Identifying Areas of Primary Care Shortage in Urban Ohio

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ABSTRACT. This study considers both spatial and a-spatial variables in examining accessibility to primary healthcare in the three largest urban areas of Ohio (Cleveland, Columbus, and Cincinnati). Spatial access emphasizes the importance of geographic barriers between individuals and primary care physicians, while a-spatial variables include non-geographic barriers or facilitators such as age, sex, race, income, social class, education, living conditions and language skills. Population and socioeconomic data were obtained from the 2000 Census, and primary care physician data for 2008 was provided by the Ohio Medical Board. We first implemented a two-step method based on a floating catchment area using Geographic Information Systems to measure spatial accessibility in terms of 30-minute travel times. We then used principal component analysis to group various socio-demographic variables into three groups: (1) socioeconomic disadvantages, (2) living conditions, and (3) healthcare needs. Finally, spatial and a-spatial variables were integrated to identify areas with poor access to primary care in Cleveland, Columbus, and Cincinnati.

KEYWORDS. ***Geographic information systems, healthcare access, spatial accessibility, primary care shortage areas***

1. INTRODUCTION

Access to primary care is recognized as one of the most important variables in the health of the general population. The relatively low cost of primary care means that it is more easily delivered than specialty or inpatient care, and if properly distributed, is highly effective in preventing the progression of disease (Starfield, Shi, and Macinko, 2005). Adequate primary care can also reduce or prevent unnecessary specialty care (Lee, 1995; Luo, 2004). To ensure adequate access to primary health services, policy makers require an accurate and reliable means of measuring access. Such measures can identify shortages in primary care to enable the allocation of resources to areas of greatest need.

Access to primary care varies according to location, partially due to the uneven geographical distribution of primary care physicians and patients, and partially due to demographic and socioeconomic differences within the population. Access to primary care at a given location is influenced by many variables, including the availability of health services in the area, the number of people in that location, the health status of the population, the socio-economic resources available, health-related knowledge, and geographical impediments between the population and primary care services (Ady and Andersen, 1974).

Primary care access has been classified into two broad categories: spatial access and a-spatial access. Spatial access refers to the spatial separation between patients and physicians as either a barrier or facilitator to obtaining adequate health services; a-spatial access refers to non-geographic barriers or facilitators (Joseph and Philips, 1984). Researchers have addressed a wide range of issues in both categories; however, little work has been conducted into the importance of these variables in assessing primary care access. This was noted by Field (2000), who compiled a list of a-spatial variables, such as age, gender, ethnicity, educational attainment, social class, unemployment, single parenthood, house tenure, housing standards, overcrowding, and transportation access, all of which could affect primary care access. Based on these a-spatial variables, he developed an index of relative disadvantage, in which all variables were standardized according to normal distribution and then combined to produce a final composite score indicative of access.[1]

Wang and Luo (2005) took a similar approach in Illinois, but included spatial variables as well as a-spatial variables. Their a-spatial variables included demographics (age, gender, and ethnicity) as well as indicators of socioeconomic status such as percentage of the population

1. The assumption underlying Field's study is that each variable receives equal weight in obtaining the composite score. However, such an approach is problematic in that socio-demographic variables are often correlated, such that a simple aggregation of indicators may be insufficient.

in poverty, female-headed households, homeownership, and income. They even included environmental variables such as residential crowding and a lack of amenities in housing units, linguistic barriers and a lack of awareness of services and issues related to mobility such as households without vehicles. These were integrated with spatial variables to identify areas with poor access to primary care.

This study took an approach similar to that of Wang and Luo (2005) to examine primary care access in the urban areas of Ohio, using the Census of Population (2000) and physician data (2008). The current study extended the work of Wang and Luo, through the inclusion of unemployment as a variable, considering the likely influence employment has on access to healthcare. More specifically, we employed a two-step floating catchment area (2SFCA) implemented in a geographic information system (GIS) to measure spatial accessibility of primary care based on travel time. We employed principal component analysis to consolidate various a-spatial variables and then integrated spatial and a-spatial variables to define the areas subject to primary care shortages. The aim was to help health departments in the State of Ohio to improve access in these areas. While our research focused upon Cleveland, Columbus, and Cincinnati, this approach is broadly applicable across a wide range of urban areas.

2. STUDY AREA AND DATA

All the tracts within Cleveland, Columbus, and Cincinnati Ohio were selected as the area of study. Population and socio-demographic data were obtained from the 2000 Census Summary File 3 (US Bureau of Census, 2000).[2] We also obtained Ohio's 2008 primary care physician data from the Ohio Medical Board. All records for service providers listed as family practice, general practice, internal medicine, obstetrics and gynecology were geo-coded according to postal code. Spatial data, such as census tracts, census blocks, and postal zones were available from the Environmental System Research Institute (ESRI). The Ohio Department of Transportation provided us with the most accurate road network data currently available.

