The Geographical Accessibility of Inpatient Services Used for Heart-Related Ambulatory Cara Sensitive Conditions in Kentucky

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Introduction

This study examines the geographical accessibility of inpatient hospital services used to treat heart-related ambulatory care sensitive (ACS) conditions in Kentucky. We measure the access of Kentucky's population to hospitals that provided inpatient services during 2002 for heart-related ACS conditions at the Zip Code Level. We focus the analysis on the identification of variability in spatial patterns of utilization, severity, etc. in relation to the proximity of appropriate services, rural vs. urban areas, and across the Appalachian boundary. We conclude by characterizing the areas and associated populations with relatively low levels of accessibility to the appropriate service facilities.

We measure geographical accessibility through calculation of average travel time between origin zip code zones and destination facilities, both to the utilized facility and to a set of appropriate hospitals within a predetermined number of the closest competing hospitals.

Geography is a primary component of medical service accessibility and has been investigated from a wide variety of perspectives and using numerous techniques. Major critiques of these studies include the use of data aggregated by large areal zones and, over reliance on simple ratios such as hospital beds to population. Developments in database management and Geographical Information Systems (GIS) make possible a plethora of more sophisticated techniques for analyzing the geographical component of accessibility using contemporary massive spatially referenced population and public health data sets.

Our research questions focus on the accessibility for patients utilizing inpatient hospital services for heart-related ACS conditions in Kentucky. For instance;

(a) Where are the appropriate facilities for inpatient services for heart-related ACS conditions and how far are people traveling to them?

(b) Is there a relationship between increasing travel time between residence and service with utilization rates, outcomes, costs, etc?

(c) Are populations from areas with the least-accessibility differentiated by additional characteristics from those in areas with better accessibility?

Background

Kentucky

Kentucky is a relatively rural state with three primary metropolitan areas, all located in the northern and central regions of the state and can be divided generally east to west, into Appalachian and non-Appalachian counties, as defined by the Appalachian Regional Commission (ARC 2005) (Figure 1). The urban areas of Cincinnati, Louisville, and Lexington form an urban core in the northern portion of the state with smaller metro areas scattered around the state. Residents of counties distant from urban centers, particularly those in Appalachia, have fewer local healthcare services available and face significant barriers to acquiring many health services (Huttlinger, Schaller-Ayers, and Lawson 2004, Stensland, Mueller, and Sutton 2002), including the lack of hospital-affiliated substance abuse treatment services in distressed counties, the lack of hospital-affiliated psychiatric services, and the lack of obstetric care.

In 2000, Kentucky ranked 5th in the nation for deaths related to Cardio-Vascular Disease (CVD); 73 of 120 counties had mortality rates from CVD above the national average (Wood, Miller, and Lawther 2000). Included in the list of risk factors associated with CVD are obesity, physical inactivity, smoking, high blood pressure, high blood cholesterol, and diabetes. Release of the most recent Kentucky health assessment paints a grim picture of the current health and well being of Kentucky residents (Surveillance and Health Data Branch 2000). In addition to ranking near the top nationwide on many health factors, such as heart disease, cancer, and obesity, Wood and colleagues (2000) found that fully 56 percent of Kentuckians had two or more risk factors associated with the disease.

Heart-Related ACS Conditions

The evaluation of preventable/avoidable hospital admissions for ambulatory care sensitive (ACS) conditions provides a valuable perspective on accessibility and utilization of hospital services. ACS conditions involve diagnoses where timely and appropriate ambulatory care, such as primary care services, can prevent or reduce the risk of increased severity and hospitalization (Billings 2003). The three types of ACS conditions include:

(a) Chronic conditions, such as diabetes, asthma, and congestive heart failure, where effective management can prevent worsening that requires hospital admission.

(b) Acute conditions, such as ear/nose/throat infections, gastroenteritis, and cellulitis, where early intervention can prevent progression that requires admission for hospital treatment.

(c) Preventable illnesses, such as pertussis, tetanus, rheumatic fever, where immunization can prevent disease onset and hospitalization.

Elevated utilization rates for a population or geographic area for these conditions can indicate restricted access to appropriate services. Effective ambulatory care might reduce the chance of these conditions from becoming severe enough to warrant hospital admission.

This set of ACS conditions does not encompass all of the potentially relevant situations for the study of health care accessibility, such as substance abuse and behavioral health problems, as well as some surgical procedures. These conditions might also be particularly prevalent among some vulnerable populations with limited access to appropriate services. In addition, even with the best primary care, some individuals with these conditions can develop more serious symptoms warranting hospitalization and there is some disagreement over what are the most appropriate services for particular conditions. In addition, the determination of what levels of utilization are appropriate or excessive is subject to debate. In other words, it is essential to interpret rates for these conditions cautiously.

For our study, we targeted a set of ACS conditions related to conditions of the heart. Heart-related conditions are the top ranked cause of mortality in Kentucky (Surveillance and Health Data Branch 2000) and are linked with disparities in health outcomes (Barnett *et al.* 2000; Kunitz and Pesis-Katz 2005). Following Billings (2003), we defined heart-related ACS conditions using ICD-9 codes (Ninth Revision of the International Classification of Diseases) (US Health and Human Services 1980):

(a) Congestive Heart Failure (ICD-9-CM Codes - 428, 402.01, 402.11, 402.91, 518.4)

(b) Hypertension (ICD-9-CM Codes - 401.0, 401.9, 402.00, 402.10, 402.90)

(c) Angina (ICD-9-CM Codes - 411.1, 411.8, 413)

We also exclude inappropriate procedures (e.g., 36.01, 36.02, 36.05, 36.1, 37.5, or 37.7).

Geographical Accessibility and Health Care Services

Geography plays a critical role in determining access to heatlh care facilities (Cromley and McLafferty 2002, Gatrell 2002). Access is mediated by proximity to appropriate health facilities including transportation and travel time as well as the individuals' ability to pay for services (Meade and Erickson 2000). The principle of distance decay describes the declining use of a particular facility as distance from the facility increases (Cromley and McLafferty 2003, Meade and Earickson 2000, Ricketts *et al.* 1994). In rural areas, proximity to facilities with appropriate specializations becomes a primary driver of specific health facility utilization. Individuals are likely to travel increasingly long distances to find appropriate care for rare or serious health problems as compared to more minor problems that can be addressed at a local clinic. Even if an individual can access services, however, one may choose not to utilize a particular service, opting rather to travel further distances or choosing a different type of healthcare service. Utilization is a matter of both access and subjective choices (e.g., Nickerson and Hochstrasser 1970) made by the individual; therefore, access does not guarantee utilization (Cromely and McLafferty 2002:235).

Many factors effect healthcare accessibility and utilization including the social and economic characteristics of patients, perceived quality of care, distance from facilities, and social and cultural norms of a particular population or community (Field and Briggs 2001). Patient characteristics such as age, sex, social class, ethnicity, geographic location (urban vs. rural), and income levels all effect the likelihood that an individual will utilize particular health services (Bertakis *et al.* 2000, Newbold *et al.* 1995). Across social and demographic groups women, minorities and low-income individuals often have the least access to and utilization rates of health facilities in the US (Cromley and McLafferty 2002:235, Millman 1993). Gornick (2003) found that "white beneficiaries and enrollees who are economically and socially advantaged and in better health-use more of the types of services that prevent illness and improve health and functioning than do other Medicare beneficiaries who are members of minority groups, less advantaged and in poorer health" (p.753); again making the connection between socio-economic status, health condition and utilization.

Because geography and social factors interact when determining an individuals' access to health services (Gatrell 2002), assessing geographic characteristics of populations, along with ethnicity, race, and sex can help identify and locate at-risk populations. Heart-related diseases, in particular, are linked to life style factors, including poor diet and smoking, and these factors are often geographically defined in western industrialized countries (Dowler 2003, Lawlor et al.

