

Geographical accessibility and Kentucky's heart-related hospital services[☆]

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Abstract

Cardiovascular diseases (CVDs) are a leading cause of mortality in the US. Rates of mortality vary spatially and demographically, influenced not only by individual patient characteristics but also by levels of accessibility to hospital services and facilities. In 2000, Kentucky ranked third in the nation for heart-related deaths. The purpose of this paper is to assess geographical accessibility and service utilization related to ambulatory care sensitive CVDs in Kentucky. This study utilizes the Kentucky Hospital Discharge Database to evaluate service utilization and the Compressed Mortality File to examine mortality related to CVDs. A spatial statistical comparison of the geographical distribution of service usage and travel time to hospitals assists in assessing the relationship between accessibility and health. Our findings suggest that the distribution of utilization and mortality is geographically variable. People living in rural areas travel further to services; populations residing more than 45 min from health facilities are more likely to be socially and economically marginalized. Spatial clustering of high rates of hospital utilization occurs in areas with lower accessibility.

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Introduction

Geographic location is a primary component of medical service accessibility investigated by other researchers from a wide variety of perspectives using numerous techniques. Accessibility is a complex concept encompassing locations of services and potential patients, mediated by the needs, perceptions, and socioeconomic characteristics of patients (Aday & Andersen, 1974, 1975; Andersen, McCutcheon, Anderson, Chiu, & Bell, 1983; Joseph & Bantock, 1984; Joseph & Phillips, 1984; Martin & Williams, 1992). A large literature focuses on accessibility issues in health services (see for example, Gesler & Meade, 1988; Khan & Bhardwaj, 1994), but some scholars criticize these studies for using data aggregated by large areal units and over-reliance on simple ratios, such as hospital beds to population (Guagliardo, 2004). Recent developments in database management and geographical information systems (GIS) make a wider variety of sophisticated techniques available for analyzing the geographical component of accessibility using large, spatially referenced population and public health data sets.

This paper places healthcare facility utilization within a broader context of supply and demand for health services. Utilizing data from the 2002 Kentucky Discharge Database (Kentucky Department of Public Health, 2004), and travel time between origin (patient ZIP Code zones) and destination facilities (hospital locations), this study assesses whether or not individuals with heart-related conditions utilize facilities in close proximity to their home. Additionally, it measures the access of Kentucky's population to hospitals that provided inpatient services during 2002 for heart-related ACS conditions at the Zip Code level, focusing specifically on the identification of variability in spatial patterns of utilization, and severity of their condition, in relation to the proximity of appropriate services, as well as considering rural vs. urban areas, and Appalachian vs. non-Appalachian locations. The specific research questions are: (1) How far are people traveling to facilities with inpatient services for heart-related ACS conditions? (2) Is there a relationship between increasing travel time between residence and service with utilization rates, outcomes, and cost? (3) Are populations from areas with the least accessibility differentiated by additional characteristics from those in areas with better accessibility?

This paper enhances our understanding of the supply and demand of healthcare services by examining the geographical accessibility and corresponding utilization of inpatient hospital services in Kentucky. Secondly, it evaluates whether different levels of accessibility are associated with different populations and if there is a relationship between accessibility, population characteristics, and severity of outcome for heart-related diseases.

The remainder of this paper consists of five sections. The first section provides an overview of healthcare services and geographic accessibility. This includes a discussion of the role of GIS and spatial analytic techniques in analyzing and measuring accessibility as well as an overview of heart-related ACS conditions, defining what those conditions are, and why they provide an important opportunity to understand healthcare accessibility in the study area. The third section, methodology, describes the disparate data sources compiled and utilized to illustrate both the supply and demand sides of healthcare services and the analytical procedures for assessing the data. Finally, our results and conclusions sections highlight and discuss our key findings and offer suggestions for further research.

Background

Accessibility vs. utilization

Accessibility to healthcare entails a complex set of factors and processes including proximity to appropriate service providers, transportation networks (e.g. travel time), individual socioeconomic characteristics and decision-making strategies, and each consumer's ability to pay for services (Meade & Earickson, 2000). Conversely, access to a particular facility does not guarantee utilization; many potential users of a service bypass the most geographically accessible service to utilize another requiring greater travel time. This section discusses the factors that affect accessibility and utilization.

The definition of accessibility has been extensively debated and refined by distinguishing between potential and realized accessibility (Aday & Andersen, 1974, 1975; Andersen et al., 1983; Joseph & Bantock, 1984; Joseph & Phillips, 1984). The current study confines itself to measures of potential accessibility; which refers to the locational relationship between service providers (hospitals) and surrounding populations (Guagliardo, 2004; Joseph & Phillips, 1984). Measures of geographical accessibility have also 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. 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 & Lindquist, 1995).

Proximity to appropriate services is a primary determinant of utilization, particularly in rural areas (Cromley & McLafferty, 2002; Meade & Earickson, 2000; Ricketts, Savitz, Gesler, & Osborne, 1994). 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 are treatable at a local clinic. Perceptions of proximity, however, are strongly interrelated with socioeconomic factors and subjective choices (e.g., Nickerson & Hochstrasser, 1970). Proximity does not guarantee utilization (Cromley & McLafferty, 2002, p. 235). An individual can choose not to utilize a particular service, avoid all care, travel to further services, or choose a different type of service.

Similarly, the individual characteristics of a patient influence the propensity to utilize particular healthcare services. For example, several scholars note that a patient's ethnicity, social class, sex, income, and age affect the likelihood that an individual will utilize particular health services (Bertakis, Azari, Helms, Callahan, & Robbins, 2000; Field & Briggs, 2001; Newbold, Eyles, & Birch, 1995). Relative proximity to an urban area is also an important factor. Those populations with the least access to and lowest utilization rates of health services in the US include women, minorities and low-income individuals (Cromley & McLafferty, 2002, p. 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). Several studies suggest that regions with high rates of socioeconomic deprivation are associated with increased risk for cardio-vascular disease (Dowler, 2001; Lawlor et al., 2005).