In this study, the approximate population point for each tract was represented by population-weighted centroids (based on block-level population data), because such centroids are more accurate than their geographic equivalent (Hwang and Rollow, 2000; Wang and Luo, 2005). Because physicians often choose to practice in populated areas, population-weighted centroids based on postal zones were also used to represent the location of primary care physicians. The threshold travel time was set at 30 minutes, which was used to approximate rational service areas and determine whether contiguous resources were excessively distant, as per the guidelines

2. 2010 Census Summary File 3 was unavailable.

for Health Professional Shortage Areas Designation (Lee, 1991; US Department of Health and Human Services, 2004). The Network Analysis module in ArcView 9.3 was used to determine network routes and calculate proximity within a maximum catchment of 30 minutes between patients and the location of primary care physicians (Lovett et al., 2002). Data related to the estimation of travel time was imported into Microsoft Excel 2003 for 2SFCA calculations.

3. APPLYING THE 2SFCA METHOD IN OHIO

Provider-to-population ratios are the most common type of spatial accessibility measure because they are highly intuitive, data sources are readily available, and they do not require tools or expertise related to GIS (Guagliardo et al., 2004). However, the use of such ratios has at least three serious shortcomings. First, they do not adequately account for interaction across regional boundaries. Second, they are blind to spatial variability within a region and thus have deficiencies such as the inability to provide accurate estimates of the availability of physician services in small geographic areas (Wing and Reynolds, 1988). Finally, provider-to-population ratios do not take into account measures of travel impedance, such as time or distance.

The two-step floating catchment area method (2SFCA) developed by Radke and Mu (2000) can help overcome these problems. The application of the 2SFCA method to healthcare questions has been increasing recently (Wang and Luo, 2005; Bagheri et al., 2006; Wang, 2007; Langford et al., 2008; McGrail and Humphreys, 2009). 2SFCA has several advantages over the conventional provider-to-population ratio method. It uses smaller area units for the distribution of populations and physicians (i.e., census tracts and postal zones instead of counties); considers potential interaction between patients and physicians across administrative borders; and accounts for travel time between patients and physicians.

Figure 1 presents a hypothetical example of the 2SFCA method adapted from Luo and Wang (2003, p.873). The two-county area contains 3 physicians and 15 census tracts representing population and the demand for the services of physicians. In the interests of simplicity, it was assumed that each census tract had only one person residing at its centroid and each physician location had only one physician practicing there. In addition, a reasonable travel time of 30 minutes was assumed. Under this assumption, the catchment around physician location a included one participating physician (cross) and eight residents (seven census tract centroids) residing within the catchment. Therefore the physician to population ratio for catchment a is 1/8. All of the centroids within catchment a (1, 2, 3, 4, 6, 7, 9, 10) were assigned an initial ratio of 1/8. Similarly, all of the centroids within catchment b (4, 5, 8, 11) were assigned an initial ratio of 1/4. Residents at centroids 1, 2, 3, 6, 7, 9 and 10 had access to physician a only and thus their ratios remained at 1/8; residents at centroids 5, 8 and 11 had access to physician b only, so their ratios remained at 1/4. However, centroid 4 is located in an area overlapped by catchments a and b; therefore, these residents had access to either physician a or b. Therefore the physician to population ratio for centroid 4 is the sum of the initial ratios in catchments a and b (1/8+1/4).

Thus, the process for calculating the two-step floating catchment area (2SFCA) method (Luo and Wang, 2003; Wang and Luo, 2005) is as follows:

Step 1 (service catchment): For each service, find all populations that fall within a 30-min driving threshold and calculate the population-to-provider ratio; and

Step 2 (population catchment): For each population, find all services that fall within a 30-min driving threshold and sum the population-to-provider ratios from step 1.

Figure 2 shows the variation in spatial accessibility to primary care resulting from the application of 2SFCA with a 30 minute catchment across the entire state of Ohio. Areas with better spatial access to primary care (higher score = higher accessibility scores) are concentrated in urban areas, such as Cleveland, Columbus, Cincinnati, and Toledo; areas with poor spatial access to primary care are mostly in rural areas.

4. CONSOLIDATING A-SPATIAL VARIABLES USING PRINCIPAL COMPONENT ANALYSIS

Population subgroups differ in terms of healthcare needs and accessibility, according to age, gender, social class, race, and other a-spatial characteristics. Based on the literature review, we included the following variables, all of which were obtained from Census data (2000). Previous studies have noted that the young, elderly, and females need primary care more frequently (Joseph & Phillips, 1984; Field, 2000; Wang and Luo, 2005). The number of seniors aged over 65, children aged 0-4, and women aged 15-44, are all known to have relatively higher needs for primary care services. Low socioeconomic status is also known to present important barriers to health access (Morris and Carstairs, 1991; Field, 2000; Meade & Earickson, 2000; Wang and Luo, 2005). Thus, we included five variables reflecting socioeconomic status in a given tract, including population in poverty, female-headed households, home ownership, median household income, and unemployment. Overcrowding or poor living conditions contribute to higher levels of ill health (Morris and Carstairs, 1991; Field, 2000, p. 315; Wang and Luo, 2005); therefore, households with an average of more than one person per room, and housing units lacking plumbing or kitchen facilities were used as indicators of a poor environment. Attitudes toward health, personal health values and knowledge related to the availability of healthcare are all known as important determiners of healthcare access (Joseph and Phillips, 1984; Andersen, 1995; Field, 2000, p. 315; Wang and Luo, 2005). Thus, this study also included black minorities, individuals without a high-school diploma, and linguistically isolated households as indicators of hesitancy to access healthcare services. Personal mobility is known to influence access to healthcare services (Field, 2000; Wang and Luo, 2005). Ineligibility to drive and reliance on public transit provide lower mobility, thereby reducing access to healthcare. This study used households without vehicles as an indicator of compromised personal mobility. For all of the above variables we used percentages in the tract, except for median household income, which was measured in dollars. Data was obtained from Census file 3 at the census tract level (SF3) (U.S. Bureau of the Census, 2001). Table 1 presents a summary of the statistics related to the above 13 variables.

