

## **INTRA-METROPOLITAN EMPLOYMENT DISTRIBUTION IN A NO-GROWTH SCENARIO: PITTSBURGH 2002-2012**

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**ABSTRACT.** *Delineation and analysis of employment subcenters reveals a dynamic and fluid land use situation in the Pittsburgh metropolitan area. Employment density thresholds and employment totals are analyzed at census block group level of geography. The choice of scale factor may explain results that differ from studies conducted using census tracts or traffic analysis zones—as most do. Concentration indexes reveal areas of intense development that are obscured in larger areas. Location quotients reveal dramatic change in employment structure. Subcenter delineation shows change in the roster and internal configuration of commercial agglomerations. The observed instability of urban structure is counter-intuitive for a time and place of virtually zero population change. This result is auspicious for possible natural experiments concerning non-growth aspects of employment distribution and land use.*

**Key Words:** *Employment, Land Use, Pittsburgh, Scale, Urban Structure*

### **INTRODUCTION**

The polycentric paradigm of urban structure has been a subject of analysis, modification, and debate for the last four decades (Agarwal et al. 2012). The debate concerns the nature of changes in urban structure since the mid-20<sup>th</sup> century. Most of the analysis is directed at metropolitan areas of more than 5 million people, but a medium-sized example such as Pittsburgh can test a crucial issue. Is the reorganization of urban structure one of re-centralization or decentralization? Moderate size and slow or, in the case of Pittsburgh, non-existent population growth represents a large number of cities. Economically maturity, ageing demographic profiles, and fertility rates dramatically below replacement levels continue to increase the number of such urban places, but they tend to be under-reported in the literature on urban structure.

Decentralization advocates cite the inability of subcenter delineation to capture a majority of metropolitan employment (Lang et al. 2009, Angel and Blei 2016b). Critics of the polycentric paradigm perceive edgeless development patterns where space and location have little relevance to function (Gordon and Richardson 1996). Such assessments are based on highly aggregated data often for multi-city studies. They overlook the variety of subcenter delineation techniques – discussed below – that capture a wide range of employment from 25% to 66% of metropolitan totals. Intense empirical study adds a topological aspect. In Shearmur's (2006) study, only 35.6% of Montreal's workforce commutes to an employment subcenter (pole), but another 32.7% commute toward one relative to the place of residence. This implies that local place-of-employment data reveal only part of the significance of subcenters to urban structure (Sang et al. 2011, Arribas-Bel and Sanz-Garcia 2014).

Much of the polycentricity or dispersal question is methodological, and Pittsburgh's no growth environment is a good laboratory to examine data and analysis technique. One issue is the data collection units which are tied to the evolving methodology of the United States Bureau of the Census. This is the modifiable area unit problem (MAUP) with its two distinct aspects (Horner and Murray 2002). The scale aspect of MAUP is relevant because spatially aggregated data units such as Public Use Micro-Sample (PUMS) areas or ZIP code zones dilute density values. Even census tracts and traffic analysis zones involve substantial spatial generalization. Census boundaries are pragmatic and are designed differently for different MSAs depending on the geometry of local cadastral systems and contrasts in recommendations of metropolitan planning organizations. This creates interpretation problems that must be recognized because polycentricity versus dispersal is in part a land use question (Coffey and Shearmur 2001, Sarzynski et al. 2014, Krehl and Siedentop 2019).

The second issue of method is the operational definition of polycentricity and of employment subcenters. Retail trade is not the catalytic driver of urban structure that it once was. Neither suburban nor central employment subcenters can be expected to match the functional profiles of mid-20<sup>th</sup> century CBDs. Agglomeration forces result in

specialization by selectively attracting firms in sectors with compatible needs, therefore subcenters of similar magnitude do not necessarily have the similarity of functional mix postulated by Christaller's market principle (Cervero and Wu 1997, Shearmur and Coffey 2002). Instead, subcenters develop distinct profiles with complementary functions (Leslie and O hUallachain 2006).

Empirical studies indicate that most employment activities experience agglomeration effects at some scale (Cervero 2001, Gong and Wheeler 2002). Matching agglomeration process with urban structure outcomes is difficult because the scale varies by sector of activity, and it varies a great deal. A methodological problem arises when a study selects one unit of census geography – block group, census tract, or traffic analysis zone – as the building block for sub-centers. This decision is pragmatic for analysis of an entire metropolitan area but it tends to accurately depict agglomeration effects of one group of economic sectors while obscuring the scale of activity for others. Localized case studies indicate that agglomeration can function at a very localized scale of analysis and the most useful scale varies by economic sector (D. Greene 1980, Rosenthal and Strange 2003, Storper and Venables 2004, Shearmur et al. 2007).