2005). While these lifestyle factors can affect any individual, several studies suggest that geographic areas with high rates of poverty and/or socioeconomic deprivation are strongly associated with increased risk for cardio-vascular disease. In a study of 4,286 British women between the ages of 60-79, Lawlor et al. (2005) found that the socioeconomic status of residential areas was more closely associated with increased heart disease than individual life course variables and Dowler (2003) suggests that low incomes are frequently associated with food poverty, including poor nutritional choices. Hahn et al. (1998) found similar geographic patterning for risk factors associated with CVD and CVD incidence at the state level. They also found that state rates of physical inactivity, diabetes, and hypertension were predictive of state rates of mortality from CVD for particular groups (Hahn et al. 1998).

Accessibility to health care facilities entails a complex set of forces and processes and plays a central role in health service utilization and public health outcomes. Gugliardo (2004) reviews major developments in the literature on spatial accessibility with particular emphasis on primary care services. (Khan and Bhardwaj 1994). Gesler and Meade (1988) review literature pertaining to the roles of relative location, distance, population characteristics, and daily-activity spaces as they pertain to regular sources of health care.

[Flesh out the section based on Guagliardo and Joseph and Phillips]

The definition of accessibility has been refined by distinguishing between potential and realized accessibility (Aday and Andersen 1974, 1975; Andersen, McCutcheon, Aday, et al. 1983; Joseph and Phillips 1984; Joseph and Bantock 1984).

Potential accessibility refers to the locational relationship between service providers (hospitals) and surrounding populations (Guagliardo 2005; Joseph and Phillips 1984). However, the literature has recognized that physical distance is not the only factor influencing use of medical facilities. Insurance status, income, education, occupation, age, gender, and individual preferences and perceptions all contribute to use of facilities. Examination of actual utilization patterns incorporating these additional variables forms the basis for revealed accessibility.

The current study confines itself to measures of potential accessibility.

Due to limited practical alternatives, county level ratios such as medical doctors-to-population or hospital beds-to-population have been used in previous studies as measures of potential accessibility (Love and Lindquist 1995). The current study overcomes some of the problems with bed-to-population ratios and medical doctor-to-population ratios by employing geographical accessibility measures that account for travel time between patient residences and hospitals using the smallest areal units for which patient locational data are available (All populated zip code zones in Kentucky).

A variety of geographical accessibility measures have been proposed and critiqued in the planning and medical geography literature (Guagliardo 2004). Such measures range from the conceptually simple counting of the number of facilities within a specified distance from a given location to more sophisticated spatial interaction models. A review of geographical accessibility measures are provided by Martin and Williams (1992) and ([A More Recent Citation?]).

The results presented in this study utilize a variety of complementary accessibility measures including:

(a) M.D.'s to population ratio

(b) Cardiac M.D.'s to population ratio

(c) Hospital beds to population ratio

(d) Distance to facility utilized

(e) Minimum distance to facility

(f) Mean distance to facility for varying numbers of hospitals (e.g., 5, 10, 25, 50, and all)

Comparison of these measures with the distance between patient residential ZCTA's and the hospital actually used and other indicators help elucidate the complex interplay of accessibility factors, patient decision-making, and health outcomes.

GIS and Accessibility To Health Care Services

Geographic Information Systems have revolutionized the way researchers explore numerous social and environmental issues (Hochberg, Earle, and Miller 2000; Longley *et al.* 1999; Lyon and McCarthy 1995), including the geography of health (de Lepper et al. 1995; de Savigny and Wijeyaratne 1995; Gatrell and Senior 1999; Ricketts 2003; Scholten and de Lepper 1990). These GIS-based investigations of healthcare services have faced major obstacles due to the massive quantity of data required for such investigations at even moderate levels of spatial scale and the lack of centralized sources of data for service locations and utilization. In addition, studies of spatial accessibility, other than those based on Euclidean distance, entail sophisticated transportation modeling systems and considerable computing power. Nonetheless, the geography of healthcare services has received increasing attention (Bullen et al. 1996; McLafferty 2003). These studies analyze healthcare need, access, and utilization and are directed at supporting the planning and evaluation of service locations (Gatrell and Senior 1999:926). In this way, researchers are developing new techniques to support spatial decision-making for healthcare delivery systems.

Studying accessibility and utilization requires assessment of the interaction between the locations of demands for health services and the locations of healthcare facilities. Previous studies utilize GIS to define health service localities (Bullen et al. 1996), assess new locations for specific health services (Forbes and Todd 1995) and to calculate the potential accessibility of specialized services to populations with limited mobility (Love and Lindquist 1995). These comparisons of health center locations and consumer demand frequently entail the integration of point-referenced data, such as hospitals, with area-referenced socio-economic data (Brown et al. 1991; Carstairs and Morris 1991). In this context, GIS identifies underserved regions and aids the social and economic characterization of associated populations.

Methods

Data

This study requires locational data for zip code zone centroids, hospital service locations, and transportation network features connecting all origin and destination locations. In addition, the study requires attribute data, aggregated by zip code zone, including total population, the number of discharges for heart-related ACS conditions, and associated socio-economic variables.

We use ZIP Code Tabulation Areas (ZCTAs) for mapping the locations of patient residences. ZCTAs are not identical to zip code zones, but are generalized representations of U.S. Postal Service (USPS) ZIP Code areas and are created by aggregating Census 2000 blocks containing addresses corresponding to particular ZIP codes. TransCAD tools calculated the coordinates of the centroid for each ZCTA to use as the origin location.

The database of hospitals and their services encompasses all of Kentucky and all hospitals located in counties of which some portion is within fifty miles of Kentucky. We obtained data for hospitals and their locations using several strategies. First, the majority of the hospital data are from the American Hospital Association Annual Survey Database (2004). Second, hospitals either not listed or that did not report service data. Third, we used all available data from published and internet sources to gather data for hospitals that did not respond to our e-mail, online, and telephone surveys [What is the best way to acknowledge Brian for his assistance?]. We compiled data for each hospital using the standard service categories defined in the AHA Annual Survey Database. The final hospital database contains 385 hospitals, 301 of which provide general medical and surgical services.

The current Kentucky State Transportation Model (KYSTM) (citation) provides the most accurate road network data set available for Kentucky. The model includes basic data, including road types, posted speed limits, and linear referencing, as well as traffic estimation and forecasting attribute data. In addition, the KYSTM includes road network data for the entire U.S. in decreasing levels of detail, providing a basis for calculating accessibility into regions surrounding Kentucky.

We use hospital discharge records for 2002, provided by the Kentucky Department of Public Health (Kentucky Dept. of Public Health 2004), to calculate utilization rates and other measures relevant to heart-related ACS conditions. Hospital discharge records are a useful means for understanding utilization patterns of low-income and other vulnerable. These data are computerized summaries of the medical record for each patient discharged from a hospital, with information on the hospital stay (diagnoses, procedures, admission/discharge dates, charges, and so on), as well the patient (age, gender, race/ethnicity, insurance status, ZIP code of residence, and so on). Institutions maintain these records primarily for payment purposes, but researchers, analysts, and planners use them for a broad range of other purposes as well.

The discharge database we used includes information about all patients discharged from any Kentucky hospital during 2002 and contains demographic and health data for individuals by zip code of residence. Included in the database are the primary treatment options, major disease categories (MDC), Diagnosis Related Groups (DRG) and ICD9 codes for diagnoses and procedures. By definition, individuals captured in the database spent at least one night in the hospital, thus the records reflect relatively acute or severe cases. Discharge records are also specific to each event, so an individual who has multiple episodes requiring separate periods of overnight care will appear in the database multiple times. The database contains 23,151 cases of hospital discharges for heart-related ACS conditions, 41.5 percent of which are male, and 68.9 percent are 65 years and older.