Socio-demographic variables within any given tract are often correlated and a simple aggregation of the indicators is not necessarily sufficient (Field, 2000). This study used principal component analysis to uncover the underlying dimensions of a-spatial variables. There are two major advantages to the use of principal component analysis in this context: (1) a large number of variables are consolidated into a small number of components for easy interpretation and mapping; and, (2) variance in the data related to the components is a clear indication of the relative importance of each variable, thereby facilitating the differentiation of primary and secondary considerations (Wang and Luo, 2005, p. 139).

Principle component analysis is used to show the substantive importance of each component, as shown in Table 2. Larger eigenvalues indicate components of greater importance. Following the rule of thumb that only eigenvalues greater than 1 are important (Griffith and Amrhein, 1997, p.169), we retained three components capable of explaining approximately 68 percent of the total variance. To better interpret and label different components, Varimax rotation was used to maximize the loading of variables on one component and minimize the loading on all others. Table 3 shows the rotated component structure with the three components labeled to indicate the major variables captured by each component. The variables with higher loadings were given priority.

The first component captured nine variables: female-headed households, population in poverty, households without vehicles, black population, unemployed population, population without high school diploma, income, home ownership, and household with >1 persons per room. This component explained 42.751 % of the total variance. All component loadings were positive except for the median household income and home ownership variables because lower median household income and lower rates of owner-occupied housing units are generally associated with deprived neighborhoods. This component provides a comprehensive indicator of socioeconomic disadvantage. Figure 3 represents the spatial distribution of socioeconomic disadvantage throughout Ohio. Areas with higher scores represent districts with greater socioeconomic disadvantages, which tend to be concentrated in urban centers.

The second component explained 14.75 % of the total variance. It included two variables:

housing units lacking complete plumbing and housing units lacking complete kitchen facilities. Both variables have positive loadings, indicating that this is a comprehensive indictor of living conditions. As mentioned previously, the proportion of properties lacking or sharing basic amenities tends to demonstrate a strong association with poor health outcomes (Morris and Carstairs, 1991; Field, 2000). Figure 4 shows the distribution of living condition scores in Ohio. Areas with poor living conditions (higher scores)are mostly located in the rural regions between Cleveland and Columbus, as well as southeastern regions.

The third component explained 10.384 % of the total variance. It included two variables: population with greater needs and households with linguistic isolation. Linguistic isolation could be associated with lower service awareness, such that immigrants who are linguistically isolated may be unable to access medical services. We labeled this component as "greater healthcare needs". Figure 5 presents the distribution of scores for those with greater healthcare needs in Ohio: higher scores indicate more pronounced healthcare needs. The areas with the greatest healthcare needs are dispersed throughout Ohio without an obvious spatial pattern.

5. RESULTS

The combination of three a-spatial variables identified by principal component analysis and one spatial accessibility measure yielded four variables for consideration in the assessment of access to primary healthcare. In the same manner as the US Department of Health and Human Services (DHHS) guidelines for health professional shortage area designation, this study employed "spatial accessibility to primary care" as the main indictor and "greater healthcare need" as the secondary indicator to identify geographic areas with a shortage of primary healthcare. To identify population groups with shortages in primary care, we used socioeconomic disadvantage as the main indictor and living conditions as the secondary indicator.

Our integrated approach led to the identification of four types of areas susceptible to shortages in primary healthcare. These results are based on a set of criteria adapted from Wang and Luo (2005), but adjusted to accommodate situations found in urban areas. First, tracts with spatial accessibility scores below 1:3500 (as used in the DHHS's designation criteria) were defined as shortage areas—labeled as areas with poor spatial access to primary care. Second, tracts with the spatial accessibility scores greater than 1:3500, but less than 1:3000 were also defined as shortage areas if their high healthcare needs score was one standard deviation above its mean value. These were labeled as areas of marginally poor spatial access to primary care with greater needs. Third, tracts with socioeconomic disadvantage scores one standard deviation above the mean were considered shortage areas. We labeled these as disadvantaged populations. Fourth, tracts with socioeconomic disadvantage scores less than one standard deviation above the mean, but greater than 3/4 standard deviation above the mean were also defined as shortage areas if their living condition scores were one standard deviation above its mean value. We labeled these as marginally disadvantaged populations with poor living conditions.