Studying accessibility and utilization requires assessment of the interaction between the locations of demands for health services and the locations of healthcare facilities. Common uses of a GIS include locating new or specialized health services and delimiting service areas for target populations (Bullen, Moon, & Jones, 1996; Forbes & Todd, 1995; Love & Lindquist, 1995). It is also common to integrate point-referenced data, such as hospitals, with area-referenced socio-economic data (Brown, Hirschfield, & Batey, 1991; Carstairs & Morris, 1991) to identify underserved areas or characterize specific populations.

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 likelihood that these conditions will become severe enough to warrant hospital admission (Guagliardo, 2004).

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

Study area

The dominant urban areas of Cincinnati, Louisville, and Lexington form an urban corridor in the north central region and are an integral part of Kentucky's economic core. While the urban centers provide a wealth of healthcare opportunities, 44 percent of the population lives outside of these urban places (US Bureau of the Census, 2003) (Fig. 1). From both a physiographic and socio-economic perspective, Kentucky has two dominant regions: Appalachia and non-Appalachia. Fully 51 of 120 (43 percent) counties are within

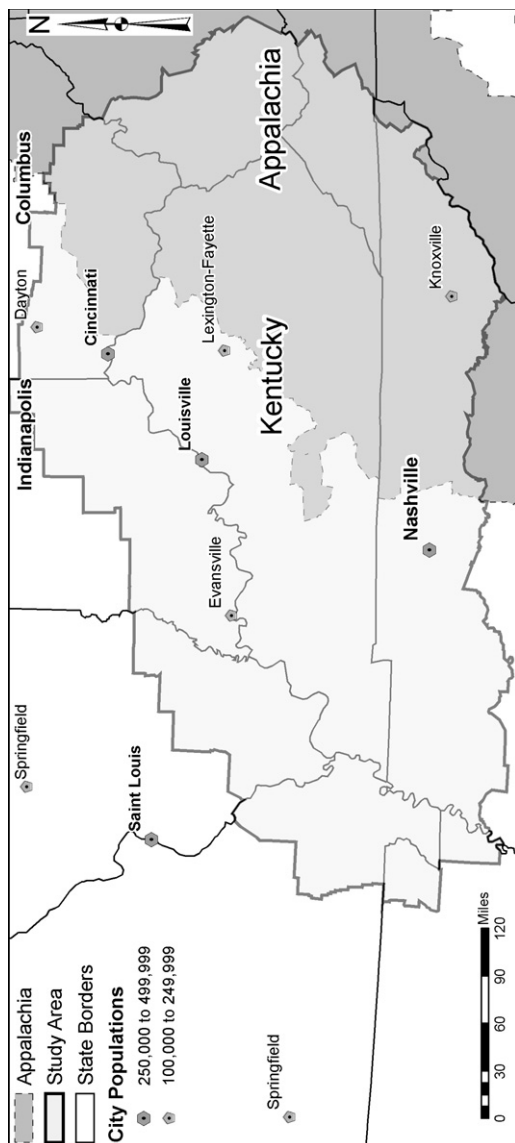


Fig. 1. Kentucky study area.

Appalachia as defined by the Appalachian Regional Commission (ARC, 2005), as is 28.2 percent of the state's population. Appalachian counties are often economically distressed and manifest low rates of educational attainment and high rates of poverty and unemployment (Hare, 2004).

This article evaluates accessibility to healthcare services for cardiovascular-related diseases (CVD). In 2000, Kentucky ranked third nationally for CVD; with CVD noted as “the leading cause of death in every county” (Wood, Miller, & Lawther, 2000, p. 2). In addition, Wood et al. (2000) found that 56 percent of Kentuckians had two or more risk factors associated with CVD, such as obesity, physical inactivity, smoking, high blood pressure, high blood cholesterol, and diabetes.

The prevalence and rates of mortality associated with CVD in Kentucky, the large proportion of the population with multiple risk factors for CVD (Wood et al., 2000), and the level of socio-economic deprivation associated with both Appalachia (Couto, 1994) and rural Kentucky in general (Hare, 2004), underscore the importance of understanding issues of healthcare accessibility in this state. Additionally, Barcus and Hare (2007) found that healthcare facility utilization clustered in southeastern Kentucky, corresponding with both high rates of heart-disease mortality and material deprivation. The overlap between high rates of deprivation and utilization fosters questions about accessibility to facilities, specifically in these socio-economically vulnerable areas, but also in comparison to the rest of the state.

Methodology

Location data

This study uses ZIP Code zone centroids, hospital service locations, and transportation network features connecting all origin and destination locations. The study also employs attribute data, aggregated by ZIP Code zone, including total population, the number of discharges for heart-related ACS conditions, and associated socio-economic variables.

This analysis utilizes 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 US Postal Service (USPS) ZIP Code areas. Kentucky ZCTAs range in size from .1 to 415.7 square miles, averaging about 51.4 square miles. They result from aggregating Census 2000 blocks containing addresses corresponding to particular ZIP Codes.

The database of hospitals and their services encompasses all of Kentucky and all hospitals located in counties of which some portion is within 50 miles of Kentucky. Data for hospitals and their locations derive from several data collection strategies. First, the majority of the hospital data come from the American Hospital Association (2003) Annual Survey Database. This database includes such information as tallies of hospital beds by major department and the presence of all services provided at the facility. Second, a short survey designed and administered by the authors, provided data about all hospitals in the study area that did not report service data to the American Hospital Association Annual Survey. Authors contacted these facilities using e-mail and telephone and provided each with paper, online and over-the-phone survey forms. Third, for those hospitals that did not respond to email, online and telephone surveys, the authors compiled data from all available published and internet sources. Data compilation for each hospital used 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) provides the most accurate road network data set available for Kentucky. The model includes road types, posted speed limits, linear referencing, traffic estimation, and forecasting attribute data. Road network data for the entire US, in decreasing levels of detail, is also included to provide a basis for calculating accessibility into regions surrounding Kentucky.