All attribute data in this project are aggregated by zip code or county. We calculated age-adjusted utilization rates to reduce the effect of age-based variability and enhance the comparison of populations with different age structures (Goldman and Brender 2000; Kulldorf, 1999; Rushton, 2003). These rates are adjusted by the direct method using the year 2000 U.S. standard population distribution (Anderson and Rosenberg, 1998). Age-adjusted rates are calculated by multiplying the age-specific rates by the corresponding weight from the specified standard population, summing the results for all age groups, and multiplying the result by 100,000.

The use of rates aggregated by area raises several methodological issues. For example, spatial patterns in the distributions of some variables might exist only at finer spatial scales (Messner and Anselin, 2002). Aggregating data by area can obscure these patterns. Using smaller areal units can alleviate this problem, but also creates another. Areal aggregated data often show heterogeneity of rates for varying populations at risk due to the different population sizes in each areal unit. Ratios for areal units with small counts are particularly sensitive to rate heterogeneity. This can generate spurious outliers, and weaken the reliability of some tests of spatial autocorrelation. Despite these problems, zip codes zones and counties appear to be useful compromises depending on the frequencies of the particular variables investigated. Most county populations are large enough to alleviate the problem of rate heterogeneity, even in cases of relatively rare events, while still providing a fine enough scale to identify meaningful patterns. Zip code zones provide finer detail in the evaluation of spatial patterns, but only for relatively high frequency events.

The ZCTA aggregated socioeconomic data are from the 2000 U.S. Census (US Census Bureau 2003). The county-level mortality data and associated socioeconomic and public health variables used are from the Area Resource File health resource information system (US DHHS, 2003).

Analytical Techniques

We use Caliper's TransCAD 4.7 to calculate travel time between patient residences and hospital service facilities, ESRI's ArcGis 9.1 for processing, visualization, and accessibility analysis, and GeoDa 0.9.5-i to apply a variety of exploratory spatial data analysis techniques. TransCAD is a specialized GIS, designed primarily for network-based transportation analysis and modeling. GeoDa is a free collection of software tools for a variety of spatial analysis techniques (Anselin, 2003 & 2004) and supports dynamic and interactive analysis of linked tables, charts, and maps. Data analysis revealed complex patterns and significant spatial autocorrelation. Spatially autocorrelated data contradict the statistical assumption of the independence of observations and underlying spatial effects can distort the results of statistical analyses (Messner and Anselin, 2002). To alleviate these problems, we selected several spatial statistical techniques that reduce the subjectivity of interpretation of spatial patterns and minimize the impact of spatial effects.

The spatial distributions of hospital usage were assessed using thematic maps, charts, and spatial statistics, including univariate Moran's I, Moran Scatterplots, and univariate Local Moran LISA cluster maps. GeoDa calculates significance values for Moran's I and Local Moran using a permutation approach that compares the data with spatially random distributions of the same data values. The spatial weights matrix used was based on queen's case contiguity. Local Indicators of Spatial Association (LISA) compare values in specific locations with those of their neighbors and test the null hypothesis of spatial randomness in their associated distributions. LISA techniques applied to a single variable highlight statistically significant clusters of positive or negative spatial autocorrelation. LISA techniques applied to two variables indicate areas in which both variables cluster.

The calculation of accessibility measures entails relating the locations of the residences of those discharged to the facility used and to other local facilities. Travel time data were calculated in TransCAD using the point locations of hospital services, the centroids of ZCTA's, and the Kentucky State Transportation Model (KYSTM), following the model constructed by Liu and Zhu (2004). Travel calculations were based on the length and speed limit for specific route segments.

We estimate travel time to the facilities used, nearest facilities, and to a set of facilities near the patients' residences. Some studies have found that given choices, patients often travel further than to the nearest hospital for medical care (Gesler and Meade 1988; Bronstein and Morrisey 1991). Such decision-making depends on a variety of factors, such as the perception of disease and available treatments (Gesler and Meade, 1988). Gesler and Meade (1988) also suggest that people more are likely to bypass the nearest clinic when they reside at increasing distances from the nearest clinic. Hence, we assess accessibility to multiple facilities near patient's residences. Specifically, we calculated mean travel times to the nearest 5, 10, 15, 25, 50, and all hospitals for each ZCTA.

Results

Service Availability andDistribution

There are 301 general medical and surgical hospital facilities in the study area (Figure 2), 103 of which are located in Kentucky. Clusters are located in the major metropolitan areas, the most important for Kentucky residents being Louisville, Lexington, and Cincinnati. The rest are generally scattered throughout the state. 41 Kentucky counties lack hospitals and two clusters of counties lacking hospitals are located in northeastern Kentucky.

Figure 3 shows the ZCTA's allocated to the hospital with the shortest travel time. The darker zones indicate larger mean travel times between all assigned ZCTA centroids and the nearest facility. Several zones of high mean travel times are present throughout the state, but the largest cluster is in the northeastern Appalachian region.

There were 8,824 M.D.'s in Kentucky in 2001, 254 of which were cardiovascular specialists. Metropolitan areas have the highest ratio of M.D.'s to population and the areas with the smallest ratios are generally scattered throughout the rural areas of the state (Figure 4a). The Appalachian region southeast of Lexington includes a modest cluster of counties with small ratios and two other modest clusters of small ratios are located in the rural areas of southwestern Kentucky. The map of M.D.'s specializing in cardiovascular diseases shows large areas of Kentucky lacking physicians (Figure 4b). Again, the areas with the highest ratios primarily coincide with the metropolitan areas. The ZCTA-level map of hospital beds per capita shows a similar pattern, but with greater geographic heterogeneity (Figure 4c).

Geographic Accessibility

Figure 5 shows 15-minute travel time bands from all general medical and surgical hospitals in the study area. 31.81% of the area of Kentucky lies within 15 minutes travel time to hospitals. 57.53% of the area of Kentucky lies between 15 and 30 minutes travel time to hospitals. 10.62% of the area of Kentucky lies between 30 and 45 minutes travel time to hospitals. 0.04% of the area of Kentucky lies between 45 and 60 minutes travel time to hospitals. 10.66% percent of the area of the state lies beyond the 30-minute travel time areas around hospitals. The two largest areas of greater than 30 minutes travel lie in eastern Kentucky and several smaller zones are scattered through the rural areas of the state. The Appalachian area along the Virginia border is often considered more rural and isolated than the northern Appalachian region, but there is a greater density of hospitals there and only small zones of greater than 30 minutes travel to hospitals. The presence of non-Kentucky hospitals near the border does not significantly affect the extents of these zones.

The application of several other measures of geographical accessibility to general medical and surgical hospitals generally reinforces this pattern. For instance, the maps of mean travel times to multiple hospitals (Figure 6) all highlight the north central Appalachian region as the largest cluster of high travel times, followed by several small clusters along the Virginia and Tennessee borders, all ZCTA's along the Mississippi River, and a large cluster in rural west-central Kentucky.

Travel Time Between Residences and Facilities

Figure 7 summarizes the proximity of residences of discharges for heart-related ACS conditions to hospitals. Travel time in minutes between the centroids of patient residence ZCTA's and the general medical and surgical hospitals from which they were discharged are measured on the horizontal axis. The vertical axis measures the cumulative share of the total population of discharges for heart-related ACS conditions. The solid curve shows the portion of all patients discharged from a hospital within the corresponding travel time in minutes specified on the horizontal axis. 90% of all patients were discharged from a hospital within 50 minutes travel time. The dotted curve shows that patients from urban and non-Appalachian ZCTA's traveled consistently less time with 94% discharged from hospitals within 50 minutes travel time. Patients residing in urban areas, either Appalachian or non-Appalachian, reside closer to the hospitals used than patients residing in rural areas, either Appalachian or non-Appalachian.

While all rural residents, both Appalachian and non-Appalachian have longer travel times, rural patients residing in Appalachia have shorter travel times to the hospitals from which they were discharged, than non-Appalachian rural residents. The two curves, however, cross at approximately the point where 80% of the patients were discharged from hospitals at less than 45 minutes travel time. A smaller proportion of rural non-Appalachian patients reside within 45 minutes travel time than rural Appalachian patients, but the curve for rural Appalachian residents flattens out more gradually than that for rural non-Appalachians indicating that a larger proportion of rural non-Appalachians live at longer travel times from the hospitals from which they were discharged. It appears that efforts, such as the several Appalachian Regional Medical Centers, has succeeded in positioned hospitals nearer to many Appalachian residents, but the scale of rural Appalachian still leaves a larger group of people further from the hospitals they use.