The results for Ohio as well as Cleveland, Columbus, and Cincinnati are shown in Figares. 6 and 7. Areas with shortages in primary care physicians are defined in these figures at the census tract level. Such shortages (based upon geography) are concentrated mostly in rural areas, particularly southeastern and northwestern townships, and do not appear in Cleveland, Columbus, or Cincinnati. In contrast, shortage areas based on population groups are concentrated mostly in urban areas. The spatial extent of these areas of need may not be large, but they are areas of high population density; therefore, they represent a substantial population.

6. CONCLUSIONS

Overall, this study shows how GIS can be used to identify areas with shortages in terms of access to primary care, using urban areas in the State of Ohio for illustration. Based on geography, the areas suffering a shortage of primary care are concentrated mostly in southeast and northwest rural areas. These areas warrant greater attention and should be the focus of further research, particularly as the state government attempts to improve healthcare access for people in rural areas. Based on population, most of the areas facing these shortages are concentrated in Cleveland, Columbus, and Cincinnati. For policies designed to benefit the greatest number of people in providing access to primary care services, these are the areas that should be targeted first. In all likelihood, for people lacking access to primary care services in the urban areas of Ohio, availability of primary care resources are less of a problem than the lack of financial resources required to pay for them.

The approach taken in this study has at least two advantages. First, the quantitative criteria are consistent and precise, with sound theoretical foundations corresponding to spatial and a-spatial variables. Second, this approach is flexible and allows for expansion (or contraction) of the areas facing shortages in primary care, according to the availability of resources. This approach could be replicated to evaluate access to primary care services in other states or jurisdictions.

This study has two limitations that should be considered. 2SFCA does not differentiate between distance impedances within the catchment (i.e., all population locations within the catchment are assumed to have equal access to physicians) and it is a dichotomous measure (i.e., all locations outside of the catchment are assumed to have no access at all). Therefore, 2SFCA method should be used with these limitations in mind, because the exclusion of distance decay and the choice of a single constant catchment size can detract from the accuracy of 2SFCA results in certain scenarios. Future work could improve the measure of spatial accessibility by better integrating these proposed extra elements within the 2SFCA.

Rapid urbanization, particularly in Asian cities, poses a tremendous challenge in meeting the growing demand for public and primary health services. The present study focusing on urban areas in Ohio could be used as a guide for cities in other countries, in their efforts to analyze access to basic public and primary health services. While carefully following the methods stipulated by previous research, we have added another important variable, unemployment status, which is likely to factor into healthcare seeking behavior. This study demonstrates how GIS technologies can be used to enhance research in public health by integrating spatial and a-spatial information into a single system and examining the relationships between them. GIS can be used to map spatial patterns interactively and make easy adjustments according to user-defined criteria. Most importantly, GIS can be used to analyze the spatial relationship and conduct complex computational tasks related to spatial data.

Table 1. Summary Statistics for Socio-demographic Variables (*N* = 2933)

Variable	Mean	S.D.	Minimum	Maximum
Population with high needs (%)	43.0235	5.26738	2.20	89.19
Population in poverty (%)	12.9024	12.66747	.00	100.00
Female-headed households (%)	20.6618	15.44423	.00	100.00
Home ownership (%)	66.8991	22.30079	.00	100.00
Median household income	41240.1838	17636.42182	.00	200001.00
Population in unemployment (%)	4.7753	3.95740	.00	48.48
Households with > 1 person per room (%)	1.8424	2.08638	.00	37.50
Housing units lack of plumbing (%)	.4956	1.04943	.00	30.22
Housing units lack of kitchen (%)	.6204	1.66072	.00	44.98
Black population (%)	15.4902	26.84327	.00	100.00
Population without high school diploma (%)	19.1592	11.49990	.00	100.00
Households with linguistic isolation (%)	1.3462	2.45480	.00	32.68
Households without vehicles (%)	10.4352	11.89600	.00	100.00

Table 2. Eigenvalues from Principal Components Analysis

Component	Eigenvalues	% of Variance	Cumulative %
1	6.156	47.357	47.357
2	1.607	12.358	59.715
3	1.062	8.166	67.881
4	.964	7.418	75.299
5	.650	5.003	80.302
6	.525	4.037	84.339
7	.494	3.802	88.141
8	.437	3.361	91.502
9	.396	3.045	94.547
10	.288	2.213	96.759
11	.152	1.170	97.930
12	.145	1.113	99.043
13	.124	.957	100.000

Table 3. Component Structure of A-spatial Variables

	Socioeconomic disadvantage	Living conditions	High healthcare needs
Female-headed households (%)	.914	-.008	.087
Population in poverty (%)	.881	.203	.142
Households without vehicles (%)	.834	.189	.218
Black population (%)	.811	-.036	-.125
Population in unemployment (%)	.803	.083	.015
Population without high school diploma (%)	.757	.277	.090
Median household income	-.734	-.128	-.328
Home ownership (%)	-.726	-.091	-.370
Households with > 1 person per room (%)	.500	.421	.179
Housing units lack of plumbing (%)	.129	.825	-.089
Housing units lack of kitchen (%)	.091	.806	.060
Population with high needs (%)	.183	-.209	.757
Households with linguistic isolation (%)	.049	.424	.623
% of total variance explained	*42.751*	*14.746*	*10.384*