Health and socioeconomic data

Data pertaining to utilization rates and other measures relevant to heart-related ACS conditions came from the 2002 Kentucky Department of Public Health hospital discharge records (Kentucky Department of Public Health, 2004). Hospital discharge records are a useful means for understanding utilization patterns of low-income and other vulnerable populations. These data are computerized summaries of the medical record for each patient discharged from a hospital in 2002, with information on the hospital stay (diagnoses, procedures, admission/discharge dates, charges, etc.), as well as the patient (age, gender, race/ethnicity, insurance status, ZIP Code of residence, etc.). Patients must remain in the hospital overnight to be included in the database. Therefore, the records reflect only the most severe cases. Although the collecting agency for these data does not report estimates of their accuracy or reliability, we assume there is an undercount. This study targets 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), closely linked with disparities in health outcomes (Barnett, Halverson, Elmes, & Braham, 2000; Kunitz & Pesis-Katz, 2005). Following Billings (2003), heart-related ACS conditions are defined for this study using ICD-9 codes for Congestive Heart Failure,² Hypertension,³ and Angina⁴ (Ninth Revision of the International Classification of Diseases) (US Department of Health and Human Services, 1980). Following Billings et al. (1993), related procedures (e.g., 36.01, 36.02, 36.05, 36.1, 37.5, or 37.7) that are not sensitive to ambulatory care are not included. The 2002 database contains 23,151 cases of heart-related ACS conditions.

To measure potential accessibility, as defined above, and to overcome some of the problems with bed-to-population ratios and doctor-to-population ratios (Love & Lindquist, 1995) this study employs geographical accessibility measures that account for travel time between patient residences and hospitals. This study uses the smallest areal unit for which patient locational data are available—all populated ZIP Code zones in Kentucky. Our research also utilizes a variety of complementary accessibility measures including: (1) MD's (medical doctor) to population ratio; (2) cardiac MD's to population ratio; (3) hospital beds to population ratio; (4) distance to facility utilized; (5) minimum distance to facility; (6) mean distance to facility for varying numbers of the nearest 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

²Congestive heart failure (ICD-9-CM Codes-428, 402.01, 402.11, 402.91, 518.4).

³Hypertension (ICD-9-CM Codes-401.0, 401.9, 402.00, 402.10, 402.90).

⁴Angina (ICD-9-CM Codes-411.1, 411.8, 413).

help elucidate the complex interplay of accessibility factors, patient decision-making, and health outcomes.

The ZCTA aggregated socioeconomic data come from the 2000 US Census (US Bureau of the Census, 2003). The county-level mortality data and associated socioeconomic and public health variables used are from the Area Resource File of the Health Resource Information System (US Department of Health and Human Services, 2003). Aggregating data by area raises several methodological issues. First, distribution patterns might exist only at specific scales (Messner & Anselin, 2002). This study uses both ZIP Code and county levels when possible to check for disrupted patterns. Zip Code areas allow us to evaluate more refined spatial data patterns than county-level data; however, the county-level analysis provide a cross-check for outliers that might be generated by using ratios based on small counts occurring at the ZIP Code area level. By aggregating the data to two scales, ZIP Code and county, the analysis gains the advantage of more refined spatial patterns without weakening the reliability of the spatial statistics. Utilizing two levels of aggregation also helps identify potential problems with the modifiable areal unit problem (MAUP). Changing the scale and aggregation of spatial data influences the spatial patterning and variability of the mapped data and the resulting interpretation. Utilizing both levels of aggregation helps minimize the potential for erroneous spatial patterning and allows greater confidence in the spatial patterns that emerge.

Analytical techniques

To assess the relationships between origin and destination, supply and demand, this study uses several different GIS and spatial data analysis methodologies, including several methods of GIS data visualization and a variety of exploratory spatial data analysis techniques. Travel time between the centroids of patient residential ZIP Code zones and hospital service facility location is also calculated. To alleviate problems of spatial autocorrelation, which distort statistical analyses (Messner & Anselin, 2002), and to increase our confidence in interpreting spatial patterns in the data, the study utilizes global and local Moran's I, and the bivariate Local Indicators of Spatial Autocorrelation.

Thematic maps, charts and spatial statistics are our primary tools for assessing the spatial patterns of hospital utilization. Spatial statistics include univariate Moran's I, Moran Scatterplots, and univariate Local Moran LISA cluster maps. The spatial weights matrix derives from queen's case contiguity. Unlike global measures of spatial autocorrelation that evaluate an entire study area, Local Indicators of Spatial Association (LISA) focuses on specific sub-areas to test the assumption of spatial randomness. LISA techniques can identify areas of spatial autocorrelation that global measures overlook. LISA techniques can assess one or two variables at a time, in each case highlighting statistically significant clusters of positive or negative spatial autocorrelation.

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 derives from the point locations of hospital services, the centroids of ZCTA's, and the KYSTM, following the model constructed by Liu and Zhu (2004). Travel time calculations derive from the length and speed limit for specific route segments. Beyond travel time to the facilities used, the authors calculated travel times to the nearest facilities and to a variety of sets of facilities close to each patient's residence. Some studies show that given choices, patients often travel further than the nearest hospital for medical care (Bronstein &

Morrissey, 1991; Gesler & Meade, 1988). Such decision-making depends on a variety of factors, such as the perception of disease and available treatments (Gesler & Meade, 1988). Gesler and Meade (1988) also suggest that people are more likely to bypass the nearest clinic when they reside at increasing distances from the nearest clinic. Hence, the authors assess accessibility to multiple facilities near patient residences, specifically calculating mean travel times from each ZCTA to the nearest sets of 5, 10, 15, 25, and 50 hospitals, as well as to all hospitals in the study area.