The Relationship Between Distance and Health Indicators

All variables, except for percentage of terminal discharges, are positively spatially associated (Table 1). The measures of travel time have Moran's I values ranging from .2112 for the mean travel time to facilities actually used to over .8506 for mean travel time to more than the 50 nearest facilities. The differences in results between different measures of travel time indicate that patients are not only using the facilities closest to them. Nonetheless, maps for all travel time measures consistently highlight Appalachian eastern Kentucky and patches of southwestern rural Kentucky as clusters of high travel time to hospitals and the metropolitan areas of Louisville, Lexington, and Cincinnati as clusters of low travel time.

The Moran's I for utilization rates for heart-related ACS conditions ranged from 0.1731 for total patients to over 0.7361 for spatially smoothed total patients. The Moran's I for utilization rates for heart-related ACS conditions for all males is slightly lower than that for all females. All maps of utilization rates for heart-related ACS conditions highlight the Louisville/Lexington corridor with low utilization rates and the region in southeastern Appalachia along the Virginia border with high. Several small clusters of low utilization rates are present in southwestern rural Kentucky. The most distinct additional patterns evident are present in the maps of emergency and urgent admittance sources. Both variables are positively spatially autocorrelated, but their clusters are present in different areas. Rates of high emergency admittance are common in several areas including Louisville, Lexington, and northeastern Appalachia. Rates of low emergency admittance are present in a large east-west band across central Appalachia. Conversely, rates of high urgent admittance are common in central and southern Appalachia. Rates of low urgent admittance are present in Louisville, Lexington and northeastern Appalachia.

Bivariate Local Moran tests of these variables against mean travel time to the nearest 25 facilities provide mixed results (Table 2). Mean travel time to the nearest 25 facilities produces positive and significant results against utilization, percentage paid using Medicaid, and percentage of urgent admissions. Mean travel time to the nearest 25 facilities produces negative and significant results against population density and percentage of emergency admittances. Mean travel time to the nearest 25 facilities produces insignificant results against percentage terminal discharges and elective admittances. These results indicate a generally moderate amount of association of most variables with travel time to facilities. Utilization rates increase as travel time to facilities increases. Furthermore, the bivariate LISA cluster map of mean travel to the nearest 25 facilities against utilization rates for heart-related ACS conditions reveals a distinctive pattern. High travel time and high utilization are concentrated in southeastern Appalachia near the Virginia border and low travel time and low utilization create two clusters, the entire Louisville/Lexington metropolitan area, and in extreme southwestern Kentucky along the Tennessee border. (Figure 8). In addition, the weak and insignificant association with percentage of terminal discharges suggests that travel time is not directly affecting outcomes.

Bivariate Local Moran tests of these variables against utilization rates for heart-related ACS conditions provide weaker results (Table 3). Utilization rates for heart-related ACS conditions produces weak, positive, and significant results against percentage paid using Medicaid and the percentage of urgent admittances. Utilization rates for heart-related ACS conditions produces weak, negative, and significant results against population density, percentage of terminal discharges, and percentage of elective admissions. Utilization rates appear to be strongly associated only with travel time to facilities.

Characterization of Impacted Populations

[crosstabulation of maps of travel time bands and populations in Kentucky] Something like .... X percent of the state's population resides beyond a 15 minute travel time radius from any general medical and surgical hospital. X percent of the state's population resides beyond a 30 minute travel time radius from any general medical and surgical hospital. X percent of the state's population resides beyond a 45 minute travel time radius from any general medical and surgical hospital. Interesting patterns by wealth? employment, age? Etc..

Methodological Observations

The capabilities of geographic information systems (GIS) to handle large amounts of data over large geographic areas at fine levels of geographic detail makes them ideally suited to measure geographical accessibility to hospitals and other medical service providers. In this paper, we examine the accessibility to over 100 general medical and surgical hospital facilities in and surrounding Kentucky from the centroids of all occupied ZIP code tabulation zones. Advancements in GIS, transportation software, as well as service and route data make possible the calculations for travel time between all ZCTA centroids and all hospital locations, including targeting the facilities used as well as various sets of facilities. In addition, the use of GIS and in this study facilitated the production of geographical accessibility measures that overcome the limitations of traditional statistics based on service to population ratios and straight-line or Euclidean distances. Network-based calculations attributes such as speed, intersection costs, and link distances provide reliable estimates of travel times between origins and destinations.

In this study, we mapped travel time using arbitrary 15, 30, and 45-minute bands to explore the areas that are potentially underserved. Further research is needed to refine our understanding of the relationship between procedures performed at hospitals and the distance traveled by patients for those procedures. What constitutes too far to travel for health care? Which procedures must be widely distributed geographically and which can be productively limited to fewer, higher-order health care centers? Answering such questions will aid in the delineation of more meaningful hospital catchment areas and facilitate the identification of underserved areas for specific conditions and procedures.

Conclusions

Access to health care services is a major policy issue that will become increasingly important as costs continue to rise and new medical technologies are developed. In addition, it is important to recognize that access to medical services is a multidimensional variable. Beyond, distance to services, such factors as insurance status, employment, income, and education jointly affect accessibility and usage of facilities.

The results of this paper show that general medical and surgical hospitals are widelt distributed in Kentucky and that most of Kentucky's population resides in close proximity to general medical and surgical hospitals. This is not surprising given that Freeman, Blendon, Aiken, *et al.* (1987:15) observed that "closing the rural/urban gap in access to health services has been a national goal for many years". [is this a fair assessment?] The results of this study, however, contradict their conclusion, "That goal now appears to have been achieved ... it is clear that major strides have been made in improving the geographical accessibility of physician and hospital services" (Freeman, Blendon, Aiken, *et al.* 1987:15-16). X% of the population living in urban areas are beyond 30 minutes of a hospital while X% living outside are more than 30 minutes from hospitals. The longest travel times extends to over 60 minutes from any hospital and are located in rural areas.

Answer the research question "Are populations from areas with the least-accessibility differentiated by additional characteristics from those in areas with better accessibility?"

More importantly, there is a relationship between utilization rates and travel time to hospitals. First, rural populations are disproportionately large users of medical services. As travel time increases, utilization rates generally increase. Second, rural populations, both within and outside specifically targeted marginalized areas such as Appalachia, have reduced accessibility to even the most general hospital services, as measured by travel time and mean travel time. Hence, decreasing accessibility is moderately associated with increasing utilization for heart-related ACS conditions. It is also important to note that some areas of Appalachian Kentucky have better access to general hospital services than rural areas outside Appalachia. This is in part due to a series of Appalachian Regional medical centers in southern Appalachian Kentucky.

Finally, our results demonstrate an urban-rural difference in geographical accessibility to general medical and surgical hospitals. Geographical accessibility to health care services in rural areas continues to require close attention by communities, policy-makers, and service providers. The results of comparisons between geographical accessibility and other factors related to public health indicate that future research needs focus on the interplay of travel and other variables including employments, income, insurance status, gender, age, race, and education.

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HOLLY R. BARCUS is ....