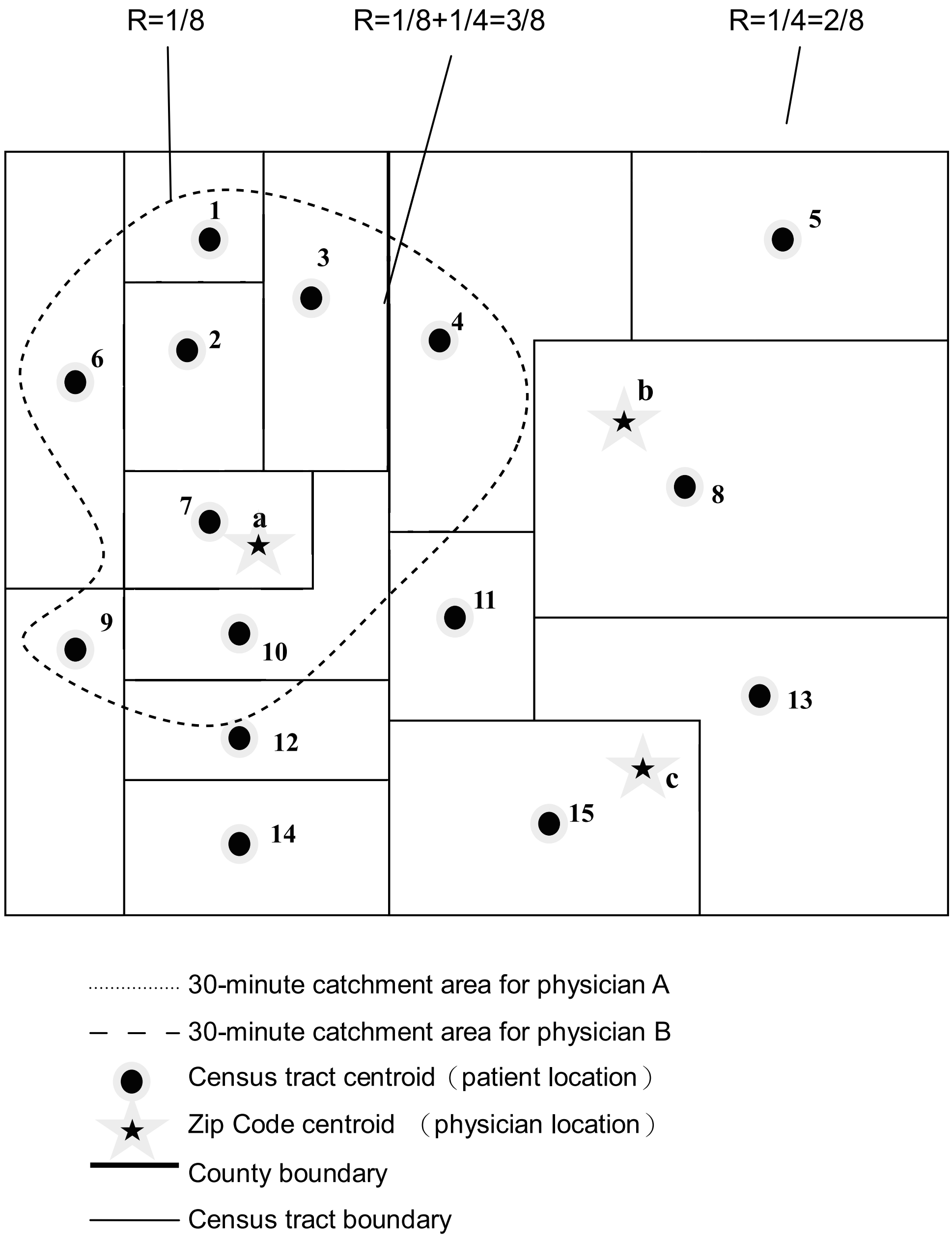

Figure 1. Simple Example of Two-step Floating Catchmentt

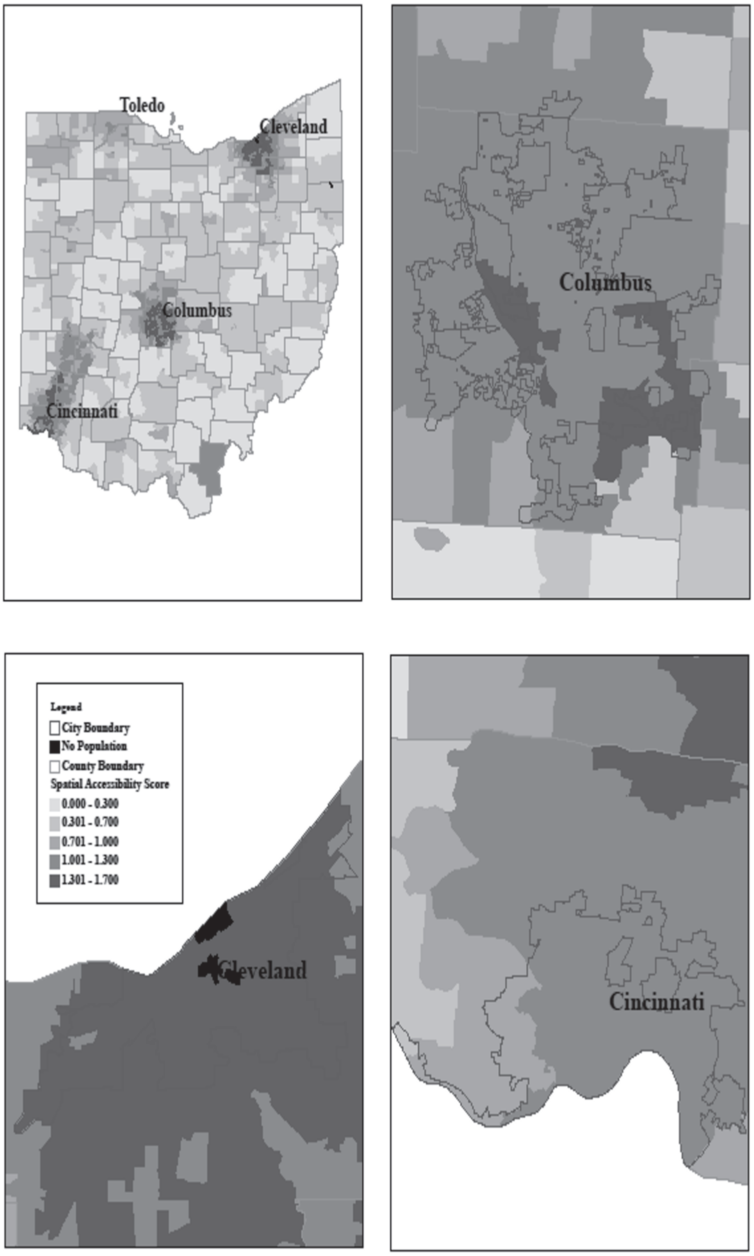

Figure 2. Spatial Access to Primary