The Pittsburgh metropolitan area, after decades of decline, is now experiencing economic and cultural revitalization without population growth (Deitrick 2015). It experienced vigorous development of a complex variety of land uses even during the decades of significant population decline, and the trend continues. Commercial areas are conspicuous in the new landscape; as in other metropolitan areas they are subcenters of employment and focal points of issues such as economic efficiency, environmental impact, social equity, and traffic congestion (Erickson and Gentry 1985, Giuliano and Small 1999, Sarzynski et al. 2006). The study covers six counties: Allegheny which encompasses the central city and five counties with direct boundaries—Armstrong, Beaver, Butler, Washington, and Westmoreland. The six counties are not the entire Pittsburgh MSA. Fayette and Lawrence Counties are excluded because they encompass only outliers of the Urbanized Area and they are not contiguous with Allegheny County. In 2002, the six-county study area had 1,017,314 total employees, by 2012 the number was 1,092,500. Population change between 2000 to 2010 is from 2,282,443 to 2,219,679. Allegheny county dominates the 6-county reference region with 55.1% of the 2010 population and 65/1% of the 2012 employment.

The analysis proceeds as follows. First, context is established with concentration (DELTA) indexes (Lee 2007). This is done at two spatial scales—the census block and the census block group—to illustrate consistencies and discrepancies. Concentrated areas of employment are necessary to support the concept of polycentric structure—the indexes measure the degree of concentration in aggregate and across economic sectors. Second, an employment subcenter delineation technique is adapted from widely accepted methodology to address the issues of clustering that DELTA indexes do not. The selected technique is applied to data from two periods for comparative purposes. Third, location quotients compare and contrast functional specialization of the subcenters over a ten-year interval from 2002 and 2012. The fourth step is to describe development paths of subcenters according to density and sectoral criteria. The conclusion outlines hypotheses that seem, from the exploratory data analysis, to deserve more attention than they have received.

## **MATERIALS AND METHODS**

Analysis of urban structure grapples with issues of contiguity and data unit size. Many studies use transportation analysis zones (TAZ). In Allegheny County, TAZ are often identical to census tracts. Some TAZ include multiple census tracts in densely settled residential areas, but TAZ are smaller than census tracts in the CBD, in the sparsely populated suburbs, and in most of the territory of the five outer counties. For the six-county study area, there are 1,095 TAZ and 675 census tracts in 2012. Census block groups are smaller than either census tracts or TAZ: the six-county area contains 1,913 in 2002 and 1,821 in 2012. Shearmur et al. (2007) use enumeration areas (EA)—the Canadian equivalent to census block groups—to analyze Toronto, Montreal, and Vancouver. The fine spatial scale effectively distinguishes shifting employment patterns in different parts of a metropolitan area. In the 21<sup>st</sup> century, the United States block group datasets offer a richer array of variables than previously because the Longitudinal Employment Household Dataset (LEHD) survey reports at the block group and block level of spatial detail (Boschmann and Kwan 2011). It is a U.S. Census Bureau product but, unlike the decennial census or American Community Survey, is compiled from employer rather than household questionnaires. It reports three income cohorts, three age groups, and 20 employment sector categories, and the margins of error estimated by the Census Bureau are much less than those of the American Community Survey.

A concentration measure, the DELTA index, measures the degree of change in employment distribution (Duncan, Cuzzort, and Duncan 1961). This index does not reveal spatial structure, but it normalizes by area and that is important because of the size variability of data units.

$$\text{DELTA} = 0.5 * \sum^n |e_i - a_i|$$

where  $e_i$  is the block group  $i$  proportion of all employment and  $a_i$  is the block group  $i$  proportion of the total land area.

The existence of blocks or block groups with no employment may skew the results. That is why DELTA calculations are reported for all blocks and block groups, and for only those that have employment.

### **Methods of Employment Subcenter Delineation**

Numerous studies have attempted to find a universal formula for subcenter delineation. Each has been problematic in some theoretical aspect (Craig, Kolhase, and Perdue 2016). Their strength is successful identification areas of interest that must be analyzed to pursue a more comprehensive understanding of urban structure. This paper adopts an empirical strategy of subcenter delineation specific to one case and applies it as a means of temporal comparison.

