid rent model in order to interpret explanatory variables of the studied phenomenon. The results of this study confirm some of the assertions of the traditional bid rent models, such as, the importance of access to the CBD among others mentioned earlier. The model structure in this study is also expanded in order to capture more factors than the traditional bid rent model.

Third, the study analyzes the employment subcenter as one integrated unit. The subcenter was first identified as a set of contiguous small zones that have high employment density, and then the boundaries between these small zones were

eliminated to create one unified employment subcenter with a defined exterior boundary. This unified subcenter is then analyzed as unified zone. Employment subcenters are treated as spatially distinct from other urban spaces in the Metroplex. In an attempt to capture the dynamic nature of urban areas, the analysis covers a time line, rather than one specific point in time.

Fourth, a detailed set of information is used in the identification process of employment subcenters matching historic data with more recent data. As far as the author knows, this is the first study that has undertaken this level of detail in the identification and analysis of employment subcenters in the DFW metropolitan area.

#### 6.4 Difficulties and Future Research

The subject of predicting the growth rate of employment subcenters is very complex and challenging to analyze. The decline of the “Dallas, Farmers Branch, Carrollton” employment subcenter is a good example of such complexity. The subcenter experience decline between the years 1999 and 2005, even though it was located between the Dallas Galleria Area subcenter and the Las Colinas Area subcenter both of which experienced high growth rates during the same time period. Research at the subcenter level, rather than at a regional level, is needed to be able to effectively characterize employment subcenters and reveal the hidden nuisances of such phenomenon.

Another concept that was emphasized by the study is the distinction between agglomeration economies (such as accessibility to transportation network) and added agglomeration economies (such as sharing infrastructure and lowering the shopping cost

for customers and the cost of face to face communication). While agglomeration economies are essential to the creation of employment subcenters, added agglomeration economies are responsible for the growth of employment subcenters. Yet, these factors are not discussed, except very briefly, in the literature.

Finally, this study tried to explain the variation in growth rate of employment subcenters in polycentric metropolitan areas. The complexity of the issue requires several separate detailed studies that when put together may explain the phenomenon better. This dissertation represents a good starting foundation for further studies on this topic.



## APPENDIX A

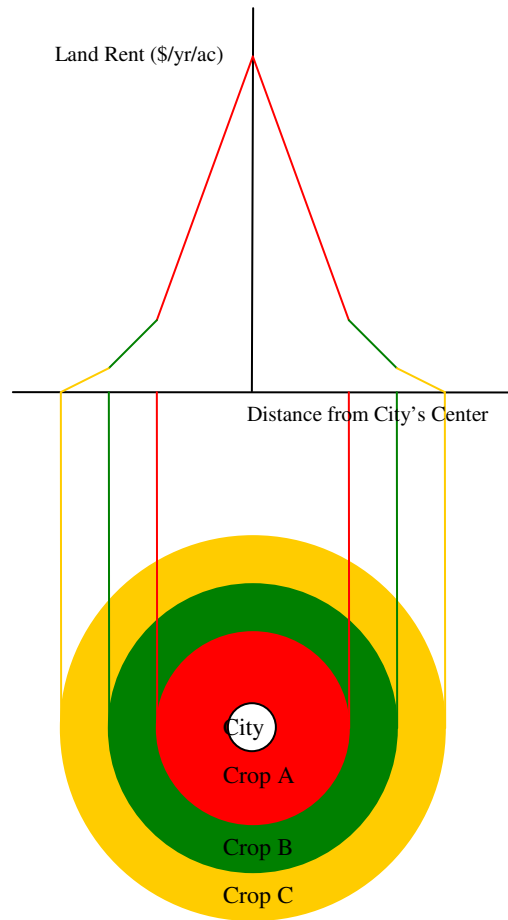
### BID RENT THEORY AND THE MONOCENTRIC CITY MODEL

The monocentric city model was built on the concept of the bid rent theory. The theory forms the foundation for the model. Introduced first by David Ricardo (1882) the theory of land rent was an attempt to explain the variation in agriculture land rent based on the concept of variation in fertility (site-specific characteristic), which make people bid more for a piece of land that is more fertile, for the simple fact that the expected production of such land is higher than less fertile lands. Farmers will bid more for a better fertile land and bid less for land with lower level of fertility. It's been assumed that access to the market is the same in all locations and only fertility matters for bid rent. The theory presents several valuable concepts such as the scarcity of goods (fixed in supply of high fertile land) and perfect competition, in addition, the user value the natural endowment of land and land rent is determined by it. Ricardo ignored the fact that land varied in location, which is addressed in the next stage of developing the bid rent theory.