Care in Cleveland, Columbus, and Cincinnati

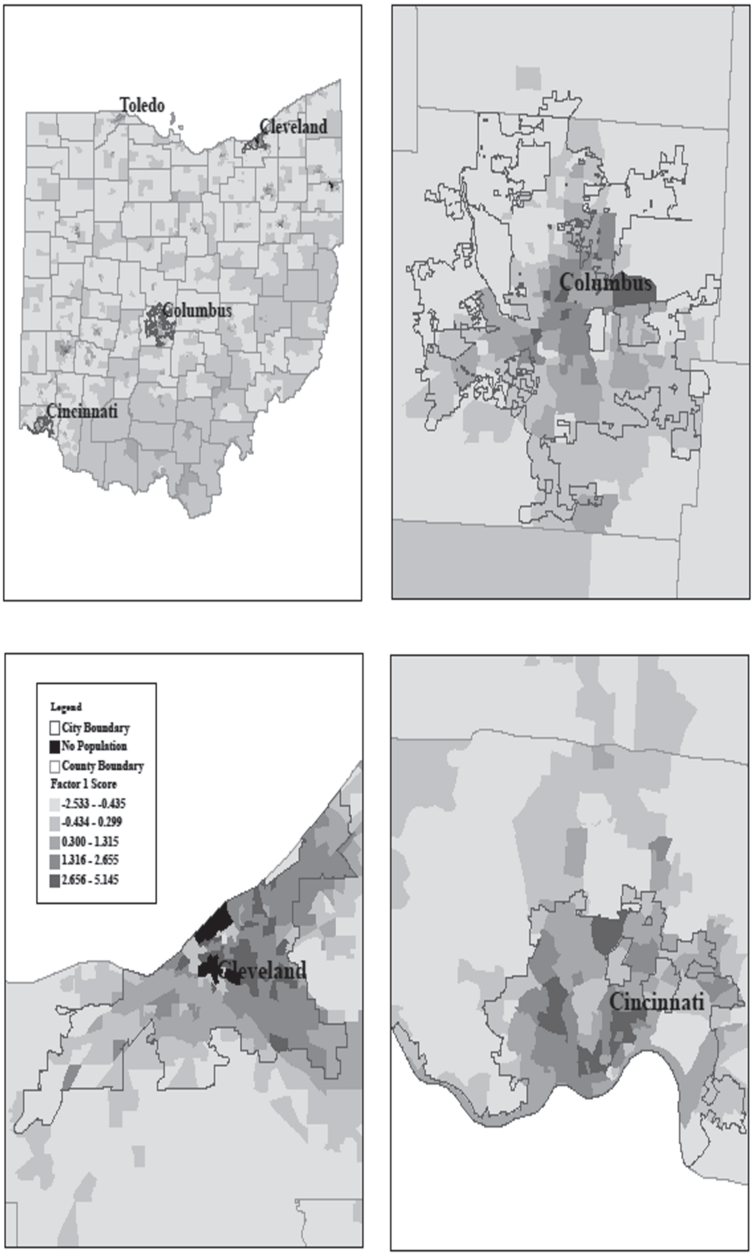

Figure 3. Scores of Socioeconomic Disadvantage in Cleveland, Columbus, and Cincinnati

