PRIMARY CARE SERVICE AREAS COMPARED TO ESTIMATED TRAVEL TIME SERVICE AREAS FOR PRIMARY HEALTH CARE

by

Sean Corrigan Finnegan
A Thesis
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Master of Science
Geographic and Cartographic Sciences

Committee:

____________________	Dr. Nigel Waters, Thesis Director
____________________	Dr. Kevin Curtin, Committee Member
____________________	Dr. Timothy Leslie, Committee Member
____________________	Dr. Peggy Agouris, Department Chair
____________________	Dr. Timothy L. Born, Associate Dean for Student and Academic Affairs, College of Science
____________________	Dr. Vikas Chandhoke, Dean, College of Science
Date:_______________	Summer Semester 2012 George Mason University Fairfax, VA

Primary Care Service Areas Compared to Estimated Travel Time Service Areas for Primary Health care

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at George Mason University

by

Sean Corrigan Finnegan
Bachelor of Science
University of Missouri, Kansas city, 2005

Director: Nigel Waters, Professor
Department of Geography and Geoinformation Science

Summer Semester 2012
George Mason University
Fairfax, VA

DEDICATION

This is dedicated to all of my family and friends who have encouraged me to take this next step in my academic career and for those who didn't have the opportunity to do the same.

ACKNOWLEDGEMENTS

I would like to give a special thank you to my friends and family that went above and beyond by encouraging me to complete my goals and attempting to understand what I do. Thanks to Dr. Nigel Waters who helped shape this thesis and Drs. Curtin and Leslie for their invaluable advice and support that helped make this thesis worthwhile. I would also like to thank the fantastic team at the Robert Graham Center, especially Dr. Jennifer Rankin, who acted as sounding boards and encouraged me to move forward with this work and complete this step in my academic career. Finally a special thanks to the American Academy of Family Physicians who helped fund my education at George Mason University.

TABLE OF CONTENTS

	Page
List of Tables	vi
List of Figures	vii
List of Abbreviations	viii
Chapter One – Introduction	1
Section One – Introduction	1
Section Two – Background	2
Chapter Two – Literature Review	6
Section One – Review	6
Section Two – Literature Review Conclusions	19
Chapter Three – MethodS	24
Section One – Study Area	24
Section Two – Methods	27
Chapter Four – Results	34
Chapter Five – Discussion	53
Section One – Data Limitations	53
Section Two – Discussion of Results	54
Chapter Six – Conclusions	62
Section One – Conclusions	62
Section Two – Future Research	64

LIST OF TABLES

Table Page
Table 1: Specialties and NPI Codes Used for definition of Primary Care........................ 25
Table 2: PCSA and Estimate Drive Time Coverage, Oregon... 33
Table 3: PCSA and Estimate Drive Time Coverage, North Carolina............................... 34
Table 4: PCSA and Estimate Drive Time Coverage, Missouri 35
Table 5: 20, 30 and 40 Minute Drive Time Polygon Estimated Coverage....................... 44

LIST OF FIGURES

Figure Page
Figure 1: Euclidian Distances Compared to Distances Based on Road Networks (Map) 10
Figure 2: Estimated Drive Times to Stroke Centers in Rural Tennessee (Map) 11
Figure 3: Number of Pediatricians to Children in Washington DC (Map)....................... 13
Figure 4: PCSAs and Corresponding Estimated Drive Times in Missouri (Map) 24
Figure 5: PCSAs and Corresponding Estimated Drive Times in North Carolina (Map).. 25
Figure 6: PCSAs and Corresponding Estimated Drive Times in Oregon (Map).............. 26
Figure 7: Process Flow of Data for Methods (Flow Chart) 32
Figure 8: Populations of PCSAs vs Populations Outisde DriveTimes (Bar Chart).......... 38
Figure 9: Populations of PCSAs vs Populations Outside Drive Times (Scatter Plot)...... 40
Figure 10: Percent of PCSA Population Outside of Drive Time in MO (Map) 42
Figure 11: Percent of PCSA Population Outside of Drive Time in NC (Map) 44
Figure 12: Percent of PCSA Population Outside of Drive Time in OR (Map) 45
Figure 13: 20, 30 and 40 minute Estimated Drive Time and PCSA in MO (Map) 48
Figure 14: 20, 30 and 40 minute Estimated Drive Time and PCSA in NC (Map) 49
Figure 15: 20, 30 and 40 minute Estimated Drive Time and PCSA in OR (Map) 51

LIST OF ABBREVIATIONS

American Medical Association	AMA
Community Health Center	CHC
Feature Class Code	FCC
Economic Research Service	ERS
Geographic Information Systems	GIS
Health Professional Shortage Area	HPSA
Health Resources Services Administration	HRSA
Medically Underserved Area	MUA
Office of Rural Health Policy	ORHP
Patient Protection and Affordable Care Act	PPACA
Primary Care Service Area	PCSA
WWAMI Rural Health Research Center	RHRC
Rural-Urban Commuting Area	RUCA
Triangulated Irregular Network	TIN
Two Step Floating Catchment Area	2SFCA
United States Department of Agriculture	USDA
United States Geologic Survey	USGS
Unique Physician Identification Number	UPIN
Washington, Wyoming, Alaska, Montana, and Idaho	WWAMI
ZIP Code Tabulation Area	ZCTA

ABSTRACT

PRIMARY CARE SERVICE AREAS COMPARED TO ESTIMATED TRAVEL TIME SERVICE AREAS FOR PRIMARY HEALTH CARE

Sean Corrigan Finnegan, M.S.

George Mason University, 2012

Thesis Director: Dr. Nigel Waters

Context: Healthcare service areas allow for the measurement of health outcomes, assessment of health care services utilization and healthcare shortage area designation. Healthcare service areas have been at the center of policy decisions and are vital for the efficient distribution of federal and state funds.

Objective: This research compared rural Primary Care Service Areas (PCSAs) to estimated 30-minute drive-time polygons centered on a primary care service access point within each PCSA.

Design: Rural PCSAs were compared to estimated 30-minute drive-time polygons created in ArcGIS based on average drive times along a road network to primary care access points. Population counts from the 2010 Census at the block level were used to calculate the population coverage of the PCSA and the estimated drive-time polygons. A quantitative comparison was made based on the difference in area and population coverage by each corresponding drive-time and PCSA polygon and the percent of population that was included in the PCSA, but outside of an estimated 30-minute drive time.

Setting: Rural Missouri, Oregon and North Carolina

Results: 72 percent of the PCSAs in the sample contained people that live outside of the 30-minute estimated drive-time polygon accounting for 14 percent of the total population living in the sample PCSAs. When considering the PCSAs that had the most people living outside the 30-minute drive-time polygon, 42.4 percent of the population lived outside of that drive-time polygon. An additional 18.1 percent of the people in these PCSAs were covered when considering 40-minute estimated drive-time coverage, but an additional 28.4 percent fell outside of the drive time when assessing the 20-minute estimated drive-time coverage.

Conclusions: The utilization of estimated drive, or travel, times may be an effective addition to the creation process for PCSAs and the evaluation of geographic access to primary health care, utilization and health outcomes.

CHAPTER ONE – INTRODUCTION

Section One – Introduction

Health care service areas have been created for the assessment of care usage and measuring health outcomes. Additionally these areas have been used to answer policy questions and designate medical care shortage areas for the distribution of both federal and state funds. A few suggested ways of creating service areas are utilizing previously defined geographies (such as Census Tracts, ZIP Codes, or counties) creating Euclidian distance buffers, and creating service areas based upon estimated travel times along road networks to ensure that populations can easily access health care services.

Accessibility issues to primary care and other services in rural areas are both abundant and have been discussed in detail in the literature (Fiedler, 2002; Joseph and Bantock, 1982; McGrail and Humphreys, 2009). Due to urbanization more physicians are choosing to locate at large university hospitals which are generally located in urban areas and fewer are choosing to serve the rural populations. This is putting a strain the remaining physicians in rural areas and the distances some rural populations have to travel to access health services. Additionally the sparse and poorly maintained road networks in rural areas sometimes cause longer travel distances and slower travel times further compounding the issues of accessibility for rural populations (Fiedler, 1981).

In this study two of these methods, previously defined geographies called Primary Care Service Areas (PCSAs) and estimated 30 minute travel times along road networks, were compared based on coverage of area and populations. This was done to evaluate how well PCSAs consider travel time and how different the two areas, and populations within the service areas are. This comparison was carried out by utilizing ArcGIS to calculate both the coverage area and the estimated population coverage of both of these geographies. Additionally, the population that is covered in the PCSAs, but fell outside of the estimated 30 minute drive time polygons was analyzed as a proxy for populations without sufficient access to primary care services within their PCSA.

Section Two – Background

The use of geography in the study of health care has been extensive and covers many different aspects. Possibly starting with the epidemiological map created by John Snow in 1854 looking at cholera outbreaks in London, geography was recognized as an important component of public health and health care (Johnson, 2006). Besides the initial implications for its importance in epidemiology, geography has proven to be vital in the application of medical care delivery and in the case of geographic accessibility to medical care for the general public (Joseph and Bantock, 1982; Guagliardo, 2004). In looking at the geographic access issue, researchers have considered a variety of ways to assess access and to locate areas of underservice, or health care shortages. Population to provider ratios within specified geographies has been one of the mainstays for these assessments. However, the two-step floating catchment area, Euclidian distances and estimated service areas based on transportation network distance and travel time have all been proposed as alternatives to the simple, but understandable provider to population ratios (Guagliardo, 2004; Pedigo and Odoi, 2010; Parker and Campbel, 1998).

To address a more specific health care service, access to primary care for Americans has long been argued to be important for limiting health disparities and lowering the cost of health care (Guagliardo, 2004), but the measuring of access is often challenging and complex. Recently efforts to ensure access to primary care have been renewed with funding made available through health care reform included in the Patient Protection and Affordable Care Act (PPACA). While this law is struggling with the challenges of budget cuts and constitutionality it is still expected to provide billions of dollars over the implementation period to assist in the provision of access to medical care for millions more Americans. This will primarily be done by requiring the extension of insurance coverage to millions more Americans through Medicare and Medicaid, but the way in which shortages and underservice designations are applied will also have to be assessed.

The creation of service areas for the assessment of sufficient access to medical care has been attempted as a way to evaluate geographic access to care, or recognize possible areas of medical care shortage. For example, the Dartmouth Institute has developed a methodology to assign Primary Care Service Areas (PCSAs) based on Medicare claims data and some Medicaid and private insurance claims. By using the US Census Bureau’s equivalent of ZIP Codes known as ZIP Code Tabulation Areas (ZCTAs) they have created PCSAs for almost the entire United States as proposed geographies for the assessment of health care outcomes, and medical care shortages and underserved areas. These PCSAs are emerging as one possible model for addressing geographic access to primary care and are being proposed as rational areas for the evaluation of shortage and underservice designations. However, their rationality has been questioned for use throughout the entire country. These questions are often more abundant when evaluating rural areas of the United States where the barrier of distance becomes more relevant than in highly populated urban areas.