Johann Von Thünen in 1886, a few years after Ricardo, sees the contrary. Location of land varies but fertility is the same everywhere. Therefore introduces a revolutionary concept that reverses the previous assumption and set the base of the contemporary monocentric city model. Von Thünen, "set for himself the problem of how to determine the most efficient spatial layout of the various crops and other land uses on his estate, and in the process developed a more general model or theory of how rural land uses should be arranged around a market town. The basic principle was that each piece of land should be devoted to the use in which it would yield the highest rent". (Hoover & Giarratani 1984, p 142-143) To explain the agriculture land use rent

pattern, Thünen's theory assumes, a flat, continuous, monocentric and homogeneous urban area, where only access to a central marketplace matter instead of fertility. He assumes that agricultural land characteristics (fertility) are the same everywhere and shipping cost as a result of distance to a central marketplace is the variable that affects bid rent. Another two more assumptions are that farmers' products are all similar in quality and the central marketplace is located in the city and surrounded by agriculture land. Consequently, farmers who produce crops that are more expensive to ship (e.g. crop A) will bid more for land close to the central marketplace than farmers who produce crops that are less expensive to ship (e.g. crop B and C). Assuming that the cost for transporting the crop of one acre of land use  $x$  a distance of one mile varies by crop, determine the agriculture land use pattern. Crop A is the most expensive to ship will be located close to the center followed by the next expensive to ship crop B then the lowest of the three crops crop C. The resulting agriculture land use patter will be as shown in figure 1. The essential insight of Thünen's theory is that as the distance increases from the center of the city, the shipping cost increase.

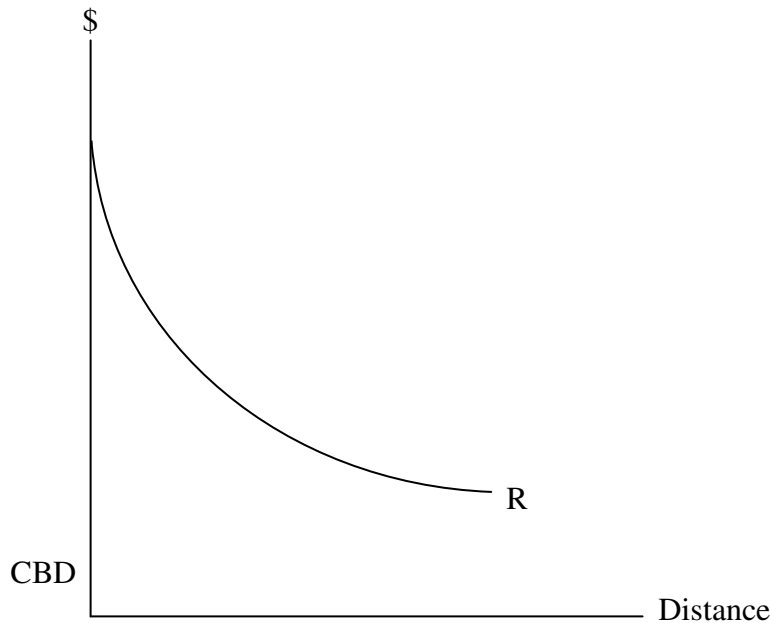
Figure 1: Von Thünen's Agriculture Land Use Pattern (Watkins, Web Page)



Based on the significant work of Thünen, Alonso (1964) extended and applied the original concepts to urban areas. Alonso is considered to introduce the formal modeling of urban spatial structure through the monocentric city model (Fujita, Krugman, & Venables, 1999). His monocentric city model was mainly to explain the population distribution in urban areas through predicting the individual behavior of households in selecting a housing location and the consequential spatial urban structure. In contrast, the firms' location selection was not investigated thoroughly in his work.