Appendix

Tables

Table 1 *Results of univariate Moran's I*

Variables	Moran's I	P-Value
Mean Travel Time To Used Facility (Minutes)	0.2112	***
Minimum Travel Time (Minutes)	0.4895	***
Mean Travel Time To Nearest 25 Facilities (Minutes)	0.8506	***
Population Density (People/Sq. Mile)	0.6802	***
Heart-Related Utilization Total Patients	0.1731	***
Smoothed Heart-Related Utilization Total Patients	0.7361	***
% Terminal	0.0021	
% Paying with Medicaid	0.1180	***
% Admitted Through Emergency	0.2694	***
% Admitted Through Urgent Care	0.3937	***
% Admitted Through Elective	0.1913	***

*Note: *** P ≤001, ** ≤01, and * ≤05*

Table 2 *Results of bivariate Moran's I against mean travel time to nearest 25 facilities (Minutes)*

Variables	Bivariate Moran's I	P-Value
Heart-Related Utilization for Total Patients	0.2153	***
Smoothed Heart-Related Utilization Total Patients	0.3863	***
Population Density (People/Sq. Mile)	-0.4847	***
% Terminal	0.0021	
% Paying with Medicaid	0.1976	***
% Admitted Through Emergency	-0.2457	***
% Admitted Through Urgent Care	0.3937	***
% Admitted Through Elective	-0.0092	

*Note: *** P ≤001, ** ≤01, and * ≤05*

Table 3 *Results of bivariate Moran's I against utilization for heart-related ACS conditions*

Variables	Bivariate Moran's I	P-Value
Population Density (People/Sq. Mile)	-0.0422	*
% Terminal	-0.0382	*
% Paying with Medicaid	0.0924	***
% Admitted Through Emergency	-0.0270	
% Admitted Through Urgent Care	0.0961	***
% Admitted Through Elective	-0.0646	**

*Note: *** P ≤001, ** ≤01, and * ≤05*

Figure Captions

Figure 1 *Kentucky study area.*

Figure 2 *Map of general medical and surgical hospitals.*

Figure 3 *Map of territorial allocation to the nearest hospital by travel time.*

Figure 4 *Maps of M.D.'s, cardiac specialists, and hospital beds per capita.*

Figure 5 *15 minute travel time bands from all general medical and surgical hospitals.*

Figure 6 *Map of mean travel time in minutes to the nearest ten general medical and surgical hospitals.*

Figure 7 *Chart of the cumulative proportion of cases against travel time to used facilities.*