Three types of methods delineate urban subcenters as concentrations of economic activity, usually based on a measure of employment. The most popular of these combines dual thresholds of employment density and total employment. Giuliano and Small (1991) study the Los Angeles metropolitan area, and their thresholds are 10 employees per acre (6,400 per square mile or 24.7 per hectare) with 10,000 total employment in contiguous traffic analysis zones (TAZ) that meet the density threshold. The 10,000 threshold is relaxed to 7,000 in the “outer” counties of Riverside, San Bernardino, and Ventura. The procedure is expedient, is consistent with concepts of agglomeration based on density, and is frequently emulated by later studies. A second type of method, the employment-resident worker ratio (E/R) reveals low-density commercial development and de-emphasizes areas of high population density. Empirical applications have used a threshold of E/R greater than 1.25 with 10,000 total workers and have captured large percentages of total metropolitan employment—66% for Los Angeles in 2000 (Forstall and Greene 1997, R. Greene 2008, Antipova and Ozdenerol 2013). This is much higher than the roughly 30% of density threshold studies. The E/R method is more direct than density measures in addressing function, but it includes areas with low values in both employment and resident population that are implausible as organizational foci of urban structure. It also excludes zones with high density of both population and employment. These tend to be in inner-city areas and may be functionally linked to the largest and most intense commercial agglomerations—thus understating their significance (R. Greene 2006). A third type of method attempts to delineate sub-centers with refinements of density gradient methods, particularly by identifying positive residuals from a monocentric model. Density is usually a ratio of employment to land area, and sub-centers are peaks relative to surrounding areas rather than to specific thresholds. This method emphasizes mathematical elegance but creates the conceptual irrationality of trying to define polycentric urban structure based on an a priori assumption of an urban center (McMillen and McDonald 1997, McMillen 2001). The method is designed to smooth employment density and work with proximity rather than contiguity. These accommodations enable a solution without local knowledge, but they obscure the real effects of abrupt land use change due to physical, legal, or social barriers (McDonald and Prather 1994, Craig and Ng 2001, McMillan and Smith 2003). Furthermore, case studies focus on Chicago and Houston—two cities whose topography is emulated relatively well by a hypothetical isotropic plain. This makes the already problematic results even more unsatisfactory for cities in settings with more physical constraints. The ‘mid-continent’ methodology is better adapted to refining density gradient theory than to development of theory about land use or agglomeration.

### **Refining the Employment Threshold Methods**

While indices based on thresholds of employment density and total have gained the widest application in empirical studies, the thresholds deduced in very large or very new MSAs are not automatically applicable elsewhere. That is why criteria established by Giuliano and Small (1991) are modified by Bogart and Ferry (1999) and Casello and Smith (2006) to study Cleveland and Philadelphia. Their method for suburban locations requires employment totals of 10,000 or more in contiguous TAZ. A core unit must have employment density of 5,000 per square mile, and contiguous units are admitted to a sub-center if they maintain the 5,000 per square mile overall density and have a minimum density of 2,000. An additional nuance divides central city subcenters at conspicuous functional barriers such as multi-lane highways, rivers, or administrative boundaries. The combined methodology is referred to here as consensus criteria because it is compiled from multiple sources.

Even at the block group level some of the units are too large for effective analysis (Figure 1). That is why the Pittsburgh CBD and other older business centers have block group densities of greater than 5,000 employees per square mile, but newer suburban agglomerations are under-represented. For 2002, ten of 21 block groups with 5,000

employees are larger than one square mile with the largest at 6.8. Eight of 21 census block groups with more than 5,000 employees do not meet the 5,000 per square mile threshold, including two in Collier and Harmer townships that don't even meet the 2,000 per square mile "add-on" criterion. Census geography delineations are closely tied to history with small meticulously delineated block groups in places that were already intensely developed at the time they were first tracted, generally in the 1940s through the 1970s. These include CBDs, other central city business districts, and older suburban shopping districts. Commercial development of the last 4 decades tends to be in large block groups that include much underdeveloped land. The temporal inconsistency of census delineations necessitates a flexible formula for subcenter definition.