Another more basic method to create rational service areas that is discussed in the literature is the creation of estimated drive times to access points (Parker and Campbell, 1998). When considering possible catchment areas of a primary care access point, some may consider the most reasonable, or rational service area would be that of the population that can reach an access point in a specific period of time. When considering federal medical shortage areas, the Health Resources Services Administration (HRSA) begins to assign points for Health Professional Shortage Areas (HPSAs) if the estimated distance (or time) it takes to gain access to primary care services is 20 miles (30 minutes), or greater. However, this method has often been challenged as too time consuming or computationally challenging in order to be assessed for the entire country.

In this study, estimated drive times were calculated based on road networks provided by Esri. These drive time polygons were then quantitatively compared through analysis in ArcGIS (Geographic Information Systems) based on the area and population coverage in relation to the PCSA's area and population coverage. This was conducted in order to assess how one proposed rational service area, PCSAs, covers its population based on a measure of geographic accessibility determined by estimated drive times as a function of distance and speed along specific segments of the road network.

Both the area and the coverage of population between these two different geographies were evaluated by looking primarily at the differences of population coverage as well as a preliminary look into the actual area in square miles covered by the PCSAs versus those covered by the estimated drive times. A specific focus was placed on the 30 minute estimated drive time as it has been implicated as an important federal policy-based distance for accessing primary care services. Additional analysis on 20 and 40 minute estimated drive times were conducted on a subset of the sample PCSAs to assess possible error in the results in the case of shorter or longer actual drive times. This study will help inform policy makers as to possible methods that should be considered to address geographic accessibility to primary care when creating service areas. It is also the intention of the author that this research develops an initial method to help identify PCSAs that may not necessarily be representing the populations seeking care within them and impress the possible importance of considering estimated drive times as a function of travel time in the practice of creating health care service areas.

CHAPTER TWO – LITERATURE REVIEW

Section One – Review

There is a significant amount of literature on the accessibility and delivery of medical services and much of the literature successfully conveys the importance of location in regards to accessibility (Joseph and Phillips, 1984; Curtis, 1982; Shanon et al, 1975). Some researchers focus on the accessibility and delivery of specific services for specific maladies such as breast cancer, stroke and myocardial infarction (Richards et al, 1999; Pedigo and Odoi, 2010; Patel et al, 2010) while others focus on emergency care (Carr and Addyson, 2010) and access to primary care (Parker and Campbell, 1998; McGrail and Humphreys, 2009; Guagliardo, 2004; Lou and Wang, 2002).

One obvious divide on the topic of accessibility to medical care is the difference between urban and rural settings. Both of these settings have unique characteristics, and methods applied to rural areas do not often fit urban areas very well and vice versa. Due to the compactness and relative ease of mobility observed in urban areas, accessibility of services becomes less about geographic access and more about affordability and convenience. On the contrary, in rural areas traveling long distances for services is sometimes a necessity and not a choice. Because geography and distance affect each of these settings differently most geographers choose one or the other in which to conduct their research and test their methods (Guagliardo, 2004; Lou and Wang, 2002; Patel et al 2010).

Geographic Information Systems (GIS) have proven to be extremely helpful to public health research and can help address multiple issues in this field. Gerard Rushton wrote a paper on different uses and methods for GIS in Public Health (Rushton, 2003). From the multiple ways of mapping disease rates, spatial clustering, smoothing out of data, to the relation of disease rates and environmental issues, Rushton lays out how GIS has worked to help visualize and analyze multiple facets of public health. Additionally, the idea of using GIS to help measure accessibility to primary care and other medical care has been discussed in detail then demonstrated in rural and urban settings in order to display the power of this tool in addressing issues of access (Phillips et al, 2000; Lou and Wang, 2003; Parker and Campbell, 1998).

While the focus of this literature review is on the applications of GIS and access to primary medical care, there are various methods used within GIS and articulated in the literature in order to assess accessibility and determine areas with accessibility barriers, or shortages of medical care providers. McGrail and Humphreys (2009) look at the two-step floating catchment area method while others focus on specific geographies, such as counties or ZIP Code Tabulation Areas (ZCTAs) to delineate need or accessibility (Konrad et al, 2009; Goodman et al, 2003). Parker and Campbell describe a number of methods that can be utilized within a GIS to evaluate accessibility to medical care in Scotland. The major difference they noted were that the straight line paths from patients to providers, or simple Euclidian distance bands around providers cover much greater areas than those showing distances based on road networks from the providers (Parker and Campbell, 1998). These same differences have been pointed out in other works based on accessibility to public transportation (Biba et al, 2010).

One of the first questions that many researchers have attempted to answer when addressing access to care is the complexity of the word access. While in the 19th century distance was recognized as a barrier to access (Hunter et al, 1986), this word has been further analyzed and defined so that it can be better explained. Guagliardo interprets the different aspects of access well in his paper on spatial accessibility to primary care. He first explains that it is a word that can have two separate meanings. He states: "… it is both a noun referring to potential for healthcare use and a verb referring to the act of using or receiving healthcare" (Guagliardo, 2004). These are important differences to note when referring to access to care and it is important to understand which of these definitions you are referring to when approaching the topic. In this study the focus was primarily on the potential for healthcare use.

Guagliardo refers to a paper by Penchansky and Thomas where they outline the five different dimensions of access: "availability, accessibility, affordability, acceptability and accommodation." Although all are important, the latter three do not directly address space or distance issues, but should be considered when addressing specific populations such as those considered to be living on low incomes, or living at less than 200 percent of the federal poverty level. However, the first two of these directly address what Guagliardo and others refer to as "Spatial Accessibility" (Guagliardo, 2003). In

Guagliardo's research and most others reviewed here, availability and accessibility are the two dimensions being addressed.

One of the many different methods used to assess the availability portion of accessibility is physician to patient ratios. This method seems to be the most basic and straightforward of all the methods used because it is a simple numerator and denominator function that returns the size of the population (the number of patients or some other variable), as a ratio to each physician. This method can be applied to various levels of geographies, from national and state levels, down to Census tract and block group levels. While it delivers a very straightforward answer as to how many physicians there are per the total or targeted population, it does not account well for distance impedances (Guagliardo, 2004). This can be seen within larger and smaller geographies. On the larger end (state or national level), it can be assessed that there are either enough or not enough physicians in a specific geographic area, but the question of where the lack or surplus of physicians is located is not answered. In the smaller geographies, such as Census Tracts or Block Groups, these calculations do not account for populations crossing these often invisible administrative boundaries (Guagliardo, 2004).

Another method that is often perceived as straightforward for the assessment of access to medical care is the calculation of straight line distances, or Euclidian distances, to care. This method simply draws concentric circles around an access point in order to assess the straight line distances from an access point to all areas around it. From this it is often seen that calculations of populations within the set distance are conducted to assess the number of those within Euclidian distance and the numbers outside. While again, this is a very direct delivery of information with straight line distances two things are not considered. One, it is rare that those distances can be traveled exactly in a straight line, and two, populations are not necessarily evenly distributed. Generally people have to travel along already created roads and paths, or networks, in order to access the point in question (Biba et al, 2010). As seen in Figure 1, when these actual paths are compared to the Euclidian distances they can often be quite different (Parker and Campbell, 1998). Additionally, it has to be understood that the assumption is that populations outside the area will not access the point, and populations inside the area will not travel outside.

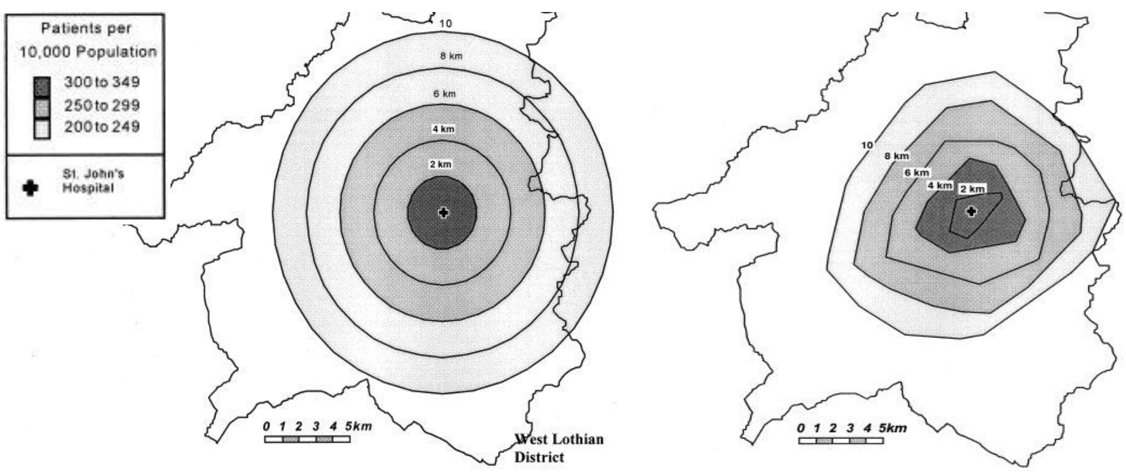

Figure 1: Euclidian distances (left) compared to network based distances (right) (Parker and Campbell, 1998).

As introduced in previous paragraphs, an alternative method for addressing access to care is distance according to estimated travel times. To be more specific, travel times are calculated by assessing travel distance along a road network and correcting for speed limits, turn impedances, road connectivity and occasionally other variables such as traffic. In a study on rural low income areas this idea of travel times is addressed and visualized by Pedigo and Odoi (2010) where they estimate 30, 60 and 90 minute travel estimates to cardiac and stroke centers based on network analysis considering connectivity, speed limits, and turn impedances. This method that can be seen in Figure 2 was demonstrated in an effort to show “disparities in geographic accessibility” for these sometimes low income populations in rural areas of Tennessee. The authors further suggest alternative travel arrangements such as air ambulances to correct these inequalities in accessibility for emergency medical needs (Pedigo and Odoi, 2010).