Finally, the study uses block group level data to assess the characteristics of populations residing within each of the travel time zones. Variables for these profiles derive from those utilized by Falkingham and Namazie's (2002) deprivation index. These variables reflect a range of social and economic characteristics that collectively are indicative of material deprivation. This analysis does not combine the variables into an index but rather uses them to compare the material status of populations across geographic areas with differential access to hospital care services. Barcus and Hare (2007) utilized this index to demonstrate significant levels of clustering within socio-economic groups possessing high deprivation scores. These measures facilitate the reassessment of whether populations identified as vulnerable also lack accessibility to health facilities. It is important to note that this study combines individual-level hospital discharge data with aggregated social and economic data. To avoid the potential for ecological fallacy, or attributing the characteristics of the aggregate population to the individual, we exercise caution in associating the aggregated characteristics of populations in particular localities, ZCTAs and counties, with the characteristics of individuals represented in the discharge database. This caution guides our conclusions, which focus on aggregate patterns without extending conclusions inappropriately or assuming explanation of individual characteristics or behavior.

Results

Service availability and distribution

There are 301 general medical and surgical hospital facilities in the study area (Fig. 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 scattered throughout the state. Forty-one Kentucky counties contain no hospitals, including two noteworthy clusters of counties in northeastern Kentucky.

Fig. 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. Even though several zones of high mean travel time are present throughout the state, the largest cluster is concentrated in the northeastern Appalachian region of the state.

There were 8824 MD's in Kentucky in 2001, 254 of which were cardiovascular specialists. Metropolitan areas have the highest ratio of MD's to population. Areas with the smallest ratios are generally scattered throughout the rural areas of the state (Fig. 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 MD's specializing in cardiovascular diseases (CVDs) shows large areas of Kentucky lacking these specialists (Fig. 4b). Again, the areas with the

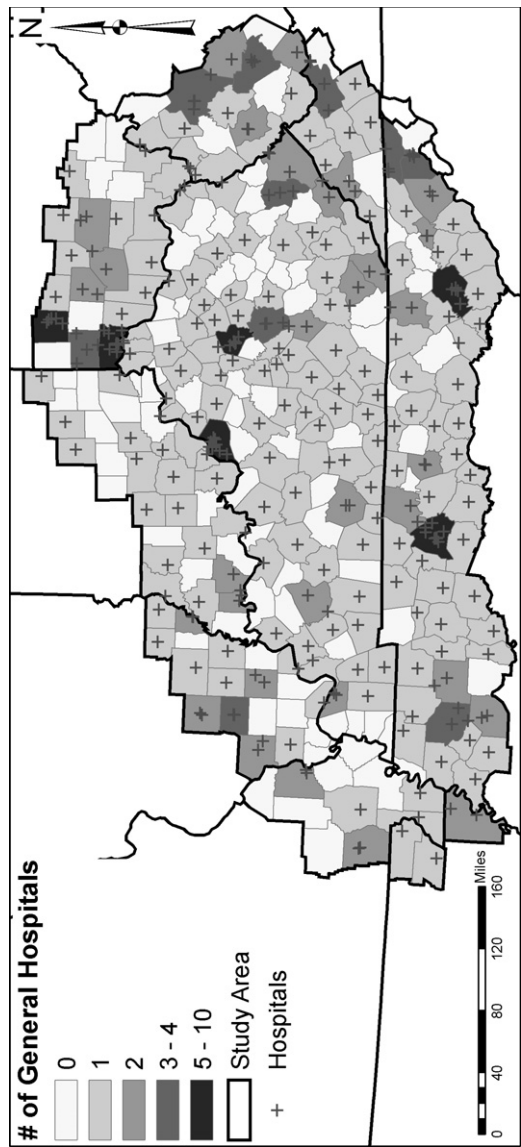


Fig. 2. Map of general medical and surgical hospitals.

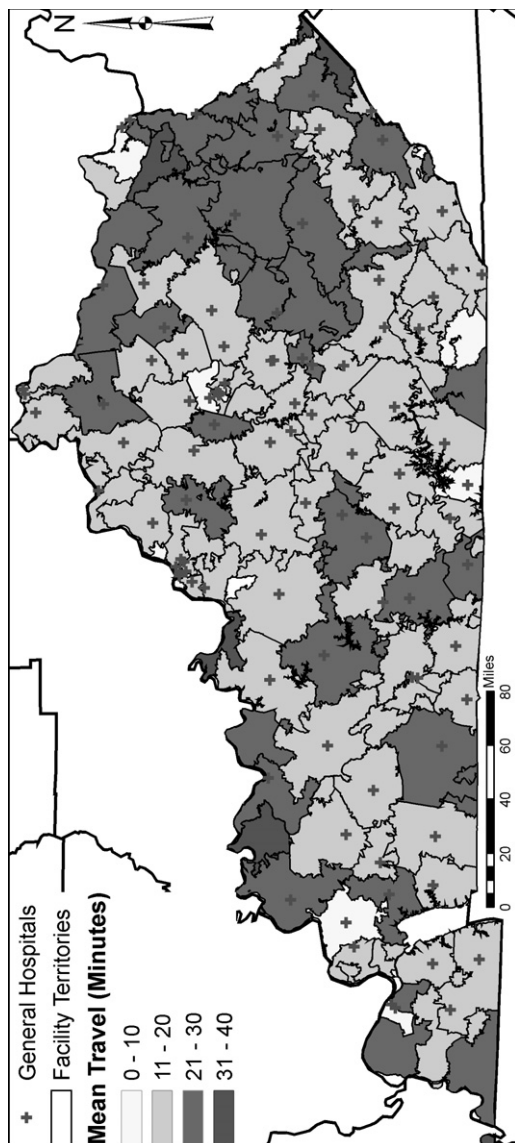


Fig. 3. Map of territorial allocation to the nearest hospital by travel time.