The basic concept of his work is the bid rent function for households and/or firms, as it is for the monocentric city model. The bid rent of a household is defined as the "maximum rent that can be paid for a unit of land (e.g. per acre) some distance from the city center if the household is to maintain a given level of utility " (Hoover & Giarratani 1984, p 153). The bid rent curve R of the actual land rents in the city reflects the outcome of a bidding process by which land is allocated to competing uses (residential demanded by households and commercial/ industrial demanded by firms) (Hoover & Giarratani 1999). (See Figure 2)

Figure 2: Bid rent Curve (Hoover & Giarratani 1999)



Similar to Thünen's theory, the monocentric model of Alonso assumes a flat, continuous, monocentric and homogeneous urban area. The central business district (CBD) represents the city center where households commute to work and shop. The combination of housing, distance from the CBD and all other goods stand for

satisfaction or utility of the household. Housing vary by quantity or lot size where distance reflect the commuting cost and all other goods consist of food, cloths, entertainment, etc. (Chapin & Kaiser 1979; Romanos, 1976).

The households fixed income divided among these three sectors to achieve maximum satisfaction (utility). The trade-offs among, housing, distance, and all other goods will reflect their location preferences. Housing and all other goods price is independent of each other, while housing price and distance is dependent. Commuting cost is positively related to distance from the CBD which the price of housing depend upon. This means, that the household lives farther from the CBD will pay more for commuting and eventually end up with less budget for housing. As a result, land rent decrease with distance from the CBD to compensate commuting cost.

“Based on these assumptions, the bid rent curves are downward sloping and single-valued; i.e. for a given distance from the CBD only one rent bid is associated with a given level of utility. The steepness of the slope of the bid rent curve depends on transport costs and the household’s (or the firm’s) demand for space. Steeper curves are associated with higher transport costs and/or less demand for space (hence, higher value attached to accessibility). Flatter curves are associated with lower transfer costs and/or higher demand for space (and, hence, preference for more outlying locations). Finally, lower bid rent curves are associated with greater utility as, assuming fixed budgets, at any given distance from the CBD, if a lower rent bid is accepted, more goods can be consumed” (Hoover & Giarratani 1984, p. 154).

There are limitations in Alonso's theory. A number of restrictive assumptions limit its ability to resemble reality as well as its ability to analyze the variation in land use. The two important assumptions of Alonso's model are: a single major center or CBD that is the monocentric city assumption and a considerable emphasis giving to accessibility. In addition, externalities such as: traffic congestion, air pollution, and factors such as increasing returns to scale, imperfect markets, the durability of inflexibility of the housing stock, technological change and the existence of multiple centers in urban areas were not considered in Alonso's theory (Romanos 1976, Quigley 1985, Arnott 1986, Krugman 1995, Bockstael & Irwin 1999). Nevertheless, the theory was powerful enough to be used widely in impact analysis of urban policies plus in analyzing urban spatial structure (e.g.: Bockstael & Irwin 1999).

According to Batty 1976 and Romanos 1976 the most complete analysis of residential location was introduced by Muth (1969) in his landmark model. Muth bases his analysis on the same set of assumptions of the monocentric city; the housing market, transport costs and the CBD. Although based on Alonso's approach Muth's contribution is unique because it includes: land, size of the house, and other factors of the housing price, what's called "housing services" and he considers the household's income as one the factors that determine transportation expenditure of individuals. (Romanos 1976).

The supply side was also considered in Muth's analysis of the housing market and treated land as a factor of production. "Moreover, he made a set of assumptions for the supply side of the housing market, the most important of which were:

- a. firms and households are competitive in both the product and the factor markets
- b. all firms producing a given commodity (including housing) are identical; they have the same production function and use both land and non-land inputs
- c. producers employ quantities of land and non-land inputs which maximize profits at each distance
- d. Land rents and housing services are set by the markets so that the profits of the housing service producers equal zero everywhere the services are produced” (Romanos 1976, p. 77).

The interrelation between housing density and accessibility was also examined by Muth. Also with the assumption of competitive, long run equilibrium he derived a set of capital-land relationships (Arnott, 1986). Simplicity, long-run static equilibrium character and exclusion of important qualities of housing (e.g. durability) are shortcomings of the model. However, Muth’s model of the housing market "was the first formal, general equilibrium model of the housing market, and almost all subsequent mainstream housing market theory has evolved from it" (Arnott, 1986, p. 969).

Muth assumed that the city provide enough residential land use to meet the demand of housing services. In his model the city would expand from its CBD to the extent necessary to achieve the market equilibrium; this is the open city assumption



(Straszheim 1986). For more discussion of Muth's model, see also Straszheim (1986), Brueckner (1986), Arnott (1986).