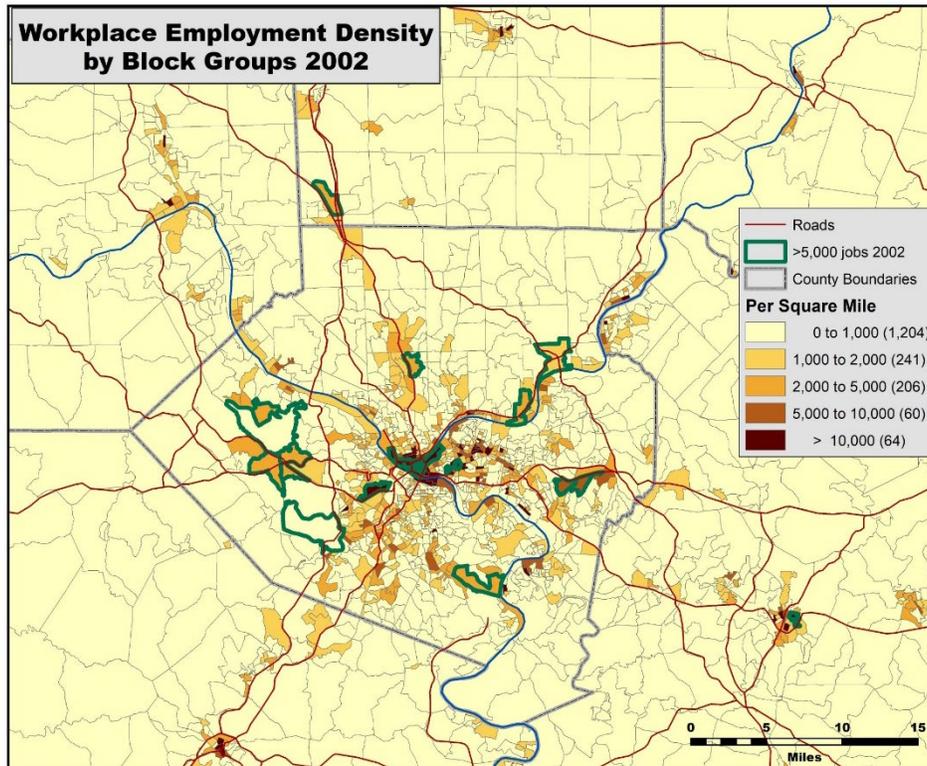


Figure 1. Workplace employment density in 2002 by census block group.

A modified version of consensus criteria involves a two-stage procedure. The first stage identifies three types of potential core areas for sub-center formation: single block groups with more than 5,000 total employees; block groups greater than .1 square mile in area with 10,000 per square mile; or contiguous block groups each with more than 2,000 total employees and density greater than 2,000 per square mile. The second stage adds contiguous block groups to a core if they exceed the density of neighboring block groups and meet one of the following criteria: 5,000 per square mile, 2,000 per square mile and add 2,000 to the core total, 2,000 per square mile and maintain subcenter density of 5,000 psm, or 2,000 per square mile and increase the overall density of the subcenter. The total area is a subcenter if it reaches the consensus criteria of 10,000 total employees. The "candidate sites" that do not attain subcenter status are also of interest, because some move to subcenter status between 2002 and 2012.

## RESULTS

From 2002 to 2012 DELTA at the block group-level declined from .7309 to .7114 for the six-county study area (Table 1). The index can be interpreted as the proportion of all jobs that must change location to create equal employment density in all block groups. The smaller units, census blocks, yield higher DELTA than block groups for both aggregated employment totals and for specific sectoral categories. Also, the sectoral category DELTA indexes are variable but consistently higher than the aggregate with only one exception—CNS 04 Construction. High values in individual block groups indicate a necessary condition for employment subcenters, but it remains for the employment threshold delineation to show their spatial organization.

### Subcenters in the Two Time Periods

Ten subcenters meet the modified consensus criteria in 2002 (Figure 2). While the focus of the investigations includes six counties, only two places outside of Allegheny County achieve subcenter status in 2002, and they are county seats that were already developed centers prior to World War II. The CBD exhibits primacy with more than double the employment total of the second largest. Oakland, in the central city, and the Airport rank second and third. Four of the Allegheny County subcenters are in the central city and four are in the suburbs. In absolute numbers of employees, the Pittsburgh CBD and other central city locations stand out with more than double the total for the suburban subcenters. Previous case studies have difficulty identifying statistically significant relationships between transportation accessibility and sub-center formation (Giuliano 1989, Giuliano and Redfean 2007, Giuliano et al. 2012). Three reasons for this are the difficulty of estimating appropriate time lags, scale issues, and uncertainty regarding the direction of causality—perhaps because it is not constant. Nevertheless, the relationship between highways and suburban subcenters is suggestive of what occurs between 2002 and 2012. The total land area within subcenters in 2002 is 39.67 square miles. Of this, 6.24 lie within the city of Pittsburgh, 29.31 fall within the suburban group, and 4.13 are within the two county-seat subcenters. Average density is 7,674 employees per square mile.