Figure 8 *Bivariate LISA cluster map of travel time against utilization rate.*

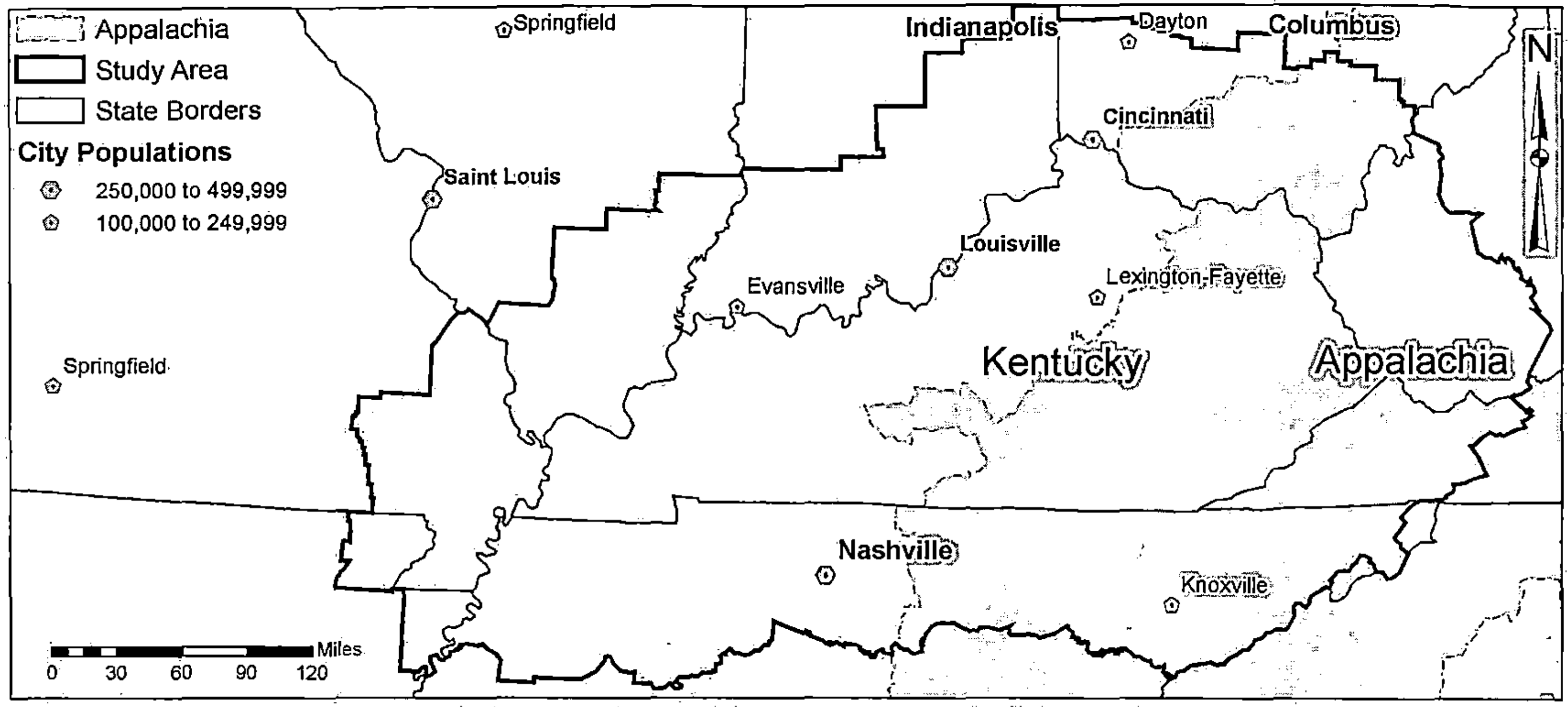

Figure 1 *Kentucky study area.*

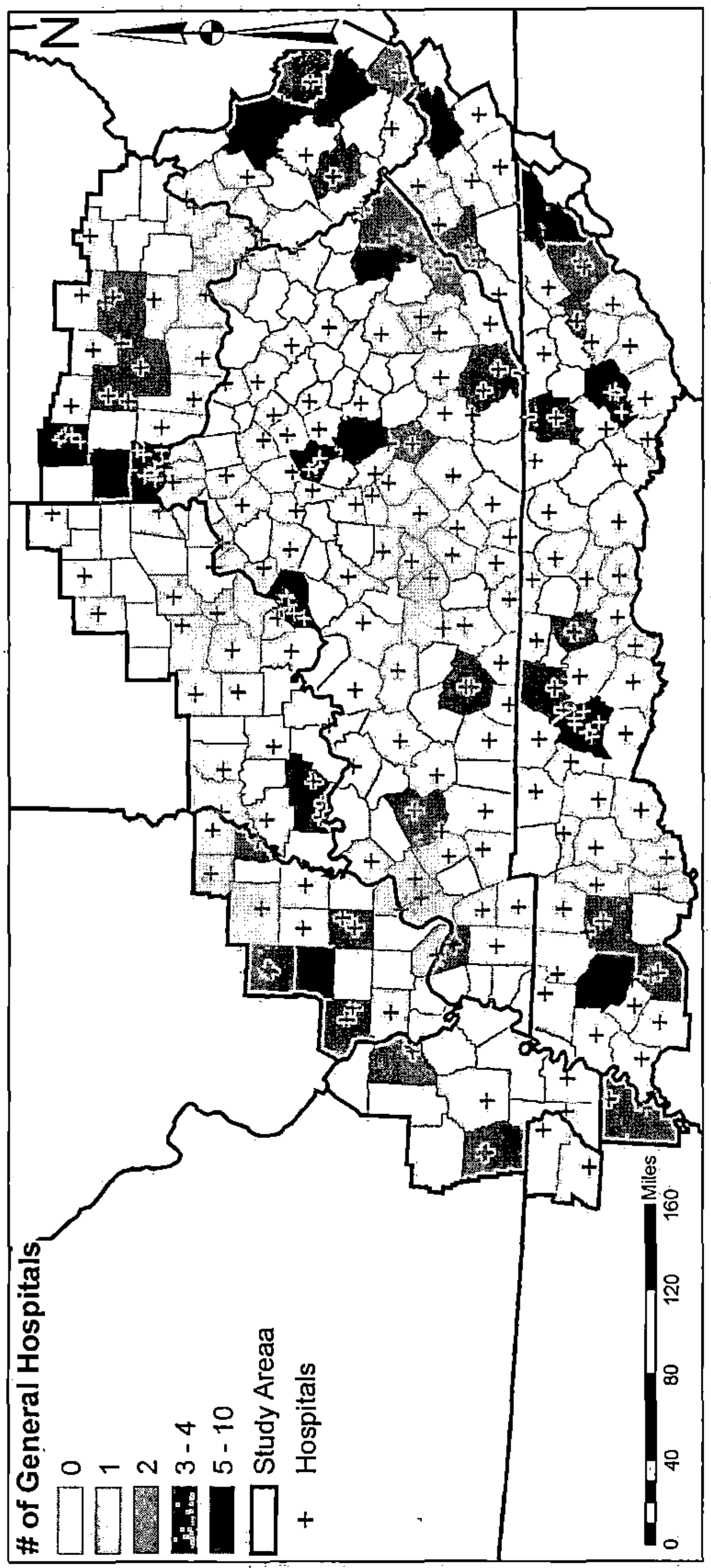

Figure 2 *Map of general medical and surgical hospitals.*

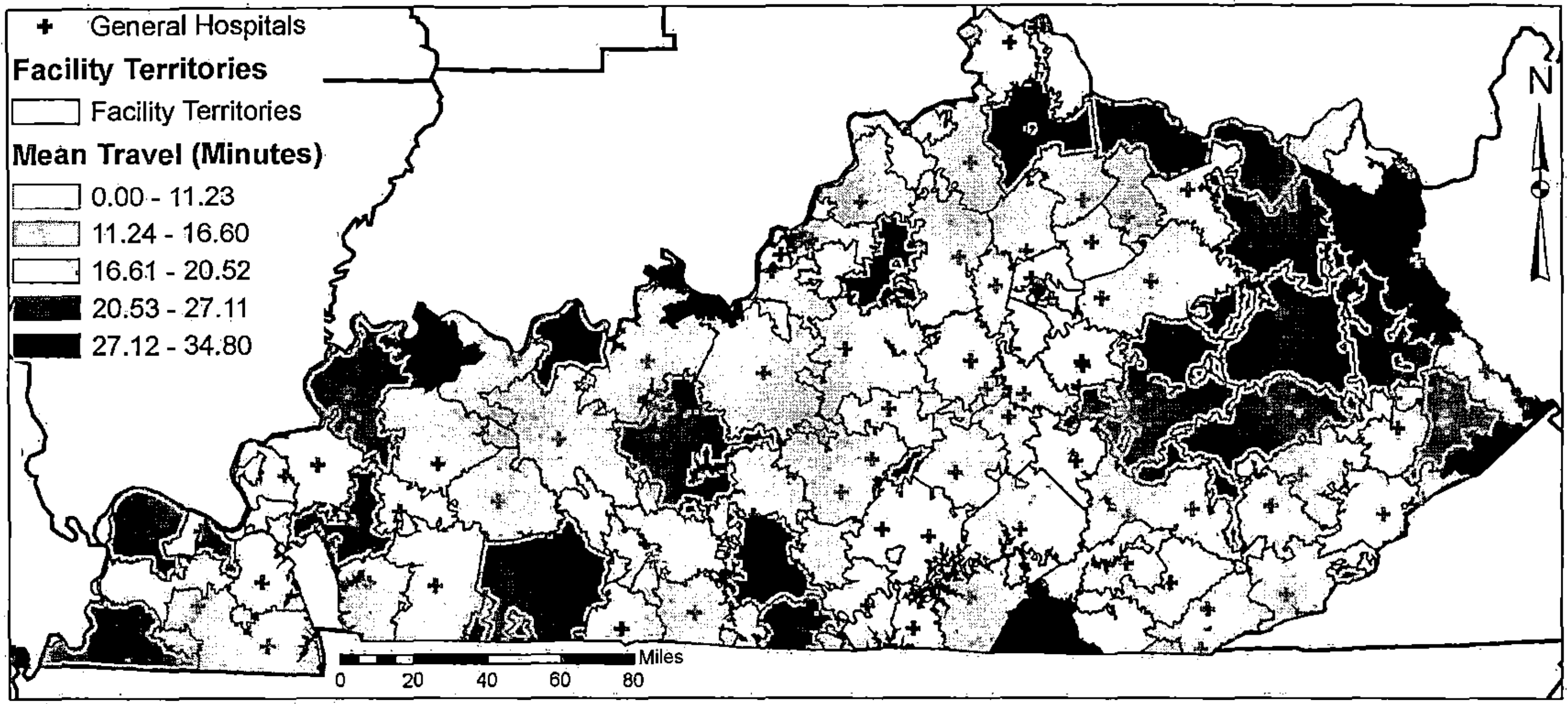

Figure 3 *Map of territorial allocation to the nearest hospital by travel time.*