Similar to the Alonso-Muth models and based on utility maximization Mills (1967) introduced his model of residential location. In contrast to Alonso who considered only the land area occupied by a house, Mills, like Muth, considers land as an intermediate factor in the production of housing, which is the final consumption good (Brueckner, 1986). Mills (1972) dropped Alonso's assumption that all employment is concentrated at the city center and that all product is produced there. Assuming that the whole urban area is used for the production of a single commodity, with an aggregate production function, he analyzed the location of employment. Urban land, according to Mills, is composed of this urban land use and transportation, where both are competing for land. Urban land at each distance from the CBD is utilized in production and transportation to achieve equilibrium. Mills used a negative exponential form to derive the equilibrium rent-distance function, similar to that derived by Muth (Romanos, 1976).

Frequently, the literature refers to all three urban land market models as the standard or the classical model or as the Alonso-Muth-Mills model (Miyao, 1986). The reason is that all three models have common analysis basis. For example, the three: "(a) shares the same theoretical basis, (b) employs the same methodological framework of budget-constrained utility maximization to derive the relationships between land use and price of land, (c) arrives at similar bid rent functional forms (the negative

exponential), and (d) employs essentially the same mechanism for allocation of land to its users – the bidding process.” (Briassoulis, web book)

In general, the monocentric city model has several properties. These properties were discussed in Brueckner (1986) advanced treatment of the monocentric city model and were summarized by Marvin Kraus. Appendix A includes the work of Marvin Kraus describing the monocentric model through diagrammatic analysis and minimal use of mathematics. In summary, the properties of the monocentric model are:

Property 1: The rental price of housing decreases with distance from the CBD.

Property 2: Individuals who live further from the CBD have higher consumption levels of housing.

Property 3: The rental price of land decreases with distance from the CBD.

Property 4: Structural density decreases with distance from the CBD.

Property 5: Net residential density decreases with distance from the CBD.

The Alonso-Muth-Mills model has been criticized from both a philosophical and methodological aspects. The philosophical aspect points out the use of a theoretical framework that depends on utility maximizing concept, in addition to, an assumption of economic rationality in decision making. The methodological criticism, on the other hand, refers to the many, frequently unrealistic, assumptions upon which it rests. “The later refers to those made to derive equilibrium land use patterns or to perform dynamic analysis of the land market which makes it difficult to generalize the results of the analysis to urban areas with many centers of employment and other imperfections in the real market. Representative lines of criticism include:

1. the narrowly rational logic for action these models postulate at a conceptual level (deductivism) which is then transcribed unproblematically upon real world processes (Cooke 1983)
  - a. with their reliance on the concept of utility and its propensity to stimulate action, these models conceive of humans as if they exist to express the utility-maximizing quality and nothing else (Cooke 1983)
  - b. the excessive emphasis these models place on accessibility as the most important determinant of urban spatial structure and the neglect of many other determinants (see, for example, Romanos 1976, Cooke 1983)
  - c. the neglect of many important particularities of housing itself and of the neighborhood characteristics (see, for example, Arnott, 1986; Straszheim, 1986)
  - d. the assumption of a perfectly competitive land market – i.e. without imperfections such as various forms of externalities (Batty 1976, Cooke 1983)
  - e. the monocentric city assumption
  - f. the their static nature, and the assumption that location is continuously variable.” (Briassoulis, web book).

APPENDIX B

METADATA FOR GIS DATA FILES OBTAINED FROM NCTCOG'S WEBSITE

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- Spatial Data Organization Information
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## BIOGRAPHICAL INFORMATION

Maher Sayel Al-Shammari was born in Jordan in 1970 where he grew up and finished high-school. He attended the King Faisal University at Saudi Arabia for his bachelor degree and graduated in the year 1994. His degree was in Urban and Regional Planning. After graduation Maher taught in the Department of Urban and Regional Planning at the same university. Since 1996 he has been studying at the University of Texas at Arlington, where he finished his master's degree in City and Regional Planning and his PhD in Urban Planning and Public Policy. He is interested in Urban Analysis related subjects and has a passion to utilize GIS related software in this area. Al-Shammari is planning to go back to his home country to teach and share his educational experience and the knowledge he gained in the United States with his colleagues and students. He will continue his work on city planning related research, in particular, the sub-field of Urban Analysis and the applications of GIS in city and regional planning.