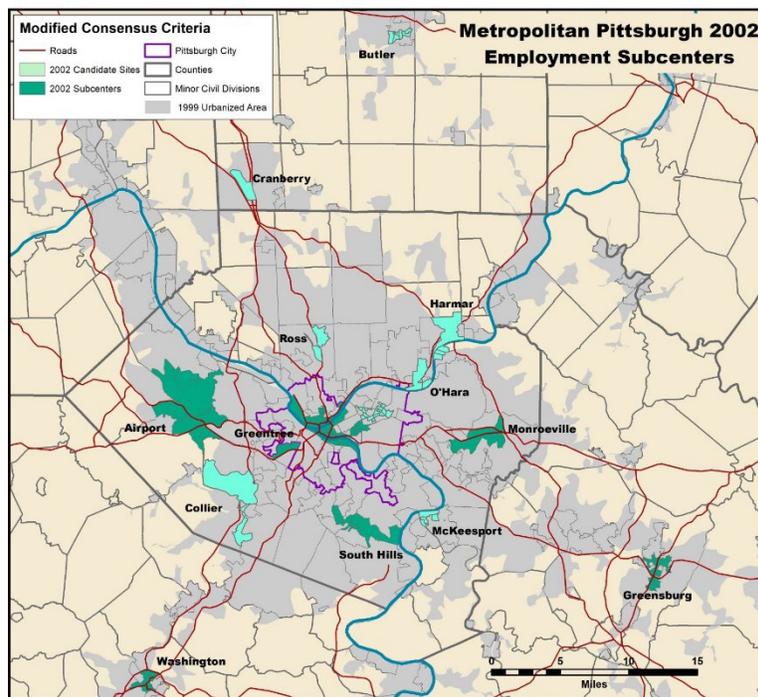


Figure 2. Metropolitan Pittsburgh employment subcenters 2002, delineated by modified consensus criteria of the density threshold method.

Central city subcenters exceed suburban ones in density in both 2002 and 2012. The exception is Greentree, but it is closer to the CBD than any other suburban subcenter. Only its political status distinguishes it from the central city subcenters. In 2002 Greentree has slightly higher density than South Side or North Side and is the third highest of all subcenters. By 2012 it drops to sixth in density rank because the central city subcenters increase, but it retains the highest density of any suburban subcenter. South Side and North Side are connected with the CBD by bridges, but the large discrepancy in density indicates that they function differently, and justifies their delineation as distinct subcenters.

For 2012, the classification identifies five central city sub-centers, five suburban ones, and two organized around county seats (Table 2). The total land area of 40.15 square miles is divided between the central city 6.21, the suburban group 31.05, and the county seats 2.89. The employee ratio of two-to-one between central city subcenters and suburban ones persists. The two county seats both shrink but still achieve threshold values. Within the City of Pittsburgh, the CBD and Oakland continue to dominate in number of employees with 90,325 and 66,050 while South Side and North Side continue to meet the thresholds. A re-configured Shadyside-East Liberty emerges from candidate

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sites of 2002. This reflects real land use change within the central city as density increases in some of the core block groups and declines in others. Much of the land use re-configuration is the result of increased employment at hospitals, partly because the hospital complexes add jobs to already high-density block groups and partly because they create demand for high income residential units in nearby locations. The Bakery Square combined retail and office complex provides an office/retail anchor in East Liberty. By simultaneously concentrating employment and increasing demand for new residential development, the process increases commercial activity in some block groups and converts commercial property to residential use in others.