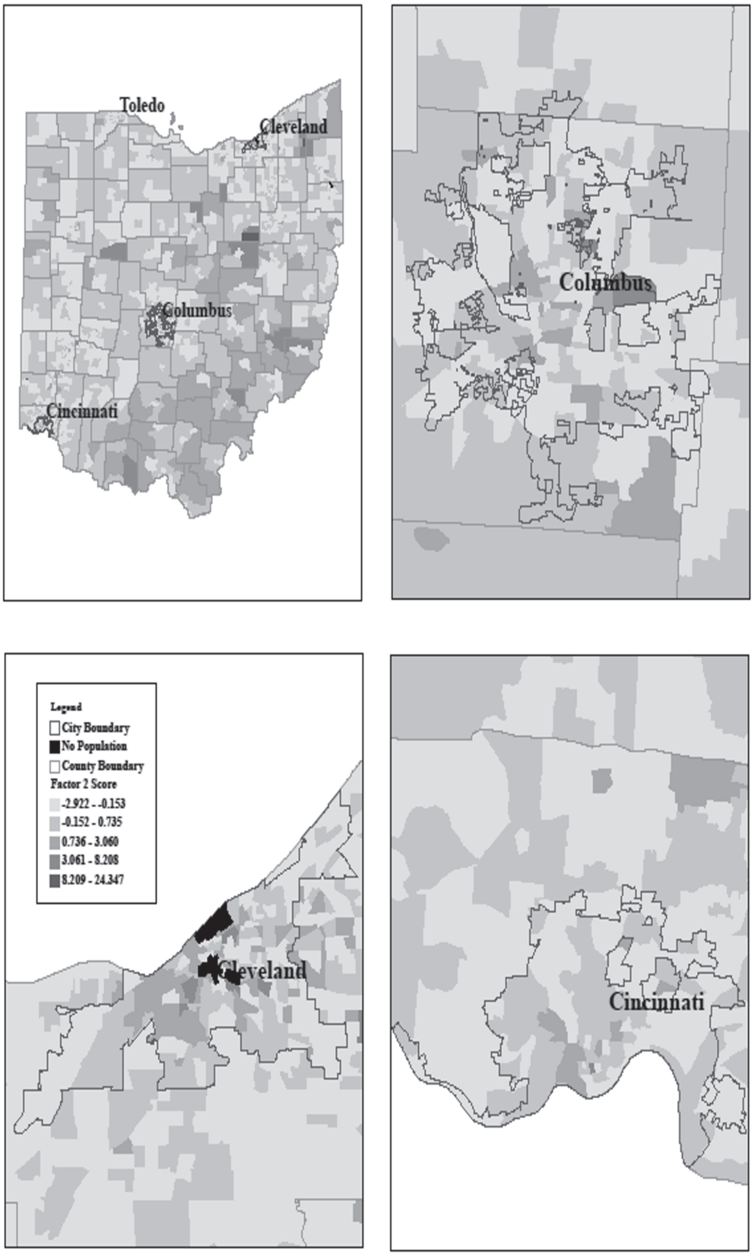

Figure 4. Scores of Living Conditions in Cleveland, Columbus, and Cincinnati

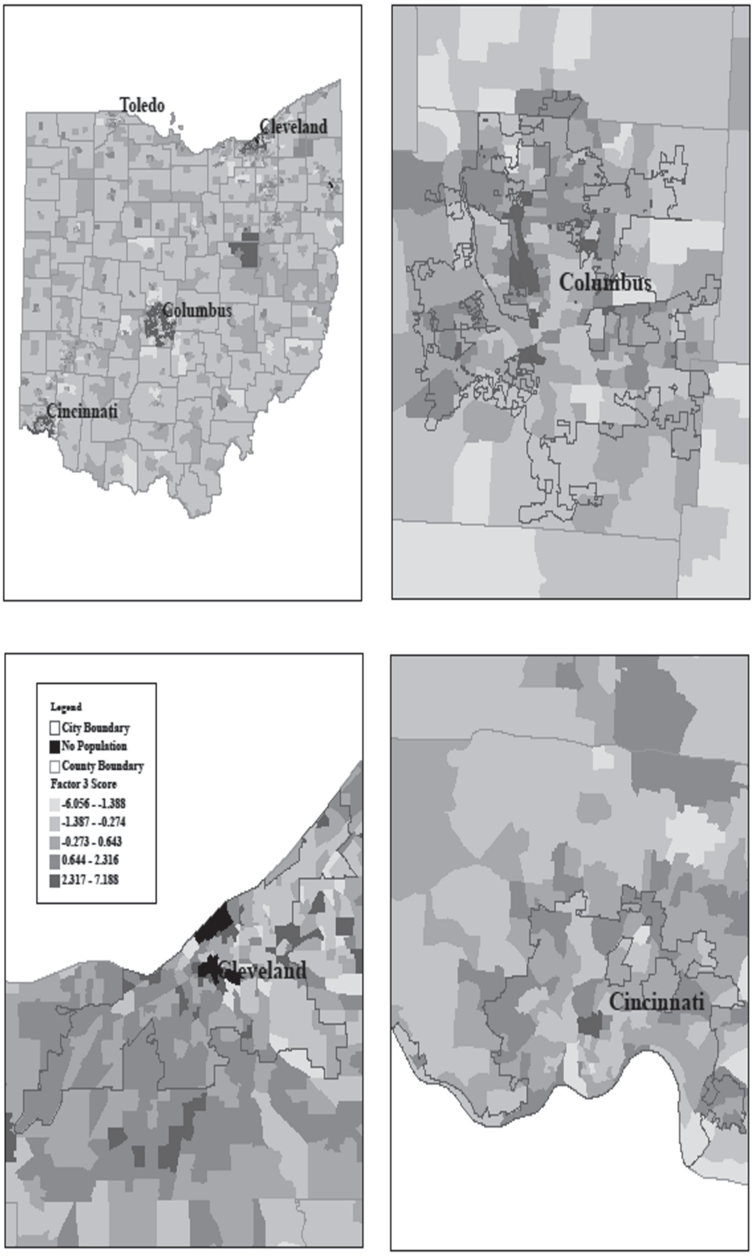

Figure 5. Scores of High Healthcare Needs in Cleveland, Columbus, and Cincinnati