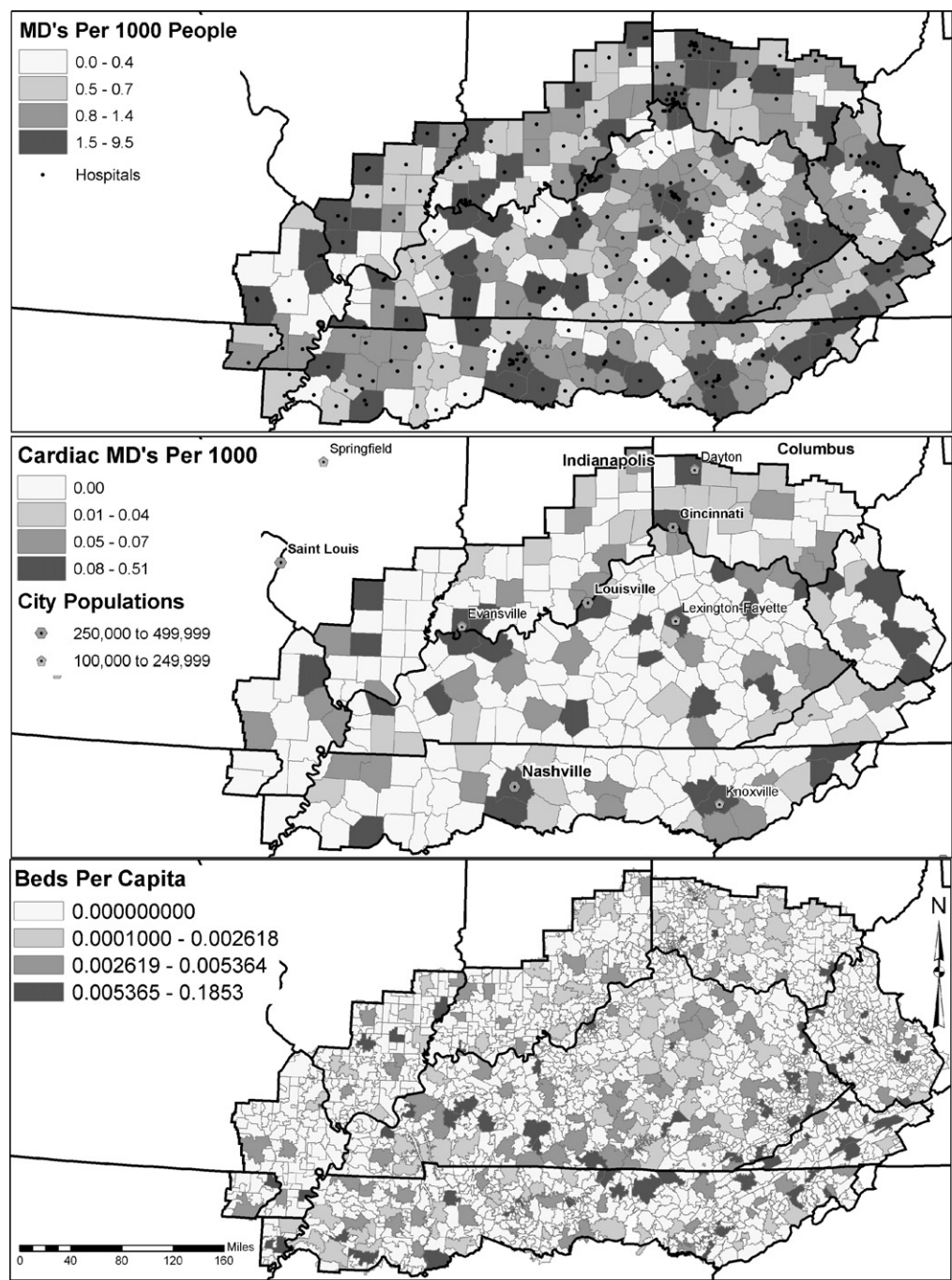


Fig. 4. Maps of MD's, cardiac specialists, and hospital beds per capita.

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 (Fig. 4c).

Geographic accessibility

Fig. 5 shows 15-min travel time bands from all general medical and surgical hospitals in the study area. Approximately 31.8 percent of the area of Kentucky lies within 15 min of travel time to hospitals (Table 1). The majority of the area, 57.5 percent, is between 15 and 30 min travel time, while the remaining 10.6 percent of the state requires over 30 min travel time to the nearest facility. The two largest areas of travel time greater than 30 min are in eastern Kentucky and several smaller zones are scattered throughout the rural areas. The southeastern Appalachian region of the state along the Virginia border is more rural and isolated than the northeastern Appalachian region, but there is a greater density of hospitals there and only small zones of greater than 30 min travel to hospitals. The presence of non-Kentucky hospitals near the border does not significantly affect the spatial extent 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 (Fig. 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.

In other words, geographic accessibility is best in the Lexington, Louisville, and Cincinnati areas and worst in rural areas. Not all rural regions, however have limited accessibility. For instance, the rural area of central Kentucky south of Lexington has good to moderate accessibility. Similar regions are evident in extreme southwestern Kentucky, and southern Appalachia. In addition, while the largest region with poor accessibility is located in Appalachia, the second largest is located in western Kentucky near the Indiana border. Finally, Fig. 6 highlights the importance of viewing accessibility not as relationships between an individual and the closest service, but as a decision-making system whereby individuals assess the merits of utilizing services from multiple service centers. Adding a single new service location might have a limited impact, while providing a system of centers with overlapping service regions has greater potential for improving accessibility and utilization.