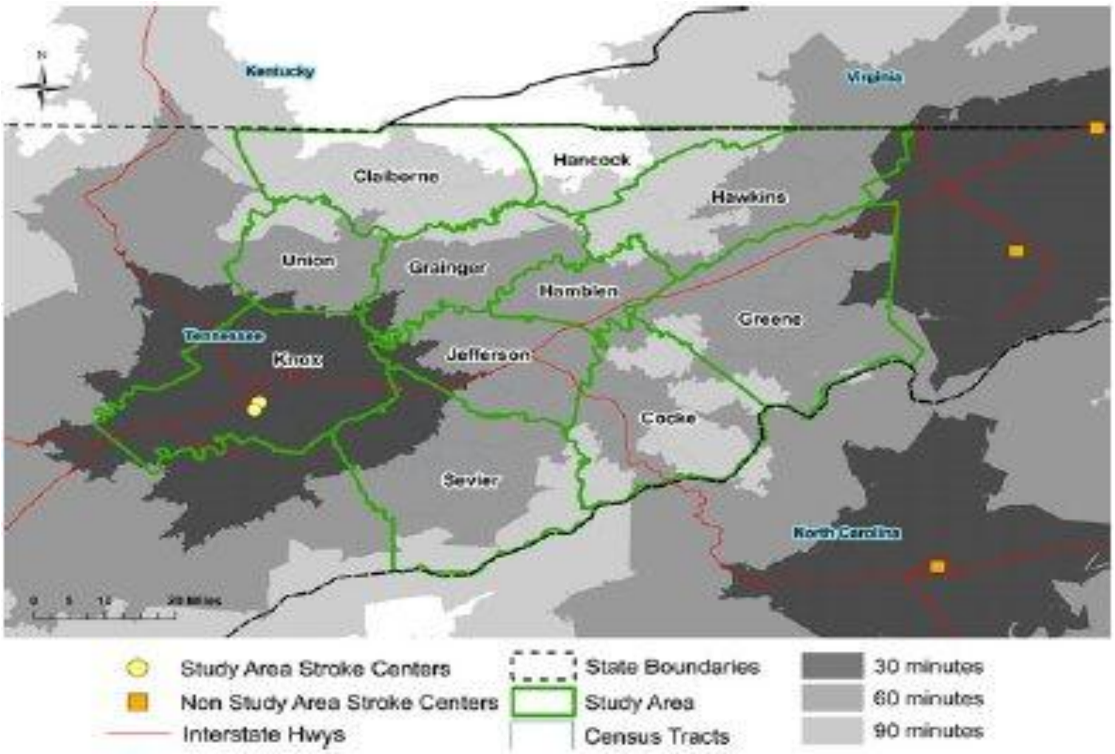

Figure 2: Estimated drive times to stroke centers in rural Tennessee (Pedigo and Odoi, 2010)

In another method and setting, Guagliardo assesses accessibility of primary care in urban areas for children by assessing the number of pediatricians per child population. He notes that distance is less of a barrier in urban settings and the ratio of pediatricians available within areas is more compelling. However, Guagliardo utilized methods that allowed him to look at a finer scale than ratios within previously outlined boundaries such as census tracts. By applying the Gaussian kernel density method to both numbers of pediatrician services based on geocoded locations and child populations according to census boundaries, he created two separate surfaces that indicated numbers of children and pediatricians for a 1/10th mile grid covering Washington DC (Guagliardo, 2004). From this he could combine the two layers in order to calculate a child population to pediatrician ratio. This process was conducted to smooth out the data that is retrieved when looking at only administrative or census boundaries and can be seen in Figure 3. He argues that this analysis can be much more accurate and relevant in urban areas (Guagliardo, 2004).

However, Guagliardo lists in detail all of the caveats, or possible issues related to this method. He used a 3 mile radius cone around the pediatrician locations as a distance thought to be reasonable for patients to travel to services. Furthermore a simple Gaussian distance decay function (or normal curve) may not always be the best option. There were no corrections made for transportation choices which may affect both the distance decay and the cone applied to the model. Finally, Guagliardo admits that the cone applied is the same as straight line distances and decay along actual road networks would be more desirable (Guagliardo, 2004).

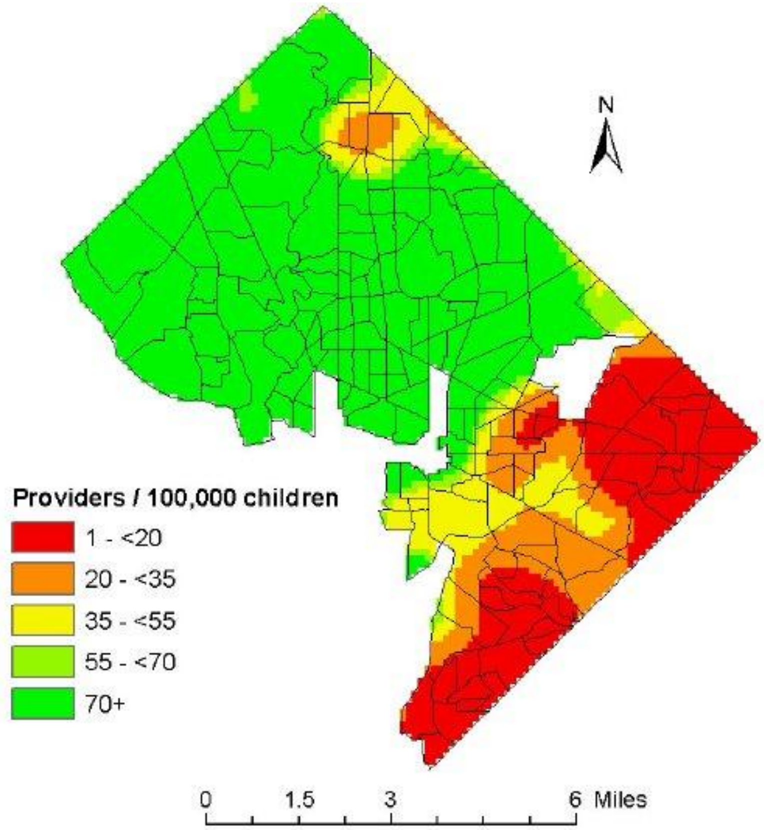

Figure 3: Number of pediatricians vs. the number of children (Guagliardo, 2004)

In studies by Lou and Wang, as well as McGrail and Humphreys another method is introduced. The two step floating catchment area (2SFCA) is advocated as a better assessment of accessibility when compared to physician to population ratios. However, its use is still cautioned due to a number of reasons outlined by McGrail and Humphreys. In some regards the 2SFCA is not much different from the cones that were used in the kernel density model from Guagliardo. First, a distance is chosen and a window is created, then a gravity model is applied to the window to adjust for certain variables, in this case population, and it is assumed that the population within that adjusted distance can gain access, and the populations outside cannot gain access. The difference in this study is that the distance in the 2SFCA is based on an estimated travel time where the distance in Guagliardo's study was simple Euclidian distance. Additionally McGrail and Humphreys admit that the selection of the catchment area size can be problematic because it can either be too small, or if it becomes too large, the choice of access point and not accessibility becomes an issue (McGrail and Humphreys, 2009).

There are a few studies that have used actual patient reported household location data in order to assist in answering accessibility questions as well as defining service areas (Phillips et al, 2000, Goodman et al, 2003). On a local level, Phillips et al outlined how the use of GIS can be extremely useful when attempting to better understand access to health care. In doing so, they took actual patient household location data from a federally funded community health center (CHC) in Boone County Missouri and weighted them based on number of visits. They then created an actual service area for the CHC outlined by census tract geographies for both unique patients as well as numbers of visits. They compared this generated service area to the original target service area and discovered that when looking at the number of visits, the actual patients being served came from notably different areas than those that the community health centers had originally targeted (Phillips et al, 2000).

On a national scale, patient data has been used to help identify actual service areas for primary care based on patient locations from national, and some state, data sets (Goodman et al, 2003). In Goodman et al.'s study, funded by the Health Resources and

Services Administration, patient location data was derived from Medicare claims, Medicaid claims in six states and commercial claims from Blue Cross and Blue Shield of Michigan. Simply put, service areas were built out of 1999 ZIP Code areas based on actual patient locations for Medicare claims nationwide. There were some corrections to make sure that the areas were contiguous and some tests were run on the Medicaid and commercial claims data to test for use by the younger populations (Goodman et al, 2003).

This claims-based analysis of primary care service areas (PCSAs) was a unique approach that addressed the entire nation and attempted to assess primary care workforce and utilization trends. However, there were a number of limitations, some of which were addressed by the authors. First, the use of Medicare data deals specifically with populations over 65 years of age. Additionally, only 63 percent of Medicare beneficiaries sought primary care within their PCSA; while this is a majority of the beneficiaries and significant, considering the number of beneficiaries, nearly 40 percent of patients within PCSAs are seeking the majority of their care outside of the generated PCSA. Also, while the comparisons of the younger populations with Medicaid and commercial insurance were comparable they were not identical and differed sometimes significantly from the Medicaid claims data (Goodman et al, 2003). In addition, there also was a lack of consideration for actual travel times in regards to the accessibility of these primary care service areas. While considerations were taken for the populations within the groups of ZIP Code areas that were used to create the PCSAs, the road networks or travel distances were not considered.

In addition to distance there are other considerations regarding the topic of access to care. One of these is the perception of quality of care and another is simply choice. In a survey conducted for a study by Borders et al, patients in rural Iowa counties noted that perceived shortages of physician care, religious beliefs, private insurance coverage and perceived quality of local physicians were all associated, positively or negatively with reasons for bypassing local physicians and traveling farther for primary care (Borders et al, 2000). While these cases are fairly sporadic and somewhat irregular, geographic access to primary health care should acknowledge that they are a continuing challenge, and ways of measuring them may.

Also seen in the literature is an introduction to possible solutions to the distance barrier for access to care. One suggestion explored is telemedicine for the treatment of mental healthcare for veterans. A number of tests to assess depression, substance abuse, post-traumatic stress disorder and other psychological disorders have been conducted and proven to be beneficial. This type of "virtual" medical treatment helps removes the barrier of distance for specific care (Olden et al, 2010). While mental health care is not directly related to the vital signs and physical health of a patient, it is sometimes addressed in primary care settings. Offering some sort of preliminary screenings virtually by primary care physicians may assist in ameliorating the distance barrier for access to care by helping to stress the need for an in person visit, or to rule out the need for such.

As seen in much of the literature, data on populations is generally drawn from the US Census Bureau. This is especially easy to do when utilizing predefined geographies such as Census Tracts or Block Groups. However, when trying to define the population within an area that does not adhere to Census geographies certain assumptions must be made. With the acknowledgement that population is not evenly distributed within generated geographies, there are methods that are utilized to estimate the geographic coverage of non-uniform geographies. Some of these methods include GIS analysis to calculate the populations within Census geographies that are intersected by, completely contained within, or have their geographic centroids within the non-uniform geographies to determine population counts.

However, Biba, Curtin and Manca (2010) developed another more accurate method called the parcel-network method. In place of using census polygons with aggregated data they utilized cadastral, or parcel data, in order to calculate the number of people within walking distance to public transit. This method uses the most disaggregated data available which provides population counts at an even smaller geography, than Census Blocks, to assess population counts. In this research it is suggested that utilization of cadastral or parcel data is far more advanced in assessing actual populations that are within walking distance of public transit access points. This method proposes to reduce the overestimates of population counts that are often seen in studies utilizing some of the alternate methods.

There have been a few papers recently emerging that challenge the importance of estimated drive times claiming that they are not absolutely necessary. Jones et al (2010) wrote a paper that addresses the differences in actual distance along road networks between patients and hospital facilities compared to the Euclidian distances between the ZIP Code centroids of the patients address and hospital facilities. Acknowledging that not all researchers have access to, or computational ability to assess road networks in their research, they successfully prove that in these cases the differences in these distances are not statistically significant. Through this they suggest that if the network data, or computational ability are not available then use of distance from geographic centroids may be acceptable in place of the availability of network distance data.

More recently, a paper has emerged claiming that the straight line distances from Census Tract centroids to the nearest hospital is strongly correlated with travel distance (0.94) and even with travel time (0.91). While this paper demonstrates that there are strong correlations present between these measurements the also acknowledge that there are exceptions to these where the travel times and travel distance are much greater than the straight line distances. These differences, or exceptions, mostly occur in detailed coastal areas and where there are large geographic obstacles presents, such as lakes and rivers with few bridges (Boscoe et al, 2012).