Table 1. Job Totals and Concentration Indexes by Employment Sector

Employment Category	Total 2002	DELTA 2002 blocks	DELTA 2002 blocks with jobs	DELTA 2002 block groups	Total 2012	DELTA 2012 blocks with jobs	DELTA 2012 block groups
All	1017314	.8680	.7958	.7311	1092500	.7964	.7114
CNS 01	1616	.9865	.9703	.8857	807	.9723	.8544
CNS 02	4513	.9750	.9520	.8215	8710	.9529	.7859
CNS 03	7902	.9837	.9699	.9062	8891	.9786	.8929
CNS 04	53718	.8881	.8280	.7123	51034	.8370	.6753
CNS 05	108679	.9428	.9042	.7816	88152	.9122	.7516
CNS 06	44464	.9322	.8868	.7872	46422	.8889	.7616
CNS 07	132198	.9369	.8932	.7992	117437	.9090	.8045
CNS 08	45067	.9497	.9150	.8097	38826	.9222	.7735
CNS 09	24862	.9715	.9528	.9011	16829	.9621	.8952
CNS 10	51648	.9640	.9415	.8829	59938	.9438	.8696
CNS 11	14034	.9634	.9343	.8680	13486	.9402	.8364
CNS 12	64650	.9470	.9141	.8580	75893	.9115	.8342
CNS 13	20341	.9910	.9830	.9495	39897	.9686	.9162
CNS 14	56578	.9413	.9067	.8370	58883	.9112	.8119
CNS 15	85869	.9656	.9346	.8290	97854	.9421	.8255
CNS 16	138250	.9456	.9112	.8441	190899	.9018	.8132
CNS 17	14909	.9683	.9417	.8411	18943	.9521	.8454
CNS 18	80987	.9465	.9074	.8064	90006	.9164	.8134
CNS 19	39588	.9234	.8748	.7866	39185	.8737	.7543
CNS 20	27441	.9699	.9499	.8790	30458	.9490	.8742

The South Hills subcenter disappears entirely due to employment losses in retail and manufacturing. The functional anchor in 2002 was Century III mall, and this complex became mostly derelict in the following decade (Tokosh 2015). Only one store remained open in 2019, and the commercial development on nearby streets does not approach thresholds in either density or employment total (Rittenbaugh 2019).

**Temporal Shifts and Employment Sectors**

For Pittsburgh, the 2002 to 2012 interval reveals significant change including the disappearance of one subcenter and the emergence of three others (Figure 3). Overall subcenter density increases by about 10% while subcenters block groups include 29.7% of the 6-county employment total in 2002 and 31.4% in 2012. The most pervasive theme in the sectoral analysis is increasing importance of Health Care and Social Assistance (CNS16) and declining importance of Retail (CNS07) in subcenter formation and maintenance (Table 3), and this is a major factor in subcenter emergence and decline (Agarwal 2015). Specific changes by 2012 are the emergence of Cranberry Township in Butler County – immediately adjacent to Allegheny County – and the disappearance of the South Hills even from “candidate site” status. The CBD, Oakland, and the Airport persist as the big three, while East Liberty and Shadyside join the list. Thus, Allegheny County remains dominant.

Table 2. Employment Subcenters 2002 with Location Quotients Relative to the Six-County Area

Employment Subcenters	Total Employment	Areas and Densities		Largest Sector:			
		Square Miles	Density	Absolute	Location Quotient		
Airport	30880	15.91	1941	S08	10742	S08	7.85
CBD	109453	1.59	68639	S10	26531	S10	4.77
Greensburg	17193	2.45	7269	S16	4012	S20	4.43
Greentree	12117	1.06	11477	S14	2840	S14	4.21
Monroeville	23544	4.61	5108	S07	7021	S07	2.3
North Side	27734	2.57	10772	S05	3990	S03	4.33
Oakland	41371	.97	42839	S15	14944	S15	4.28
South Hills	17116	5.06	3383	S07	5832	S07	2.62
South Side	12060	1.11	10820	S16	2084	S09	2.41
Washington	12404	1.68	7400	S16	3372	S20	3.79
All subcenters	304472	39.67	7674	S16	42400	S10	2.16