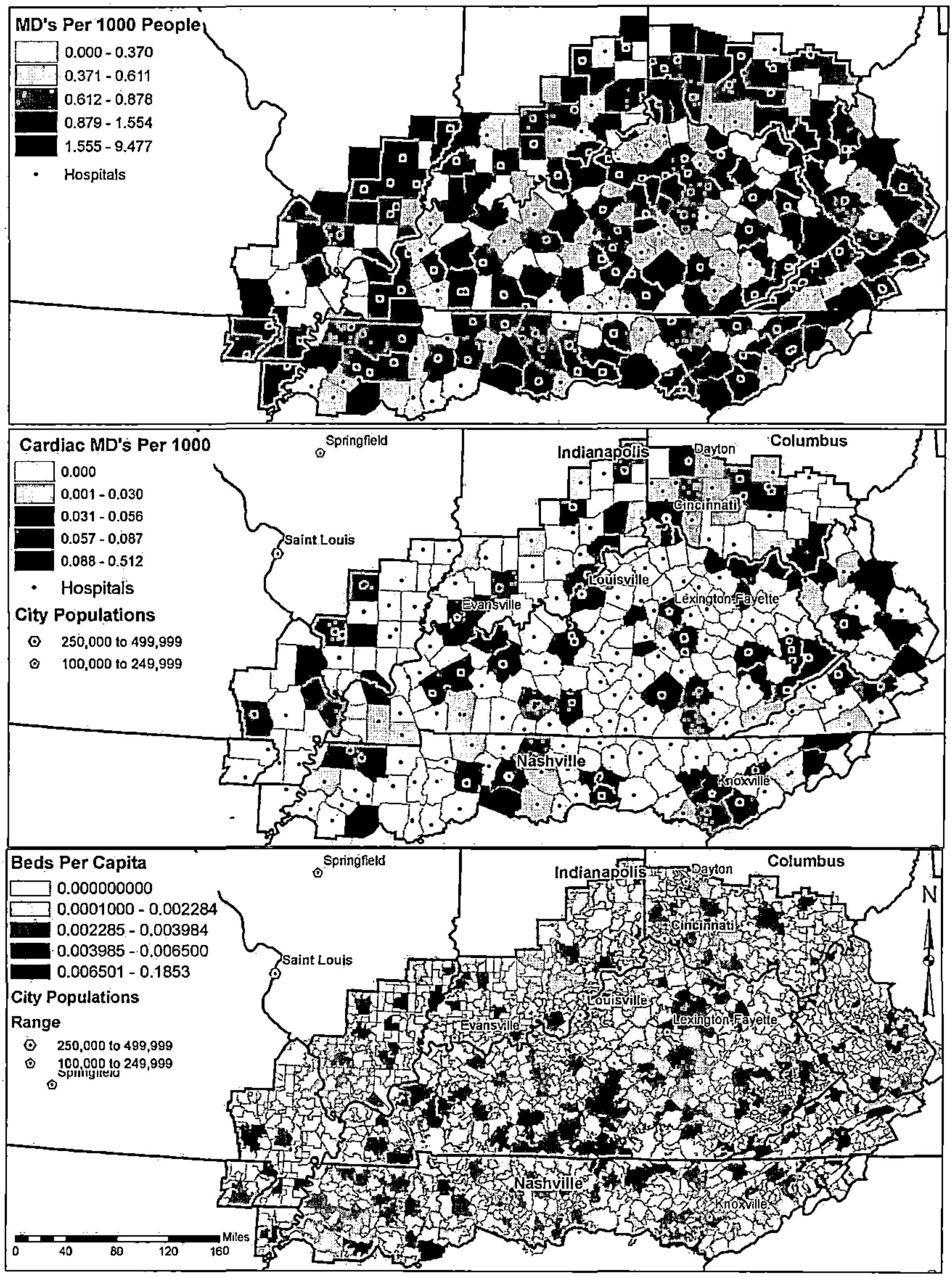

Figure 4 *Maps of M.D.'s, cardiac specialists, and hospital beds per capita.*

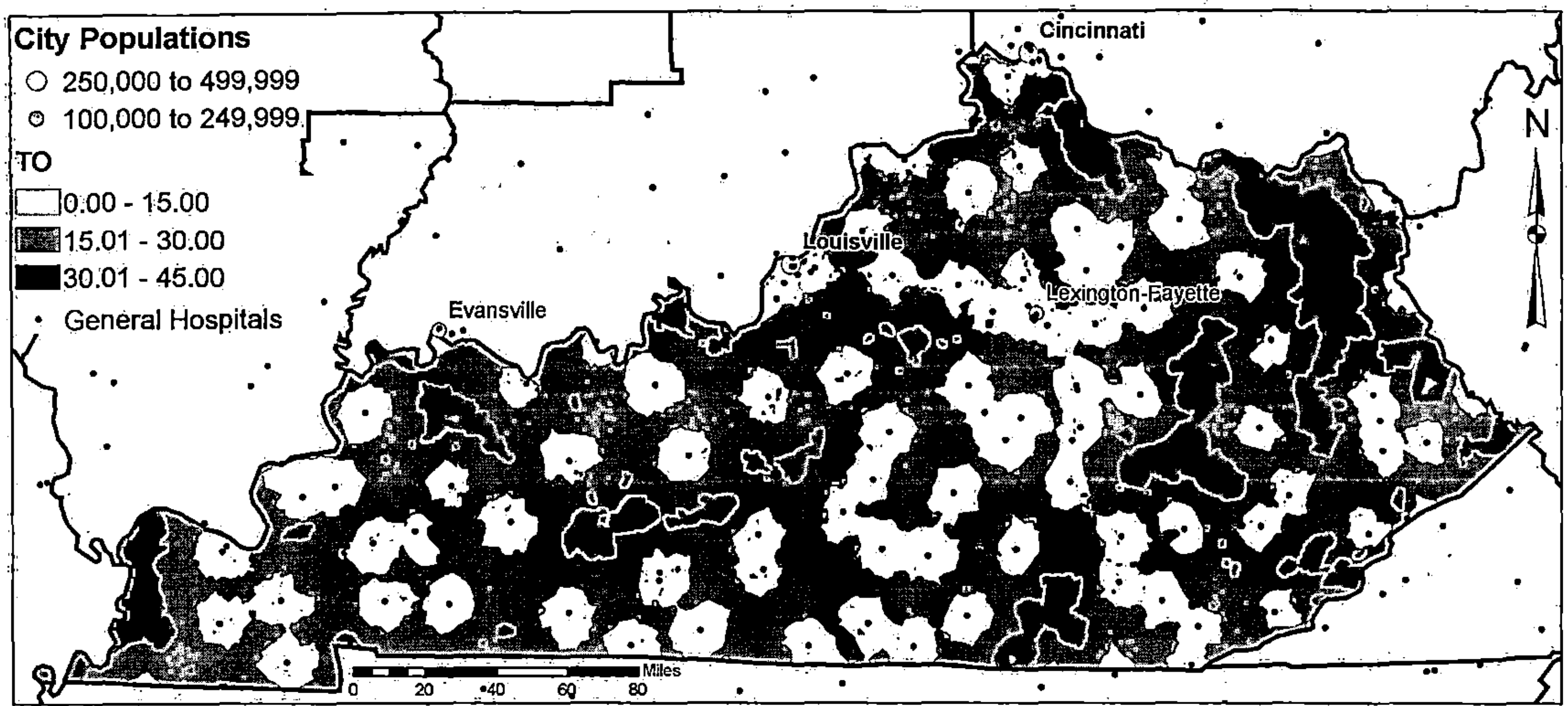

Figure 5 *15 minute travel time bands from all general medical and surgical hospitals.*

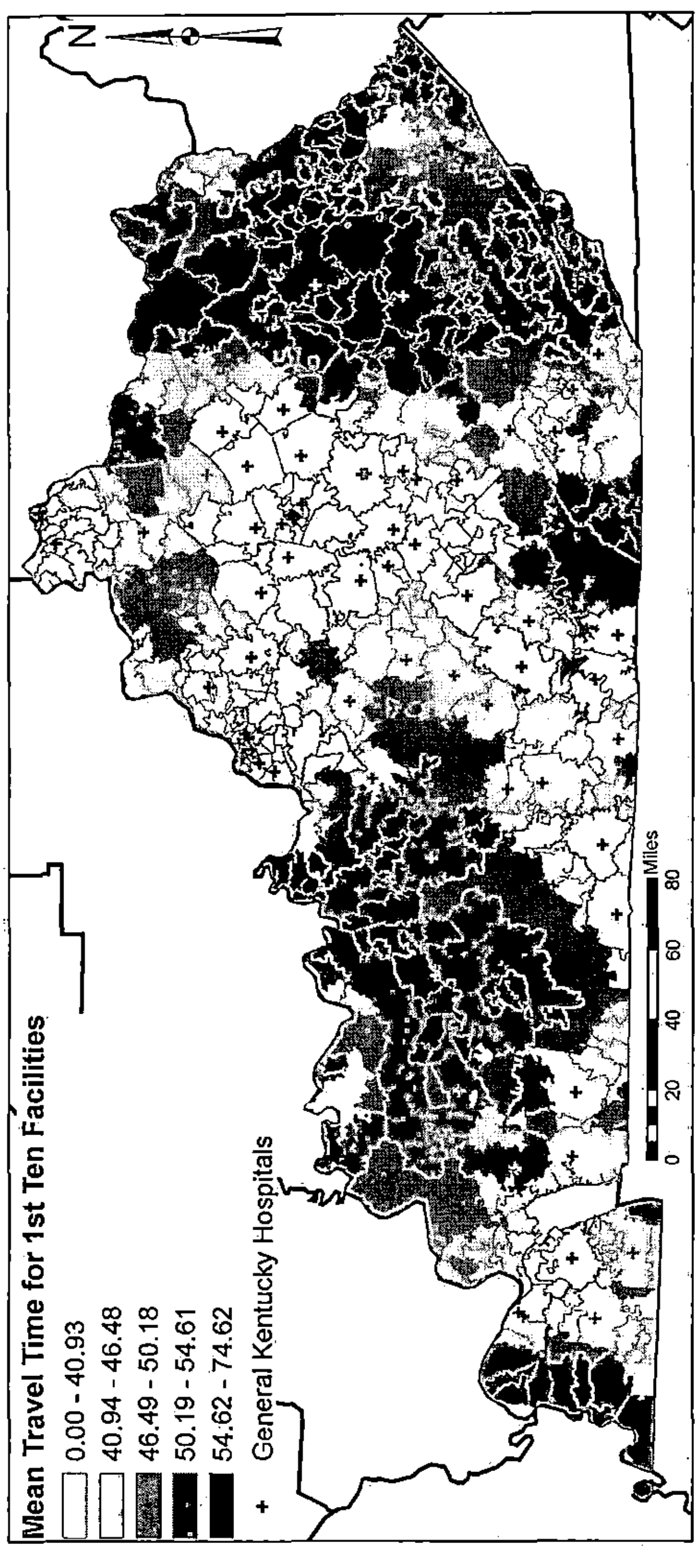

Figure 6 *Map of mean travel time in minutes to the nearest ten general medical and surgical hospitals.*