Section Two – Literature Review Conclusions

While it is apparent that GIS is a powerful and vital tool for assessing issues related to access to health care there are multiple considerations that should be addressed as to the choice of methods used when analyzing access questions. While there are no perfect methodologies to date, the methods discussed in this review are widely used, but their limitations must be fully disclosed in order to accurately deliver the end outcomes and conclusions of the analysis. Considering that many of these studies are aimed at the dictation of policy it makes it even more important to discuss the limitations and possible inaccuracies so that poor decisions are not made and implemented into policies for access to primary care and furthermore all medical care.

Conceding that provider-to-population ratios and straight line, or Euclidian, distances may be the most simple to understand, these two methods can also be misleading as to the reality of the accessibility circumstances. Although each of the other methods (2SFCA, gravity models, kernel density method, and estimated drive times) do improve upon addressing questions to spatial accessibility, each have their own limitations and if not carefully considered and explained can be misleading as to the accessibility or lack thereof to primary care and other medical care. In regards to the creation of rational service areas based on spatial accessibility, estimated travel times along road networks seem to be the most basic when looking simply at the geography and distance portions of travel time. However, when assessing actual patient data, and quality of local healthcare, such methods are not always the most accurate.

The creation of PCSAs based on actual Medicare data is intriguing, but there are questions as to whether these areas address the general public as well as the special populations that are represented by the data sources. Additionally, it may be interesting to see how the estimated drive times to the service access points compare to the shapes and coverage of the PCSAs and if reaching a primary care service point within the PCSA is realistic, or rational, for all populations within them according to currently accepted distance or travel times as laid out by the Federal Government. Furthermore, although the PCSAs are derived from actual patient usage, on average, only 63 percent of the

Medicare beneficiaries sought care within their outlined primary care service area and thus PCSAs may not fairly address the entire general public within the PCSA.

The research of Jones et al (2010) attempted to prove that shortest paths along road networks are highly correlated with straight line distances from patients addresses and zip code centroids to admitting facilities. However, it does not address the issues surrounding the definition of service areas for the assessment of health care shortages. Furthermore, it did not address estimated travel time along the road nor the straight line distances. Also, the distances (up to 450 miles) they were considering stretched the correlations between the Euclidian distance and drive distances along the road networks which appears to have strengthened the correlation. Overall, this research does not sufficiently address issues of geographic accessibility.

In the work by Boscoe et al (2012), more proof that drive times may not be as vital in the consideration of travel time and therefore potential accessibility of services. However, the authors do admit that there are a number of special cases that do not hold true to the proof. While removing these cases from their sample of more than 66,000 didn't affect the correlations, they still exist. It is also quite possible that these special cases occur more often in rural areas where road networks are less developed. Again, Boscoe was not looking at an entire potential service area of a hospital, but simply shortest paths to them, from Census geography centroids.

It seems that the utilization of actual patient location data is the most compelling, but access to patient data is very challenging due to the rules of Health Insurance Portability and Accountability Act (HIPAA) of 1996 which helps protect the privacy and identity of patients. Therefore the majority of research has focused on aggregations of patient data or simply general population figures as provided by the US Census bureau, or in the case of Biba et al. cadastral data. While patient locations have proven to be extremely useful when assessing actual service areas of specific medical care, the research in this paper utilized simple population figures as patient data is difficult to acquire.

While the study of spatial accessibility of health care and the impedance of distance, or travel time, are extremely important, there are many reasons behind why patients chose to seek care where they do and the option of choice should also be acknowledged. Quality of local care is one of the reasons that people often seek medical care farther away from their home and therefore efforts towards supplying quality primary care physicians and continuing education for physicians in remote areas should be made. In addition, methods (such as telemedicine or mobile clinics) that utilize technology to overcome the challenges of spatial accessibility should be considered as possible tools for solutions until equal geographic accessibility for all populations is available.

This research challenges that the evaluation of travel time to primary care access points is important in the creation and evaluation of PCSAs and uses the method of estimated drive times in ArcGIS to assess the potential geographic accessibility of the populations within PCSAs to primary care service access points. While the population calculations using cadastral parcel and land uses data may be more accurate, the data is not as readily available in rural areas and for this initial test case may not be necessary.

Therefore, the population coverage of the two areas was calculated using census data and the differences in coverage were assessed based on quantitative differences in the coverage of both population and area. Due to the lack of readily available Census Block level data for age and race, the population's age and race distribution was not analyzed.

CHAPTER THREE – METHODS

Section One – Study Area

The comparison of estimated drive time service areas to PCSAs focused on rural PCSAs in the state of Missouri, Oregon and North Carolina. Missouri was selected as a test area due to familiarity by the author as well as the fact that it is considered in the literature of Phillips et al (2000). Oregon and North Carolina were selected in an attempt to get a sample from three different parts of the country (East, Central and West) and due to the availability of 2010 Census data. Figures 4, 5 and 6 show the three states with each of the eligible PCSAs and corresponding estimated 30 minute drive time service areas.

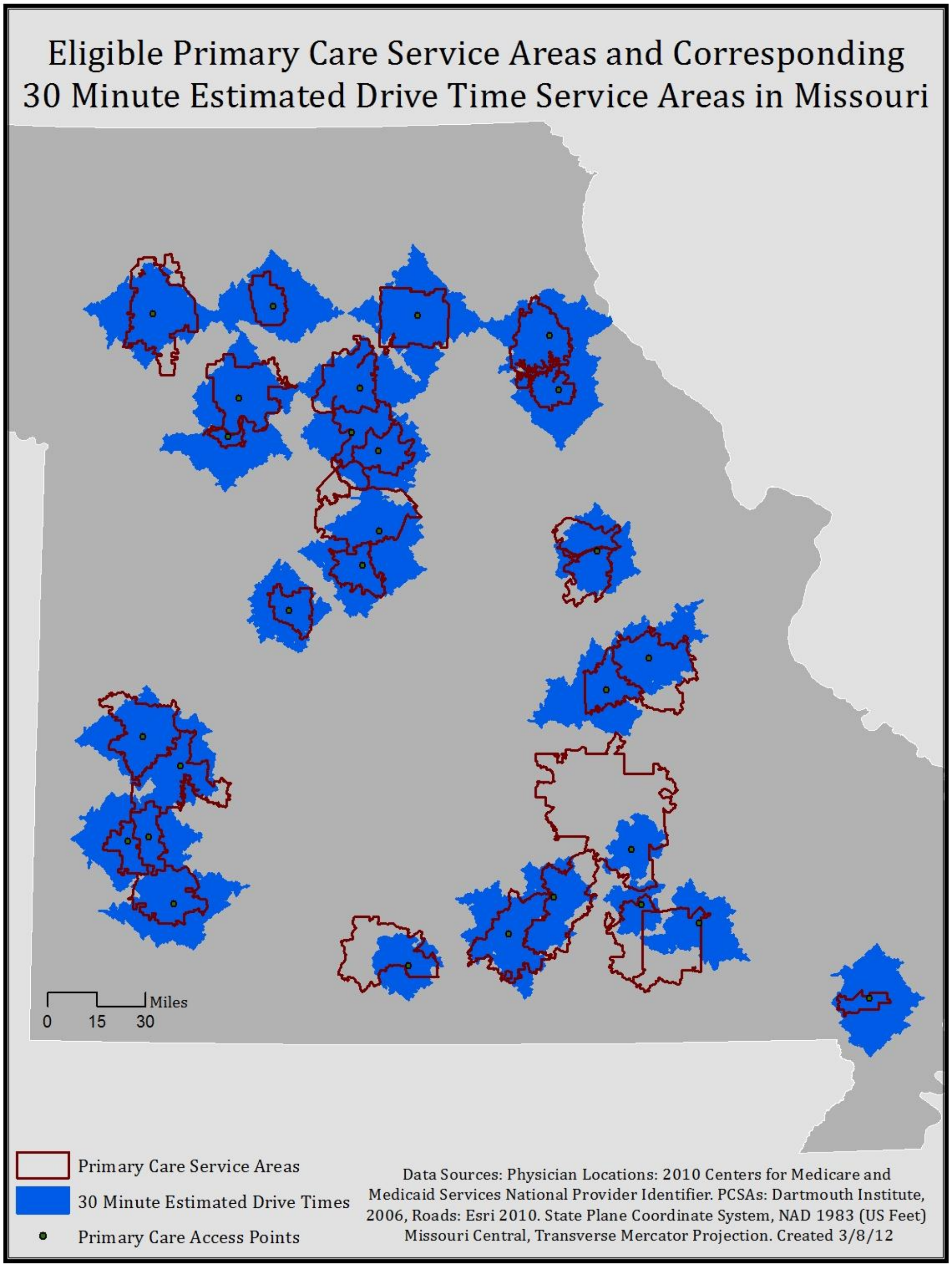

Figure4: Missouri Primary Care Service Areas and 30 Minute Estimated Drive Times.

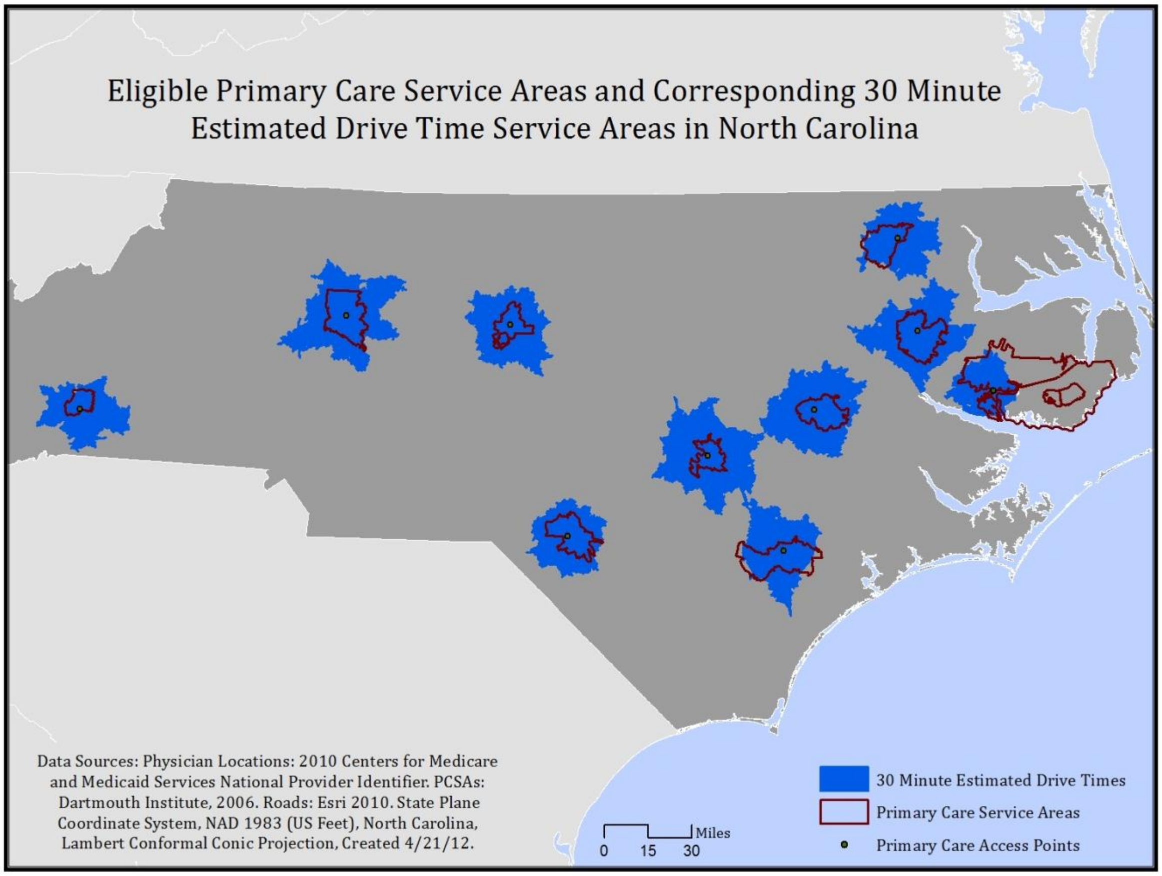

Figure5: North Carolina Primary Care Service Areas and Estimated 30 Minute Drive Times