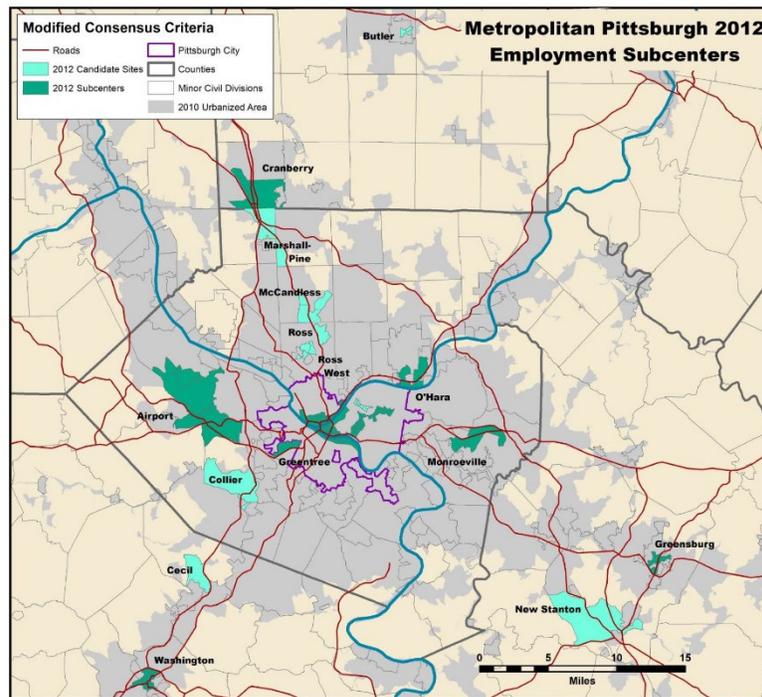


Figure 3. Metropolitan Pittsburgh employment subcenters 2012, delineated by modified consensus criteria of the density threshold method.

The largest absolute employment sector is Health Care and Social Assistance CNS16, 13.9% of subcenter employment in 2002 and 19.9% in 2012. The highest location quotient for subcenters compared to the 6-county area is Finance and Insurance (CNS10) reflecting the influence of the CBD—but it declines from 2.16 in 2002 to 1.96 in 2012. Of nine subcenters identified in both years, four have changed leading sector by absolute value, and two change leading sector by location quotient. New entries have either CNS16 or Management of Companies and Enterprises (CNS13) as leading sector. Changes in sectoral alignment are conspicuous in the second and third largest subcenters of the study area. The Airport subcenter loses a large absolute contingent in Transportation (CNS08) while increasing dramatically in total employment. This reflects the evacuation of U.S. Airways from its Pittsburgh hub, while the Airport subcenter experiences rapid diversification. In a decade that might have been a catastrophe, the subcenter

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gains 10,000 employees. The airport facility continues to serve as a catalyst for development in ways not statistically correlated to direct sectoral employment. By 2012, Retail (CNS07) is the largest absolute employer in the airport subcenter while CNS08 retains the highest location quotient. The leading absolute employment sector in Oakland changes from Education (CNS15) to CNS16 although the former continues to have the highest location quotient. The fourth largest subcenter, North Side, switches even more dramatically changing in absolute employment from Manufacturing (CNS05) to CNS16, and changing in location quotient from Utilities (CNS03) to Arts, Entertainment, and Recreation (CNS17). Adaptation is paramount to survival. Monroeville was the iconic retail agglomeration of the metropolitan area for four decades from the 1960s to the 1990s, but it clings to subcenter status despite the loss of more 2,575 retail jobs by developing a high location quotient in Administrative and Support and Waste Management Remediation (CNS14). Meanwhile another retail agglomeration, South Hills, ceases to qualify as even a “candidate site” because it fails to grow in any other sector.

Table 3. Employment Subcenters 2012 with Location Quotients Relative to the Six-County Area

Employment Subcenters	Areas and Densities			Largest Sector:			
	Total Employment	Square Miles	Density		Absolute		Location Quotient
Airport	40510	17.60	2301	S07	5986	S08	3.79
CBD	90325	1.44	62830	S10	26682	S10	5.38
Cranberry	17901	6.45	2775	S13	3175	S13	4.86
Greensburg	10092	1.12	9046	S16	4052	S20	6.16
Greentree	11800	1.05	11244	S14	3154	S14	4.96
Monroeville	16878	3.51	4804	S07	4446	S14	2.60
North Side	30506	1.73	17610	S16	8549	S17	6.97
Oakland	66050	1.04	63619	S16	25884	S15	3.84
O’Hara	15772	2.44	6476	S16	5970	S13	4.49
Shadyside/E. Liberty	15385	0.85	18082	S16	6181	S16	2.30
South Side	17569	1.15	15233	S18	2463	S09	2.24
Washington	10284	1.77	5800	S16	3578	S20	4.05
All subcenters	304472	40.15	8544	S16	68202	S10	1.96

During the decade under study, Cranberry is anchored by Westinghouse headquarters that employed 4,300 as of 2013, and subsequently closed (Olson 2013). Cranberry includes strip malls and suburban office complexes of suburban low density—no block group achieves 5,000 employees per square mile and one with total employment of 6,120 is less than 2,000 psm. While the impression of sprawl is correct, the statistical indicators are exaggerated by census delineations because intense development occurs along U.S. Highway 19, within one-half mile of the highway along intersecting arterials. The concentration of development along narrow corridors is obvious in the field but indistinguishable at census tract-level and ambiguously visible at the block group level in the census geography.