Figure 6. Urban Areas Identified as having Primary Care Shortages Using the Integrated Approach (Geographic Area)

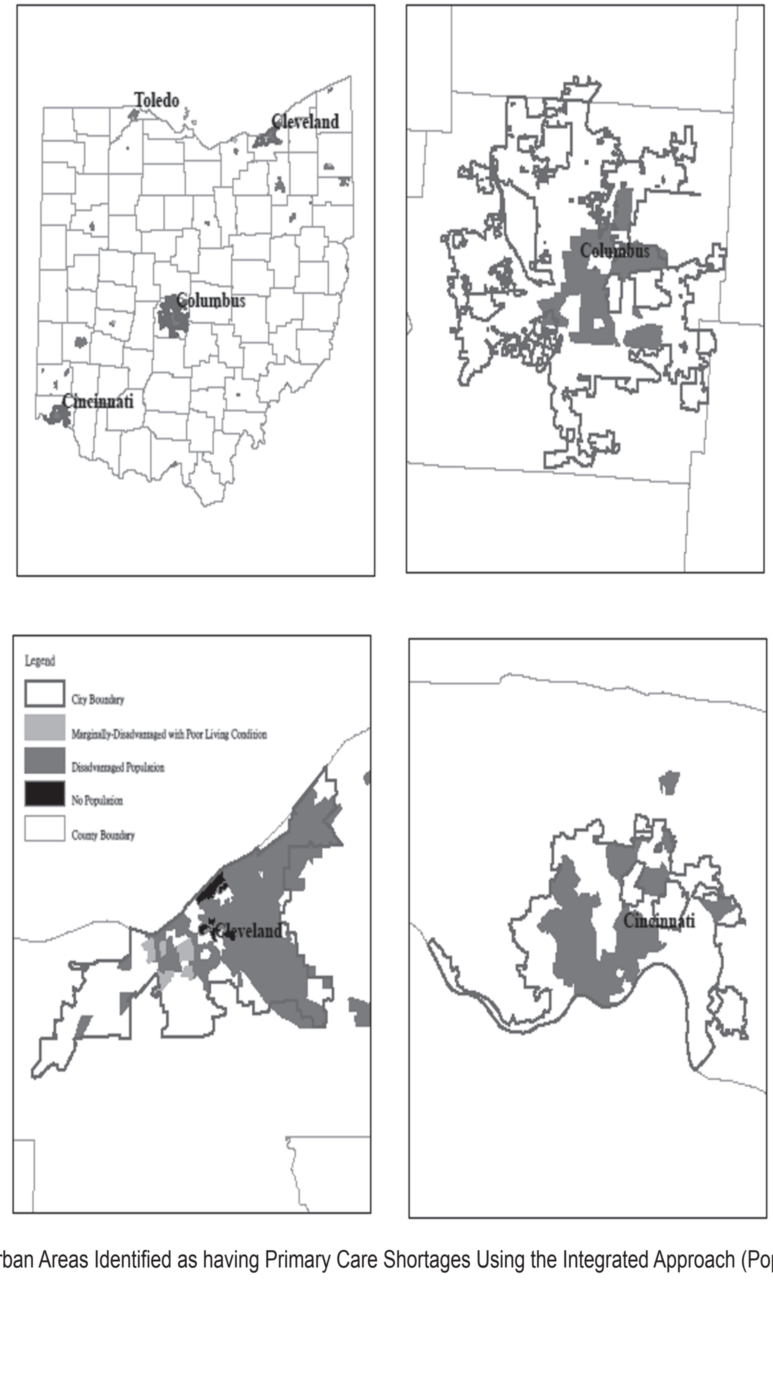

Figure 7. Urban Areas Identified as having Primary Care Shortages Using the Integrated Approach (Population Group)

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