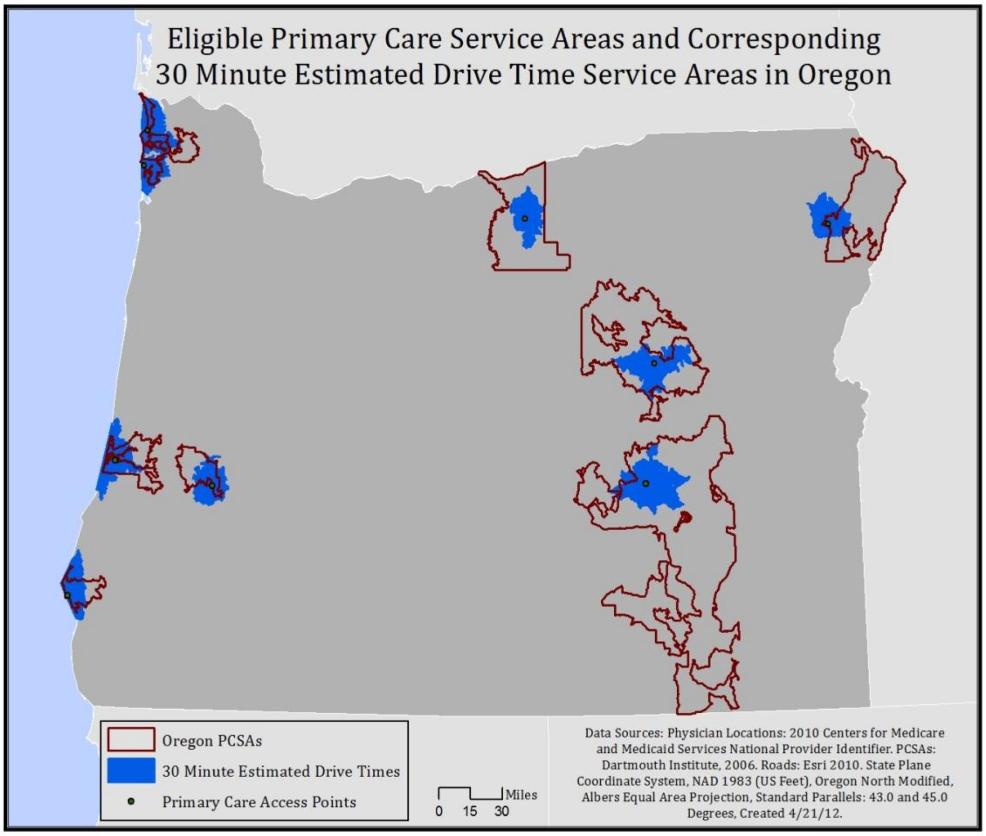

Figure6: Oregon Primary Care Service Areas and Estimated 30 Minute Drive Times.

Section Two – Methods

Primary care access points were selected from the Centers for Medicare and Medicaid Services (CMS) National Provider Identifier (NPI) database and the definition of primary care included specialties and sub-specialties of Internal Medicine, Family Medicine, and Pediatrics. A list of the NPI Codes that were queried to select the primary care access points is displayed in Table 1. Using SAS software the database of NPI codes was queried to select only physicians that had declared their primary specialty to be one of those considered to be primary care. Once primary care physicians were isolated and geocoded according to their “practice address” in the NPI database, these points were joined based on location to the PCSAs. Only PCSAs containing single primary care service access points were further analyzed based on the assumption that the single access point was used in the Dartmouth analysis as the access point for that PCSA.

Table 1: List of specialties and NPI codes used to isolate primary care providers.

Specialty	**Sub-Specialty**
Family Medicine - 207Q00000X	
	General Practice - 208D00000X
	Addiction Medicine - 207QA0401X
	Adolescent Medicine - 207QA0000X
	Adult Medicine - 207QA0505X
	Bariatric Medicine - 207QB0002X
	Geriatric Medicine - 207QG0300X
	Hospice and Palliative Medicine - 207QH0002X
	Sleep Medicine - 207QS1201X
	Sports Medicine - 207QS0010X
Internal Medicine - 207R00000X	
	Adolescent Medicine - 207RA0000X
	Geriatric Medicine - 207RG0300X
Pediatrics - 208000000X	
	Adolescent Medicine - 2080A0000X

30 minute estimated drive times were calculated based on a road shapefiles provided by Esri. The 30 minute drive time was selected as it is considered by the Health Resources and Services Administration (HRSA) to be acceptable travel time to access primary care services (HPSA designations) and was therefore the focus of this research, but 20 and 40 minute drive times were analyzed for a subset of the data and given some consideration and discussion. Drive times were calculated as an estimated travel cost

based on the length of each segment divided by the average speed according to the US Census Bureau's Feature Class Code (FCC). Turn impedances were considered, U-turns were allowed and restrictions were given to one way streets where the data was available. Segment connectivity is based on the general rules, according to Esri, that there are only connections to other road segments when two segments begin, or end at the same point.

Each road network was put into a North American Datum 1983 (US Feet) State Plane coordinate system for the state and zone in which the primary care access point resides. An equidistant projection was applied to the coordinate system in attempt to gain the most accurate measurement of length for each of the road segments within the states and zones. Once the length has been calculated for each segment within each state and zone, the cost, or travel time, was calculated by dividing the length by the estimated speed as defined by the US Census Bureau's Feature Class Code.

The generation of service areas utilized the Service Area tool in Esri's ArcGIS Network Analyst toolbox. This function employs Dijkstra's algorithm (Dijkstra, 1959) for shortest path functionality and creates polygons for the service areas "by putting the geometry of the lines traversed by the Service Area solver into a triangulated irregular network (TIN) data structure." However, it further states that "The polygon generation algorithm has additional logic to produce the generalized or detailed polygons and to deal with the many special cases that can be encountered (Esri, 2010)." The service areas are calculated by applying the "cost" to the TIN as an elevation. From this, contours are drawn around the specified breaks outlined in the tool and service areas are drawn accordingly (Sandhu, Personal Communication, 2012)

Once the estimated drive time polygons have been created, both the PCSAs and the drive times were re-projected into an Albers Equal Area projection within the same State Plane coordinate system. The areas of each polygon were calculated in the attribute table. The inclusion of the census block information for the estimated drive times was calculated based on their containment of the geographic centroids of the Census Blocks by utilizing the Calculate Geometry function in ArcGIS and calculating the X and Y coordinates for each of the Census Blocks after the data has been projected to the NAD 1983 (US Feet) State Plane coordinate system and projecting it in an Albers equal area projection modified to each state plane zone.

Rurality was designated based on the Rural-Urban Commuting Area codes (RUCA) developed originally developed by the Office of Rural Health Policy (ORHP) the, United States Department of Agriculture's (UDSA) Economic Research Service (ERS) and the WWAMI Rural Health Research Center (RHRC). The RUCA was originally developed at the census tract level, but was reapplied to PCSAs by the Dartmouth Institute. The PCSA RUCA table was joined with the PCSAs in ArcGIS for each of the states in the study. The four category classification of census geographies was applied to isolate the rural PCSAs in the study areas. This classification was created by RUCA WWAMI Rural Health Research Center and is as follows:

- urban: 1.0, 1.1, 2.0, 2.1, 3.0, 4.1, 5.1, 7.1, 8.1, 10.1;
- large rural: 4.0, 4.2, 5.0, 5.2, 6.0, 6.1;
- small rural: 7.0, 7.2, 7.3, 7.4, 8.0, 8.2, 8.3, 8.4, 9.0, 9.1, 9.2;
- isolated: 10.0, 10.2, 10.3, 10.4, 10.5, 10.6.

The PCSAs that had RUCA codes in the Small Rural, or Isolated categories were considered to be rural and included in the study (Four Category Rurality).

Once all estimated drive time polygons had been created based on the distances calculated in the equidistant projections, the PCSA and drive time polygons were projected into an Albers equal area projection so that relatively accurate areas could be calculated. After all of the service areas were created and projected, the areas and population coverage for each polygon were calculated and recorded for comparison. Tables for each of the states were created illustrating the sum, average and difference in the area and population coverage for each PCSA and corresponding estimated drive time polygons.

Additionally a table calculating the population that fell within the PCSA, but outside of the 30 minute estimated drive time polygon was recorded. These figures were calculated using the select by location functionality. Each geographic centroid of the Census Block was selected and the populations were summed and recorded. Then by removing from that selection the Census Block geographic centroids that also fell completely within the 30 minute estimated drive times the populations of those geographic centroids were removed and the remaining populations were summed and recorded showing the population that falls within the PCSA, but outside of the 30 minute drive time.

Figure 7 illustrates, in the form of a flow chart, the steps taken from the original data sources (in blue) to calculate the figures needed for this analysis. After the estimated drive time polygons were created and the rural PCSAs were defined as rural, or not rural, they were considered original data sources for the remaining data processes in the steps.