## DISCUSSION

Over a ten-year period, the six-county reference area of the Pittsburgh MSA registers a small increase in percent of employment in threshold-level subcenters. Neither this nor the slight decrease of DELTA indexes supports a trend toward a dispersed city. Despite problems inherent to the calculation, values are high enough and consistent enough to indicate the contrary. Employment is concentrated, the degree of concentration changes little, and key sectors that might be considered "command and control" functions are particularly concentrated. For the Pittsburgh MSA, sectoral change in the employment profile appears to be the major driver of change in urban structure.

The actual roster and composition of subcenters changes substantially even though their aggregate totals are similar. Numerically, results for density threshold subcenter delineation resemble previous studies. Giuliano and Redfean (2007) and Redfean (2009) note persistence of 32 out of 48 sub-centers over 20 years, this study observes persistence of 10 of 13 over ten years. Also, the percentage of total employees in sub-centers hover around 30% for both metropolitan areas. Nevertheless, there are reasons to interpret the Pittsburgh case differently. Giuliano and Redfean conclude that the system is remarkably stable while I see evidence of instability. Their interpretation may

be calibrated to an expectation of greater change over a 20-year period compared to 10 and to the fact of population growth in the Los Angeles metropolitan area. The rate of change is remarkable for Pittsburgh because it occurs in the absence of population growth. Agglomeration is not one phenomenon but many, it changes in character with technology and political circumstance, and it affects different sectors of economic activity differently (Phelps and Ozawa 2003). In its post-modern form it involves networks as well as clusters, and that form is an active contributor to the changes observed in this case study (Johansson and Quigley 2004).

The methodological innovation of this study, from census tracts or TAZ to smaller block groups produces noteworthy results. This realization leads to three empirical observations. First, suburban expansion of commercial land use is rampant despite decades of slow economic growth and population decline. A research path emphasizing the functional specializations of sub-centers, should be pursued more aggressively and with a greater variety of metropolitan cases. Second, the transportation system is intertwined with subcenter development in ways that are not transparent. Modal orientation may help to explain why nodal accessibility sometimes correlates with rapid development and sometimes does not. Third, low density employment areas should not be arbitrarily dismissed from analysis of agglomeration. Large numbers of jobs are found in areas that fall below conventional threshold densities but are still concentrations in a relative sense. This would be true using either absolute density thresholds or spatial analysis functions. Part of this is artifact of over-bounded data collection units, and part of it is a real difference in the spatial scale of new development, but further research is necessary to determine the relative significance of the two factors.

The results of this study suggest future research. The Airport subcenter indicates that between-sector attraction and aversion can influence subcenter development, but detailed investigation is left to future research. Also, it would be useful to analyze why the retail-oriented South Hills subcenter collapsed while the similarly-oriented Monroeville managed to adapt, and the data hint that inter-sectoral agglomeration may be a factor. For 2012, eight areas meet one of the core candidate requirements but fall short of the 10,000 threshold criteria. Subsequent study should focus on these candidate sites because they have implications for the process of sub-center development, evolution, and disappearance. They could also say something about the appropriate scale to analyze agglomeration effects for a variety of urban functions.

The role of sectoral change indicates that the configuration of subcenters is as much a driver of lifestyle preference as it is a product. Concentration indexes indicate that sprawl is not inevitable and high-density spatial units are common in the suburbs. Both indicators raise pragmatic questions for planning and policy, and each also has implications for theory. We do not yet have laws of network structure that explain causality in the transportation land-use connection or of land use path dependencies that explain sectoral effects on concentration, therefore we are not yet ready to develop an elegant theory of polycentric urban structure (Amedeo and Golledge 1975, Boarnet and Wang 2019). That is why more attention should be paid to research at the lower rungs of the theory-building hierarchy—specifically at analysis of the processes involved in the profound land use changes that have been and are being observed.

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