Travel time between residences and facilities

Fig. 7 summarizes the proximity of residences of people discharged 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. Ninety percent of all patients discharged from a hospital within 50 min travel time. The dotted curve shows that patients from urban and non-Appalachian ZCTA's traveled consistently less time with 94 percent

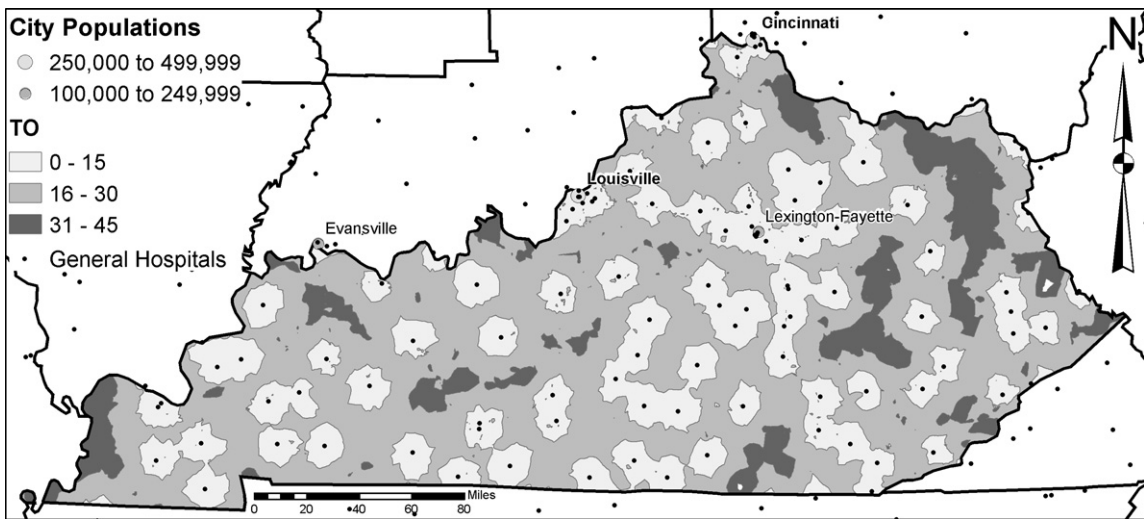


Fig. 5. The 15 min travel time bands from all general medical and surgical hospitals.

Table 1
Land area by distance from healthcare facility

Distance bands	Land area (miles ²)	Land area (%)
<15 min	12,854.74	31.81
>15 and <30 min	23,248.45	57.53
>30 and <45 min	4291.65	10.62
>45 and <60	16.64	0.04
>30 min	4307.81	10.66
Total	40,411	100.00

discharged from hospitals within 50 min 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 discharged, than non-Appalachian rural residents. The two curves, however, cross at approximately the point where 80 percent of the patients discharged from hospitals at less than 45 min travel time. A smaller proportion of rural non-Appalachian patients reside within 45 min 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 have longer travel times from the hospitals from which they discharged. It appears that efforts, such as the several Appalachian Regional Medical Centers, have succeeded in positioning hospitals nearer to many Appalachian residents, but the scale of rural Appalachia still leaves a larger group of people further from the hospitals they use. [Cromley and McLafferty](#) noted previously that access does not guaranty utilization (2002, p. 235). Choice of which service to use can be influenced by many factors such as family networks, perceptions of particular service centers, length of waiting for scheduled appointments, desire to see particular doctors, and cost. Clearly, in addition to geographic accessibility, there are other obstacles limiting utilization of the most accessible hospitals.

The relationship between distance and health indicators

All variables, except for percentage of terminal discharges, are positively spatially associated (Table 2). The measures of travel time have Moran's I values ranging from 0.2112 for the mean travel time to facilities actually used to over 0.8506 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 but those at greater distances as well. 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

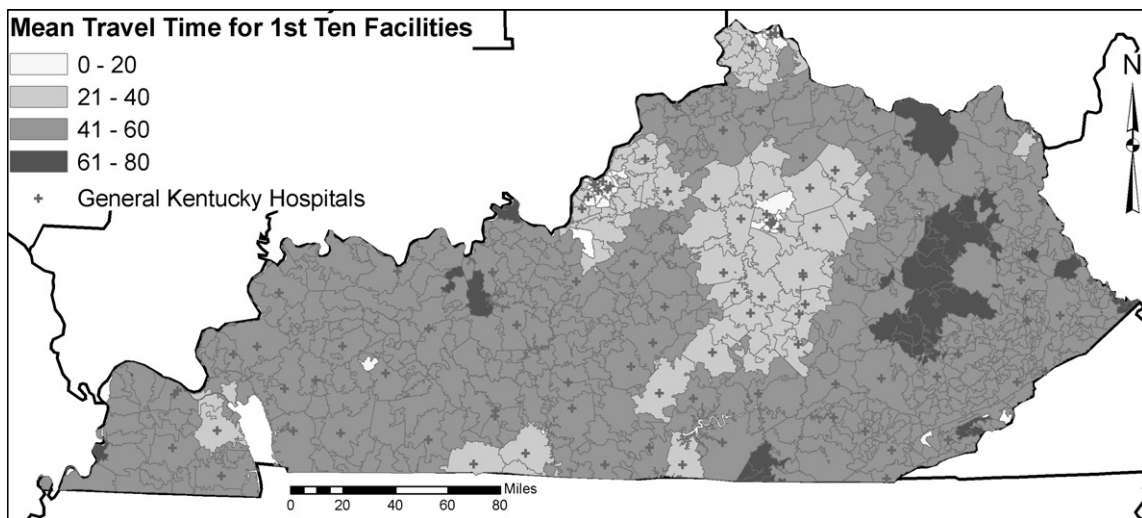


Fig. 6. Map of mean travel time in minutes to the nearest 10 general medical and surgical hospitals.