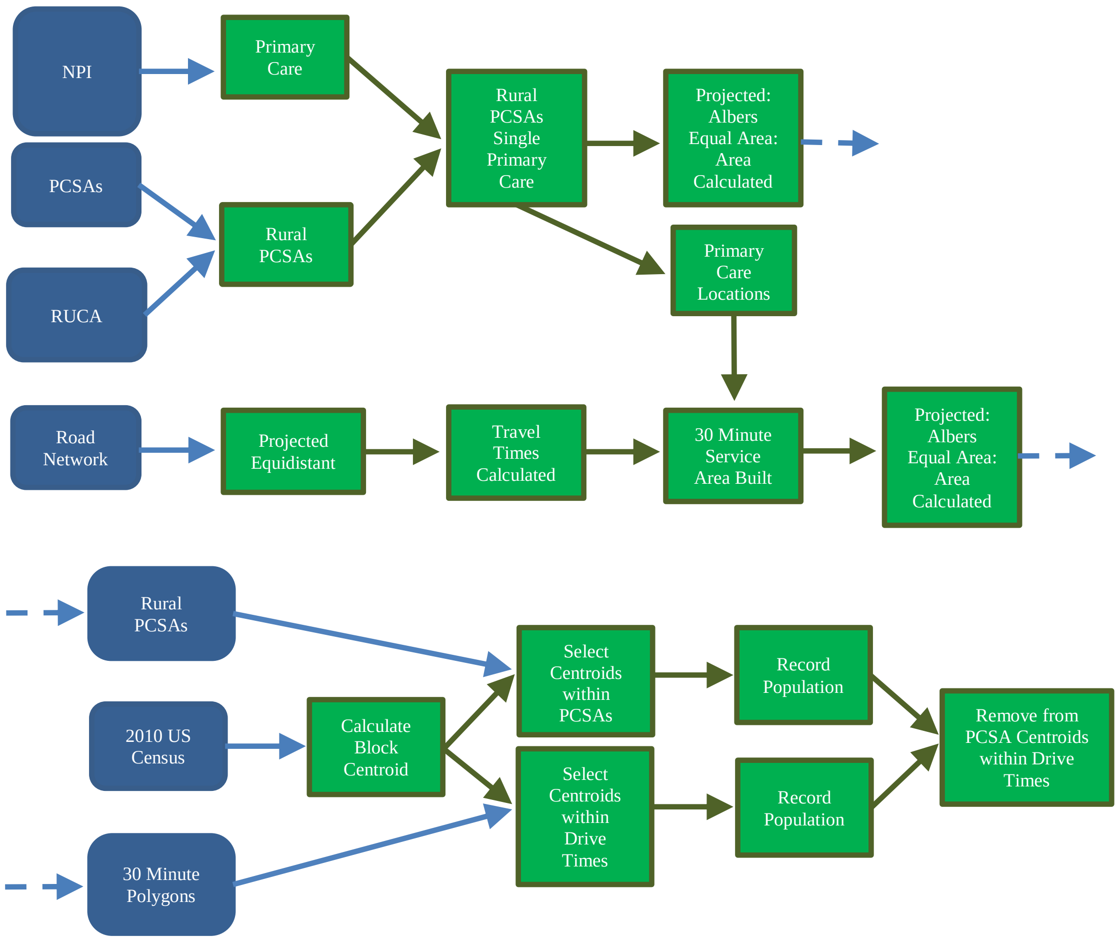

Figure 7: Data process flow chart showing methods for analysis.

Once the initial results were recorded, percent of the population within the PCSA that fell outside of the estimated drive times were calculated for each PCSA and corresponding drive time. This is an indicator that some of the population may not be able to easily access the primary care access point within the PCSA and therefore may be performing "poorly." Additionally, averages and standard deviations from the mean were also calculated for all of the PCSAs within each state in order to help illustrate the range of the data. For the PCSAs that had the highest percent of population falling outside of the 30 minute drive times were analyzed once again applying the same methodology to estimated 20 and 40 minute drive time polygons.

A correlation test was conducted between the populations of the PCSAs as the independent variable and the population that were within the PCSAs, but outside of the estimated drive times as the dependent variable. The R, R squared and the adjusted R squared were all calculated in order to assess how well this sample predicted the performance of that analysis of other PCSAs and drive times. The sample size was based on the number of rural PCSAs within the three states containing a single primary care access point (N=47) according to the Center for Medicare and Medicaid's National Provider Identifier dataset. The mean differences were calculated for both the population coverage and the areas covered.

CHAPTER FOUR – RESULTS

The three states in the study area produced a total of 47 PCSAs that met the requirements of being in a "rural" area and contained only one primary care service access point. Missouri had the most PCSAs, 28, North Carolina had 10 and Oregon had 9 PCSAs. Each of the states had broadly varying area and population coverage for both the PCSAs and the estimated drive times. However, Oregon was the only state where PCSAs covered more area than the estimated drive times. North Carolina had the largest difference in area between the PCSAs and drive time polygons with the drive times covering much larger areas than the PCSAs. Overall a total of 15 of the 47 PCSAs covered more area than the estimated drive times: 7 in Oregon; 7 in Missouri; and 1 in North Carolina.

In regards to population coverage of the two different geographies, far fewer PCSAs covered greater populations than were covered by the 30 minute estimated drive times. A total of 8 PCSAs contained populations higher than that of the drive times. Four of these were in Missouri, 3 in Oregon, and 1 in North Carolina. The total population difference between these 8 PCSAs and drive times was 24,858 in Missouri, 3,931 in Oregon and 1,151 in North Carolina. However, the total populations covered by PCSAs in each state were fewer than the population covered by the estimated drive times.

In Tables 2, 3, and 4 the sum, average and standard deviation of each PCSA and estimated drive time service areas are displayed for each respective state. Table 2 refers to Oregon which had the greatest number of PCSAs that were larger than the estimated drive time service areas. A total of 7,545 more square miles were covered by the PCSAs than the drive times and averaged more than 838 more square miles covered per PCSA. However, the standard deviation was also the greatest in Oregon with 1 standard deviation being 1,371 square miles. When considered in total, the population coverage of Oregon PCSAs was less than those of the estimated drive times. A total of 12,419 additional people were covered in the estimated drive times averaging 1,380 per PCSA and a standard deviation of 2,804 which shows a wide variation covering positive and negative differences between the PCSA and drive time population coverage.

Table 2: Area and population differences of Oregon PCSAs and estimated drive time service areas.

N=9	PCSA Area (Sq Miles)	Drive Time Area	Area Difference	PCSA Population	Drive Time Population	Population Difference
Sum	10,015.42	2,470.39	-7,545.03	53,613	66,032	12,419
Average	1,112.82	274.49	-838.34	5,957	7,337	1,380
SD	1,465.49	101.43	1,371.08	5,375	6,117	2,804

In Table 3 the PCSAs and 30 minute estimated drive times in North Carolina are compared. Unlike Oregon, the PCSAs of North Carolina were relatively small and covered significantly less area than the estimated drive time service areas. In total the estimated drive time polygons covered more than 3,228 square miles more than the PCSAs. The average drive time polygon was more than322 square miles larger than the PCSA. When considering population coverage the estimated drive times included much larger populations than the PCSAs. In total there were 635,668 more people in the estimated drive time service areas than in the PCSAs with an average of 63,567 more per drive time area. However, as seen in the standard deviations of both the area and population coverage, single standard deviations are large and are close to the average difference.

Table 3: Area and population differences of North Carolina PCSAs and estimated drive time service areas.

N = 10	**PCSA Area (Sq Mile)**	**Drive Time Area**	**Area Difference**	**PCSA Population**	**Drive Time Population**	**Population Difference**
Sum	2,223.79	5,452.02	3,228.23	122,472	758,140	635,668
Average	222.38	545.20	322.82	12,247	75,814	63,567
SD	249.04	134.11	320.98	7,435	64,494	59,475

Table 4 displays comparisons between the PCSAs and estimated drive times in Missouri. Missouri had the largest numbers of PCSAs that qualified for the study and both the land and population coverage were greater in the estimated drive time service areas than the PCSAs. Drive times covered more than 3,830 square miles more than the

PCSAs and averaged more than 136 square miles more per drive time/PCSA comparison. The total population coverage of the drive time service areas was 302,555 greater than that of the PCSAs and included an average of 10,806 more people than the PCSAs. The standard deviation for the difference between the estimated drive time service areas and the PCSAs in Missouri shows a wide distribution of data. The standard deviation of the actual area difference is greater than the average indicating that differences in the size between the estimated drive time and PCSA vary dramatically.

Table 4: Area and population differences of Missouri PCSAs and estimated drive time service areas.

N=28	PCSA Area	Drive Time Area	Area Difference	PCSA Population	Drive Time Population	Population Difference
Sum	8,846.69	12,677.62	3,830.93	194,118	496,673	302,555
Average	315.95	452.77	136.82	6,933	17,738	10,806
SD	214.04	141.27	301.05	5,045	12,910	7,865

In addition to the area and population coverage differences in the estimated drive time service area and the PCSAs, another variable that was calculated is the population coverage of the PCSA that was not also covered by the drive time polygons. This variable represents the population within the PCSA that may potentially have geographic challenges to accessing primary care. In this set of PCSAs and estimated drive time polygons greater than 74 percent (35 of the 47) of the PCSAs contained populations that fell outside of the 30 minute estimated drive times. While the populations that fell outside of the estimated drive times varied, the overall population was about 14 percent of the total population within the PCSAs. It is important to remember that these figures are all based upon the location of the Census Block centroid and the populations within those centroids were included within the geography in which they fell completely within.

Figure 8 is a chart of the total populations within the PCSAs and the populations within those PCSAs that fell outside of the 30 minute drive times. The 35 PCSAs that contain populations that do not fall within the 30 minute drive exclude populations that range from 1 to 16,883. The PCSA with the greatest population that is not covered within the 30 minute drive time service area is in southern Missouri. Nearly 95 percent of the population included in this PCSA is outside of the 30 minute estimated drive time.

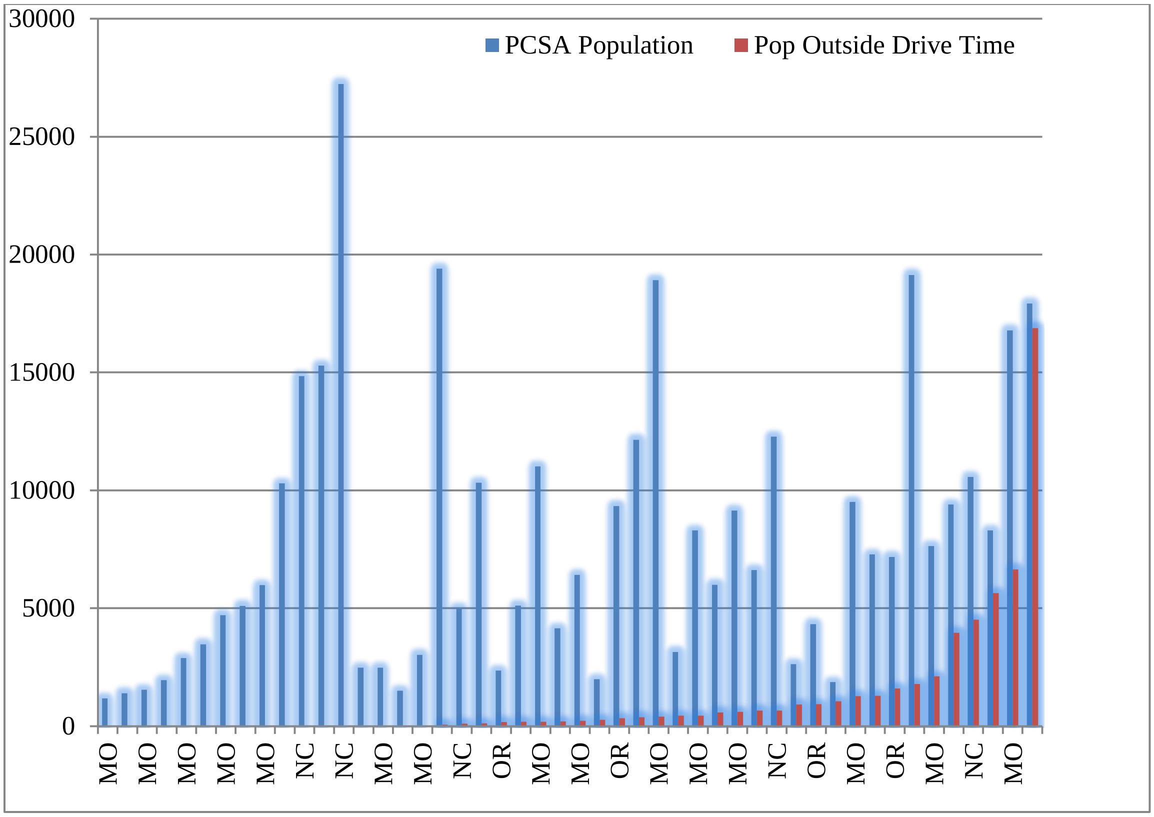

Figure 8: Population of PCSAs and the population that fall outside of the 30 minute estimated drive time polygons.