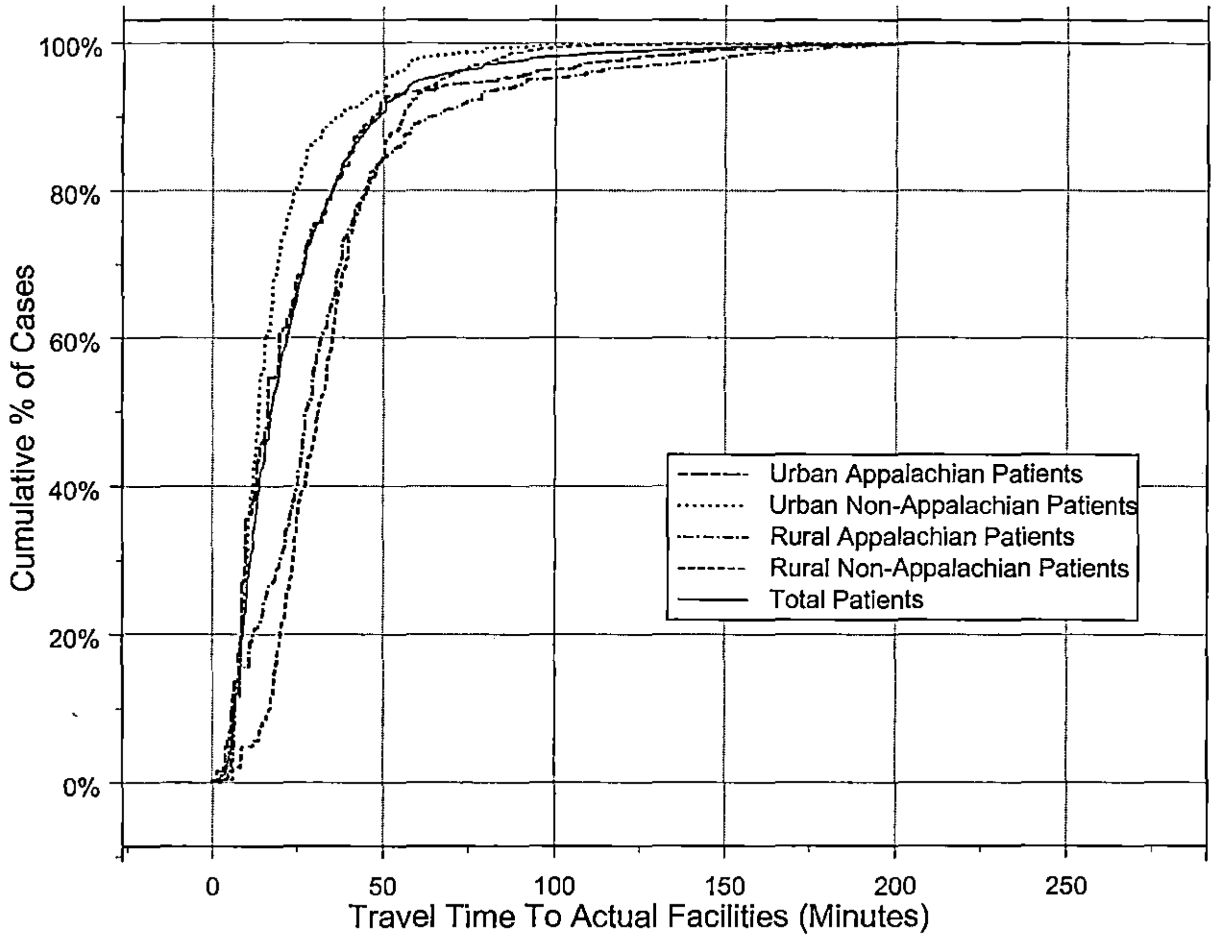

Figure 7 *Chart of the cumulative proportion of cases against travel time to used facilities.*

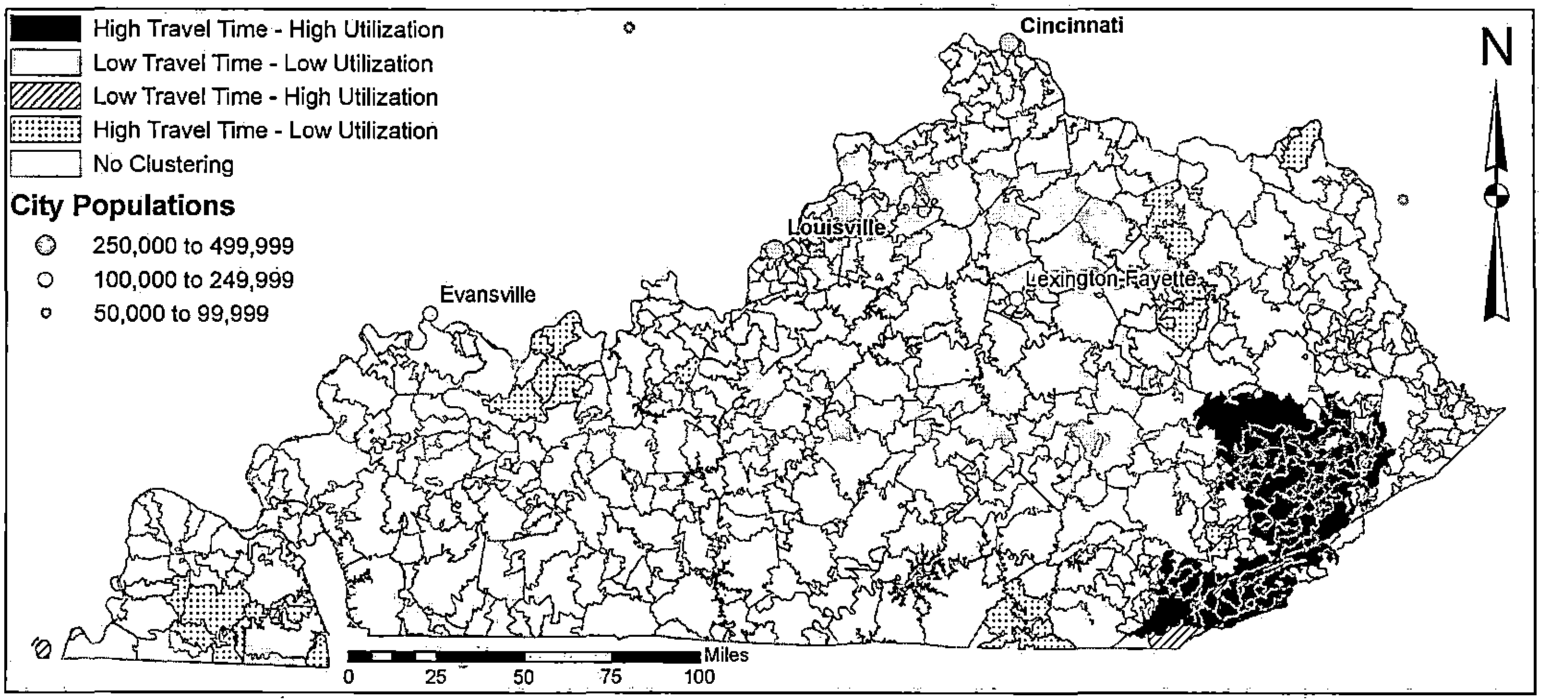

Figure 8 *Bivariate LISA cluster map of travel time against utilization rate.*