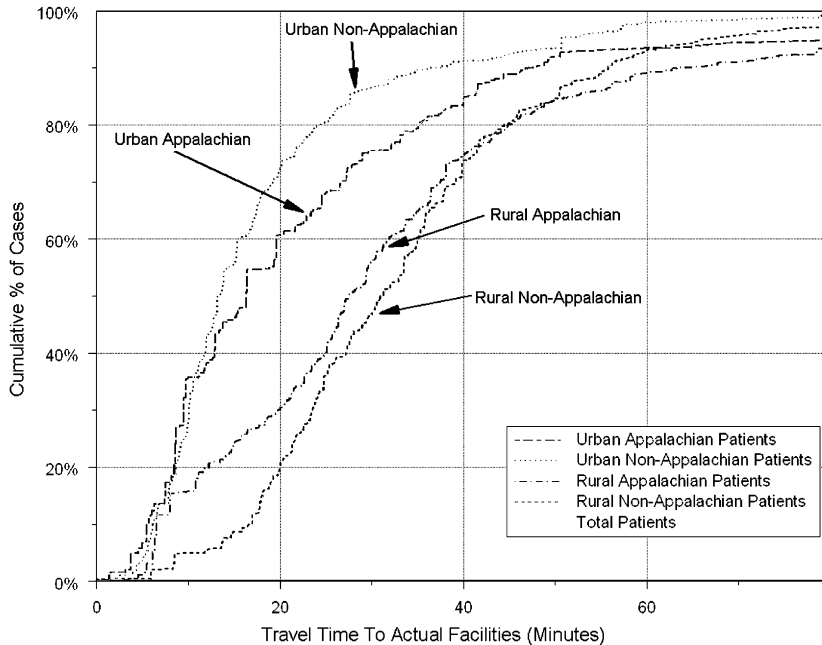


Fig. 7. Chart of the cumulative proportion of cases against travel time to used facilities.

Table 2
Results of univariate Moran's *I*

Variables	Moran's <i>I</i>	<i>P</i> -value
Mean travel time to used facility (min)	0.2112	***
Minimum travel time (min)	0.4895	***
Mean travel time to nearest 25 facilities (min)	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: *** $P \leq 0.001$, ** ≤ 0.01 , and * ≤ 0.05 .

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 utilization rates. Several small clusters of low utilization rates are present in southwestern rural Kentucky. The most distinct

Table 3
Results of bivariate Moran's *I* against mean travel time to nearest 25 facilities (min)

Variables	Bivariate Moran's <i>I</i>	<i>P</i> -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: *** $P \leq 0.001$, ** ≤ 0.01 , and * ≤ 0.05 .

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 3). 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 moderate level 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 (Fig. 8). In addition, the weak and insignificant association with percentage of terminal discharges suggests that travel time is not directly affecting hospital outcomes.

Bivariate Local Moran tests of these variables against utilization rates for heart-related ACS conditions provide weaker results (Table 4). 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.

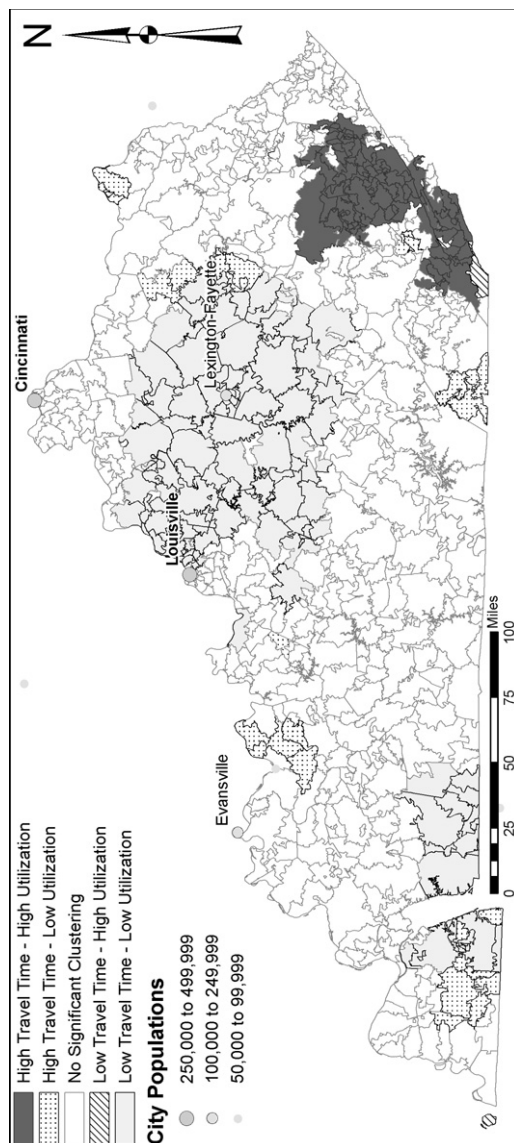


Fig. 8. Bivariate LISA cluster map of travel time against utilization rate.

Table 4

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

Variables	Bivariate Moran's <i>I</i>	<i>P</i> -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: *** $P \leq 0.001$, ** ≤ 0.01 , and * ≤ 0.05 .

Table 5

Comparison of population characteristics by distance from healthcare facility

Variables	Travel time from healthcare facility (mean values) (min)		
	15	30	45
No fuel (%)	0.23	0.2	0.2
No plumbing (%)	1.17	3.1	4.9
Phone (%)	95.3	94.1	91.6
Owner occupied (%)	66.2	80.8	79.3
Families in poverty (%)	13.6	14.0	21.3
White collar workers (%)	28.0	24.1	21.4
Median HH income (\$)	34,954.8	34,170.0	25,456.3
High school ed. (%)	74.3	68.9	59.6
Unemployed females (%)	6.4	6.3	7.8
Unemployed males (%)	6.6	6.2	8.9
Unemployment (%)	6.5	6.2	8.6
Age < 18 (%)	23.5	25.5	25.2
Age 18–64 (%)	62.4	62.6	61.4
Age 65+ (%)	14.1	11.9	12.7