As a way to evaluate if a PCSA's population is predictive of the population excluded from the drive time, a correlation between the PCSA populations and the populations outside of the PCSA was analyzed. Figure 9, a scatter plot, illustrates the weak correlation between the population of the PCSAs and the populations that fall outside of the estimated 30 minute drive time. While there are some observations that seem to co-vary, implying a correlation, the numbers of PCSAs that had no population outside of the estimated drive times and the few PCSAs that had large percentages of populations falling outside of the estimated drive time create outliers that weaken the correlation significantly. The most noticeable outlier is the larger PCSA in Southern

Missouri were greater than 94 percent of its population fell outside of the estimated drive time. This correlation has an R equal to .336 for this specific sample, but an R square of only .113 and an adjusted R square of only .093.

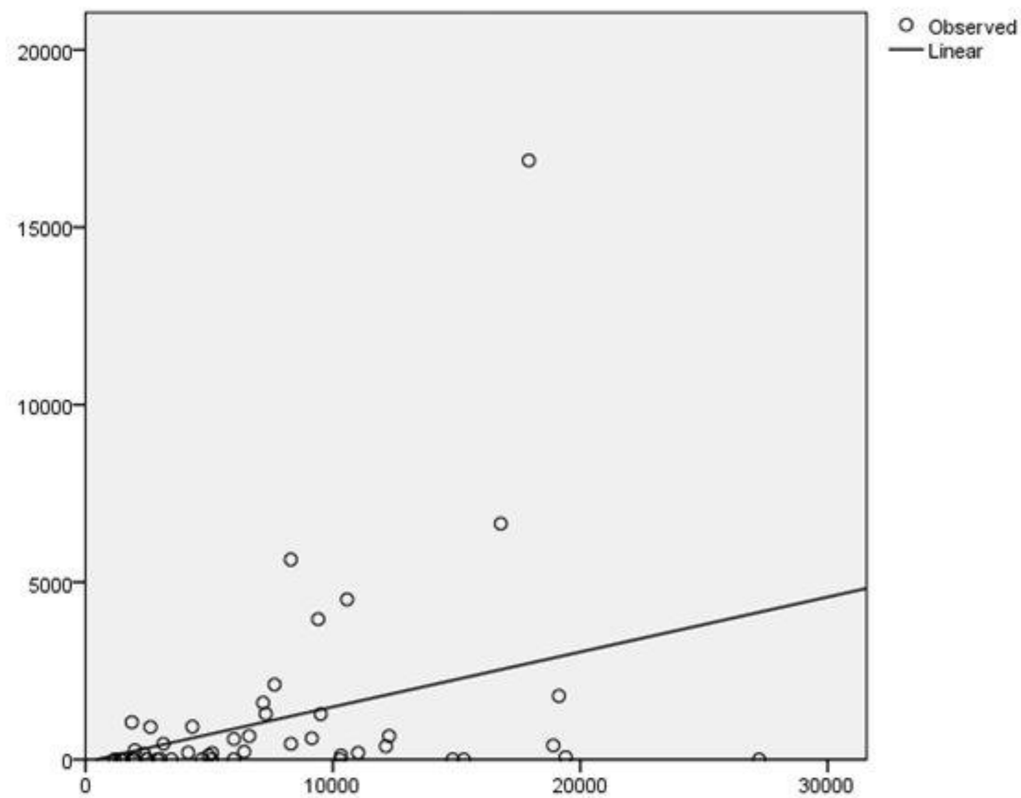

Figure 9: Scatter Plot of PCSA Populations Compared to the Populations that Fall Outside of the Estimated 30 Minute Drive Times. PCSA Population is along the bottom of the plot and the estimated population outside of the drive time is along the left hand side.

Figures 10, 11 and 12 show the percent of the populations that fall within the PCSAs, but outside of the estimated 30 minute drive times. The PCSAs for all states were divided into quartiles based on the percent of the population for each PCSA that fell outside of the 30 minute estimated drive time. The PCSAs where the population fell entirely within the 30 minute estimated drive time were treated separately and are noted in white as having zero percent of their population outside of the estimated drive time service areas.

In Figure 10, Missouri, the greatest number of PCSAs fall into the highest quartile. 6 PCSAs have more than 21.4 percent of their population falling outside of the estimated drive times. These 6 PCSAs have 27.67 percent to 94.21 percent of their populations falling outside of the estimated drive time service areas. There are a total of 7 PCSAs in Missouri that have no populations outside of the estimated drive time.

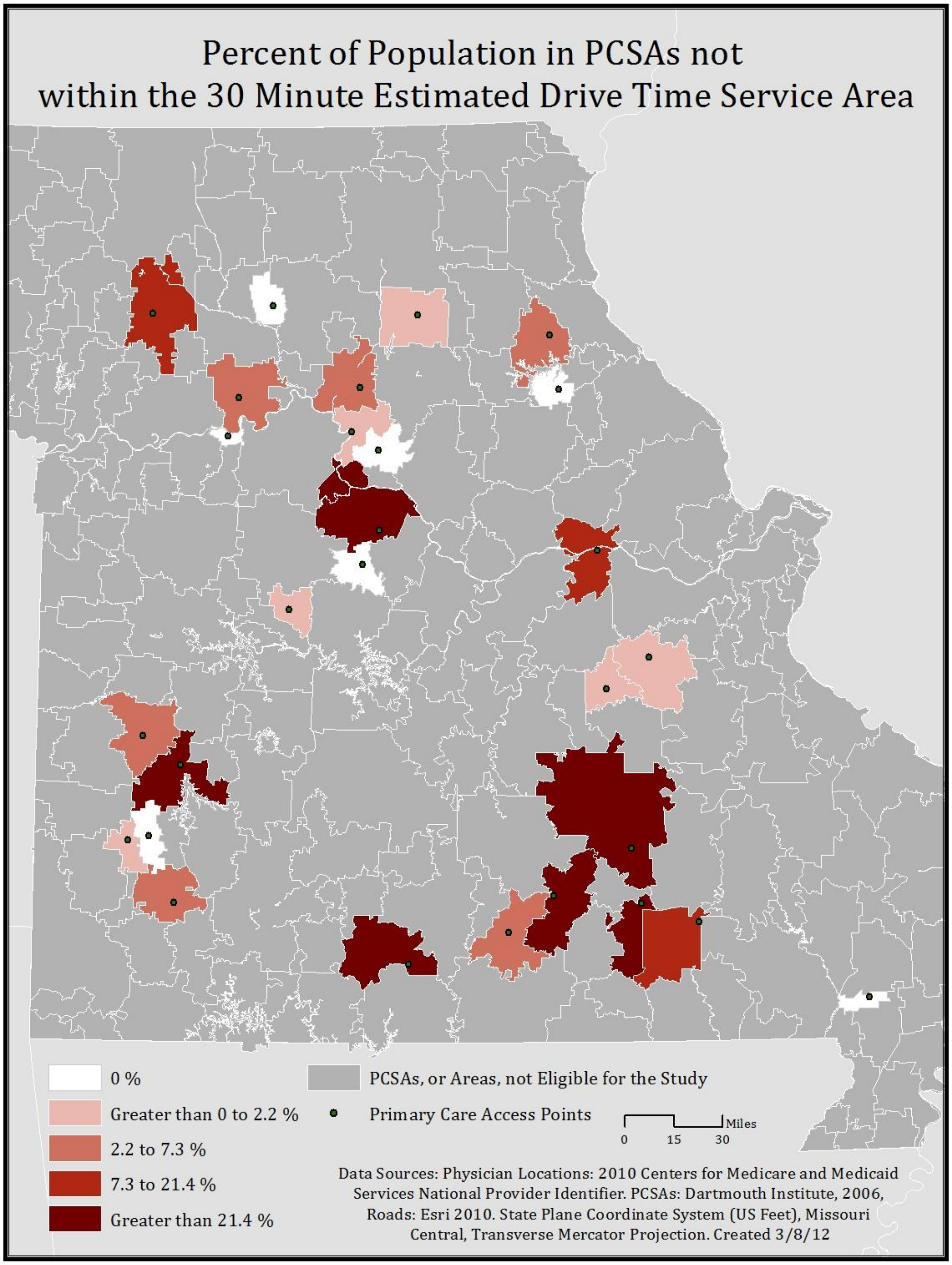

Figure 10: Missouri PCSAs and the Percent of the Population that Falls Outside of the 30 Minute Estimated Drive Time.

In Figure 11, North Carolina, the majority of the PCSAs have zero percent of their population outside of the estimated drive times. Five of the Nine PCSAs show no populations farther than an estimated 30 minute travel time to the primary care access points within them. However, one of the PCSAs has more than 42 percent of its population outside of the estimated 30 minute travel time to the primary care access point within it. There is also one PCSA that has a population of 5.4 percent and three PCSAs that have from zero percent to 2.2 percent of their population outside of an estimated 30 minute travel time.