Characterization of impacted populations

This study divides the population of Kentucky into groups based on their proximity to medical and surgical hospitals using the 15, 30, and 45-min travel-time increments. About 64.2 percent of the population of Kentucky resides within the 15-min travel time radius from any general medical and surgical hospital, 31.7 percent between a 15 and 30 min travel time and 4.1 percent between 30 and 45 min travel time. Table 5 lists the characteristics of each of these groups. Several noteworthy trends are apparent from this table. First, residents at greater distance from medical and surgical hospitals have higher levels of unemployment, lower education, and lower median household incomes, on average, as compared to groups that reside in closer proximity to these facilities. Fewer are white-collar workers and a higher proportion is impoverished and without complete plumbing. Lower percentages of the population have telephones. The degree of material deprivation, loosely defined by the 11 variables, increases as proximity to medical care facilities declines. For example, there is an observable difference of almost \$9500 average

median household income between those closest to and furthest away from facilities. Likewise, poverty rates increase seven percentage points between the two areas. These profiles provide a general overview of the status of the populations in these travel time zones. A simple ANOVA reveals that the differences between these three groups are significant across all variables except the percentage of households without fuel, percent female unemployment, and percent of population 18–64.

The geographic distribution of these populations, particularly those that live furthest from facilities and have the highest levels of deprivation are also noteworthy. Map 8 illustrates the distribution of areas at greatest travel distance from medical and surgical hospitals. It is clear that areas within the Appalachian region are far more likely to have lower levels of accessibility than other areas in the state. Pockets of high travel times and deprivation are particularly extensive in the northeastern Appalachian counties. While the total population of Appalachian Kentucky comprises only 28.2 percent of the total population of Kentucky, fully 64.8 percent of the total population residing at distances between 30 and 45 min travel time to a medical or surgical hospital live in Appalachia.

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. This paper examines 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 facilitates 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.

This study maps travel time using arbitrary 15, 30, and 45-min bands to explore the areas that are potentially underserved. Refining our understanding of the relationship between procedures performed at hospitals, and the distance traveled by patients for those procedures, requires further research. What constitutes too far to travel for healthcare? Which procedures must be widely distributed geographically and which can be productively limited to fewer, higher-order healthcare 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 healthcare 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 utilization of facilities.

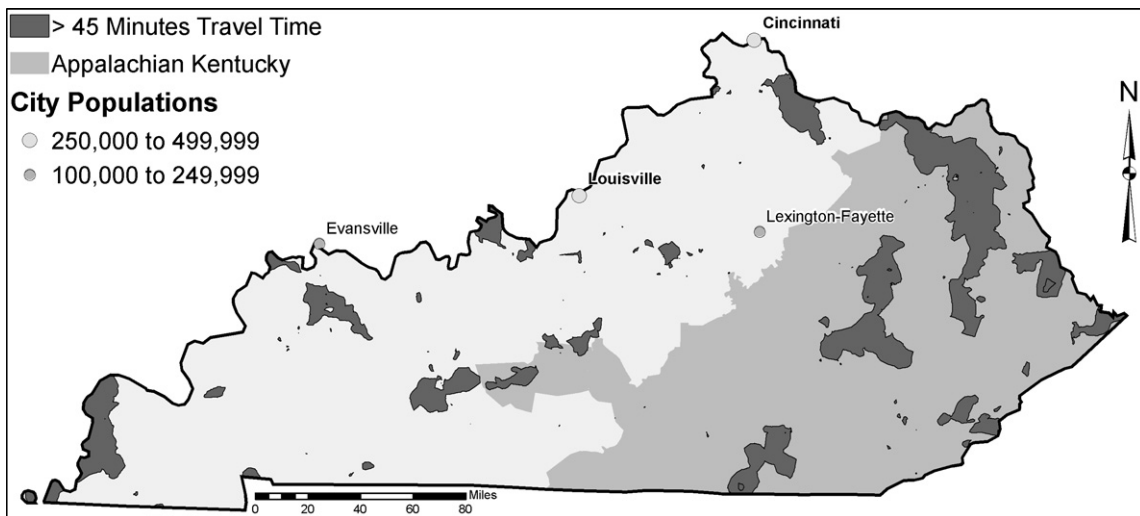


Fig. 9. Areas in which the population has more than 45 min travel time to the nearest healthcare facility.

The results of this paper show that general medical and surgical hospitals are widely distributed in Kentucky and that most of the Kentucky population resides in close proximity to general medical and surgical hospitals. This is not surprising given that Freeman et al. (1987, p. 15) observe that “closing the rural/urban gap in access to health services has been a national goal for many years”. The results of this study, however, call into question the generalizability of their conclusion to all rural areas: “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 et al., 1987, pp. 15–16). In 40 percent of Kentucky’s rural counties, at least some proportion of the population live more than 30 min from a hospital. In some cases, such as Owsley and Carter counties (both in Appalachia), nearly the entire area of the county exceeds this travel time. Patches of the longest travel times extend to over 60 min from any hospital and are located almost exclusively in the rural areas of eastern Appalachian Kentucky (Fig. 9).

Populations with the least accessibility to medical and surgical hospitals are also those that have the greatest levels of material deprivation, as measured across the 11 aforementioned variables. From a policy perspective, this is problematic given the high levels of utilization for residents of these areas. Several additional factors may be at work, for example, do individuals put-off treatment because of poor access thereby increasing the severity of the condition once treatment becomes imperative?

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. Tempering this finding, however, is the disproportionately large segment of the population with the least access that is located within the Appalachian region. Despite investment in this region, the majority of Kentucky residents with restricted accessibility to medical facilities are still located in this region, although overall residents of Appalachian Kentucky comprise less than one-third of the total state population.

Finally, our results demonstrate an urban–rural difference in geographical accessibility to general medical and surgical hospitals. Geographical accessibility to healthcare 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 employment, income, insurance status, gender, age, race, and education.

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