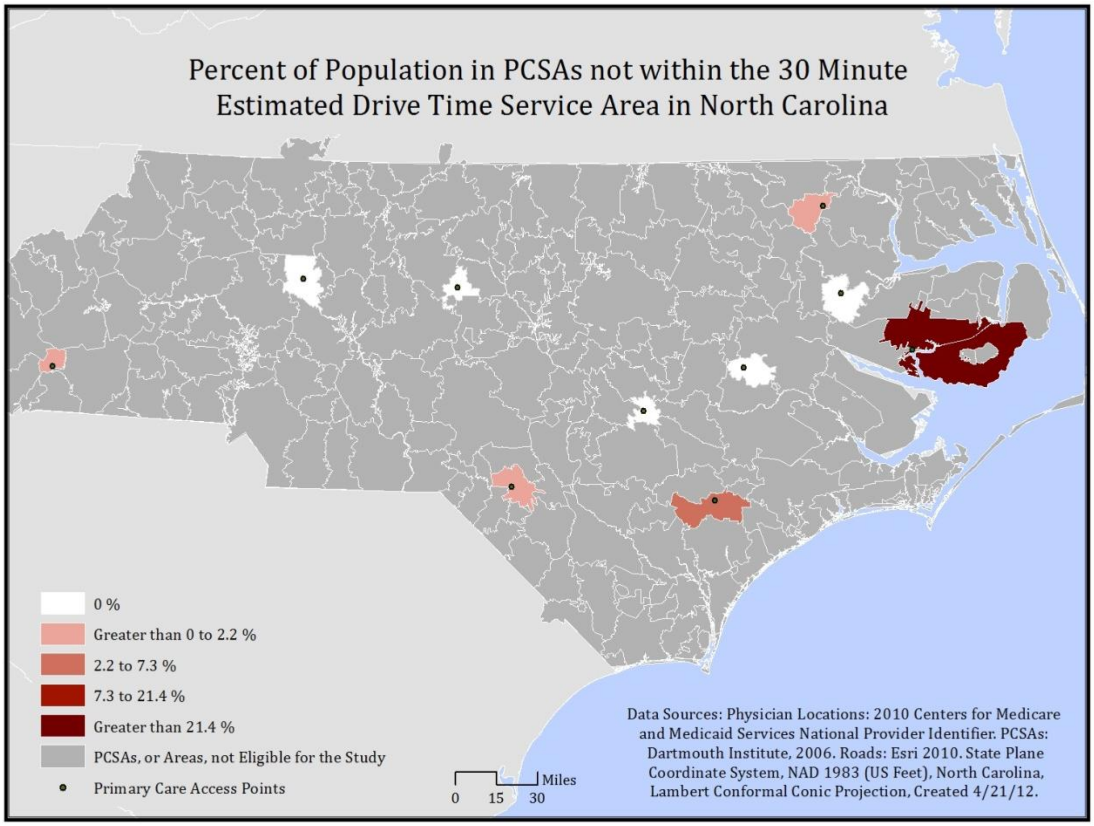

Figure 11: North Carolina PCSAs and the Percent of Population that Falls Outside of the 30 Minute Estimated Drive Time.

Oregon, in Figure 12, has the largest average size of PCSAs, but only three have populations greater than 21.4 percent outside of the estimate 30 minute travel time. There is one PCSA that has zero percent of its population outside of the estimated travel time service areas, one with 2.2 to 7.3 percent and the remaining four have 7.3 to 21.4 percent of their populations outside of the estimated 30 minute travel time polygons.

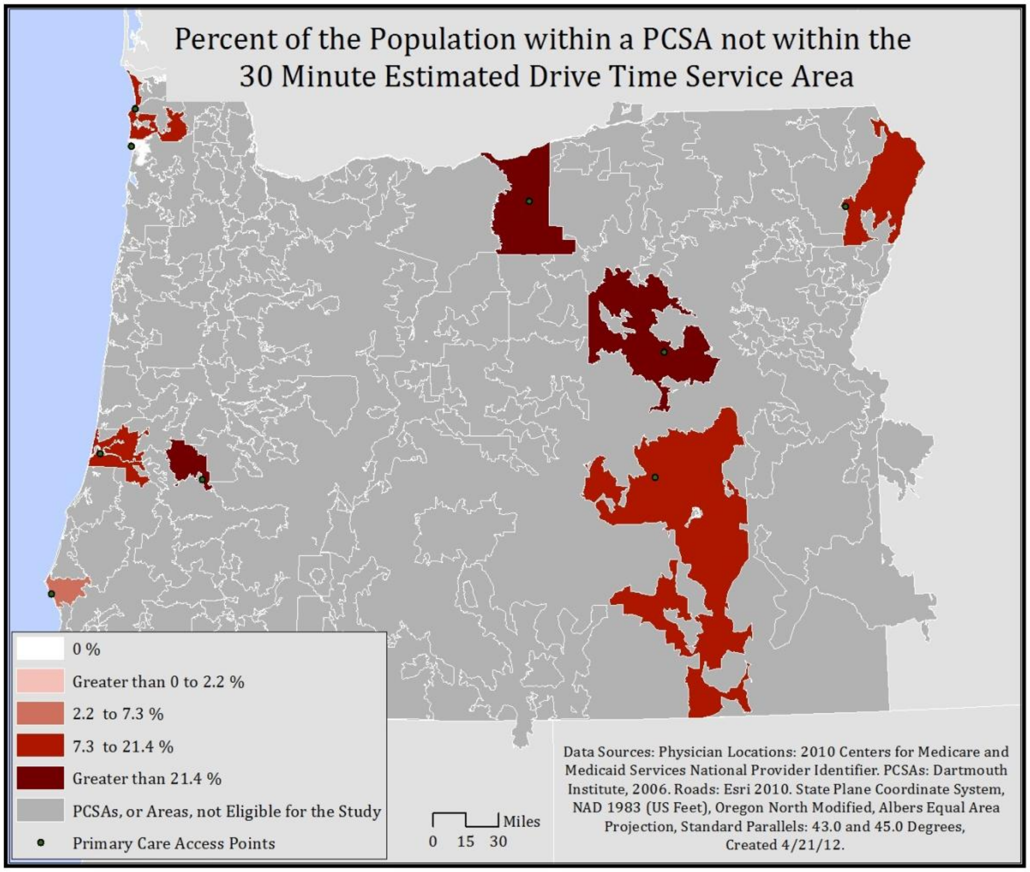

Figure 12: Oregon PCSAs and the Percent of the Population that Falls Outside of the 30 Minute Estimated Drive Time.

Of the PCSAS with that fell within the highest quartile of populations not within the drive times, further analysis of the population coverage was tested. In addition to the 30 minute estimated drive times, 20 and 40 minute estimated drive times were calculated to see how many more (or fewer) people were covered in the case that travel times varied. Table 5 shows the average additional populations covered, or excluded, from the estimated drive times if the travel times were either greater, or less, than 30 minutes.

Table 5: Populations and percent of populations outside of the 20, 30 and 40 minute estimated drive time polygons.

N = 11	Population Outside 30 Minutes	Percent Outside 30 Minutes	Population Outside 20 Minutes	Percent Outside 20 Minutes	Population Outside 40 Minutes	Percent Outside 40 Minutes
Sum	45,533	-	68537	-	28755	-
Average	4,139	42.42%	6231	70.86%	2614	24.32%
SD	4,690	22.93%	5451	28.10%	4687	25.64%

There were a total of eleven PCSAs that were analyzed for the additional estimated drive time areas: Six were located in Missouri; four were in Oregon; one in North Carolina. On average 28.44 percent more population would be excluded if the 20 minute estimated drive time areas were considered and 18.1 percent more would be included if the 40 minute estimated drive times were considered. In the PCSA that had the largest percent of the population excluded from the estimated 30 minute drive time, an additional 3.1 percent would be excluded in the 20 minute estimated drive time and only 0.4 percent more of the population would be included in the 40 minute estimated drive time. In contrast, another PCSA located in Missouri that had 34.9 percent of its population excluded from the estimated 30 minute drive time would have excluded an additional 54.6 percent if considering the 20 minute drive time, but would only have 7.6 percent of its population excluded if considering the estimated 40 minute drive time. Figures 13, 14 and 15 show the PCSAs that fell within the highest quartile of percent of population outside of the estimated 30 minute drive time polygons and also show the additional, or excluded coverage, for Missouri, North Carolina and Oregon, respectively. In Figure 13, for Missouri, the 20 minute estimated drive times cover an average of 391.9 square miles less than the PCSAs and the 40 minute estimated drive time polygons cover an average of 50.4 percent more area than the PCSAs.

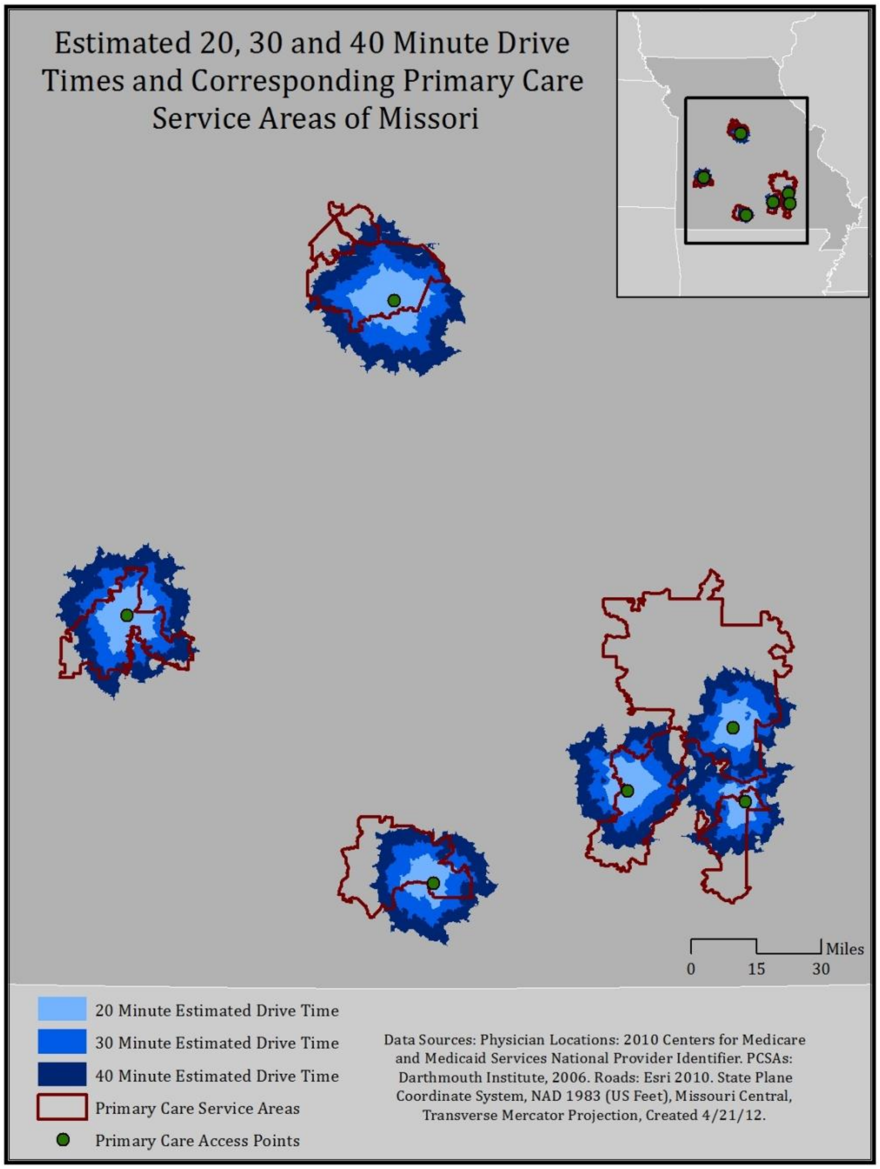

Figure13: 20, 30 and 40 minute estimated drive time polygons and corresponding PCSAs in Missouri.

Figure 14 shows the single PCSA in North Carolina that excluded a large percentage of people from the estimated 30 minute drive time and the additional 20 and 40 minute estimated drive times. Compared to the estimated 30 minute drive time with an exclusion of 42.69 percent of the population in the PCSA, the 20 minute drive time excluded more than 58 percent of the population within the PCSA. In contrast, the 40 minute estimated drive time only excluded 33.76 percent of the population. The difference in area coverage ranged from 760 square miles not covered by the 20 minute estimated drive time and less than 229 square miles not covered by the estimated 40 minute drive time.

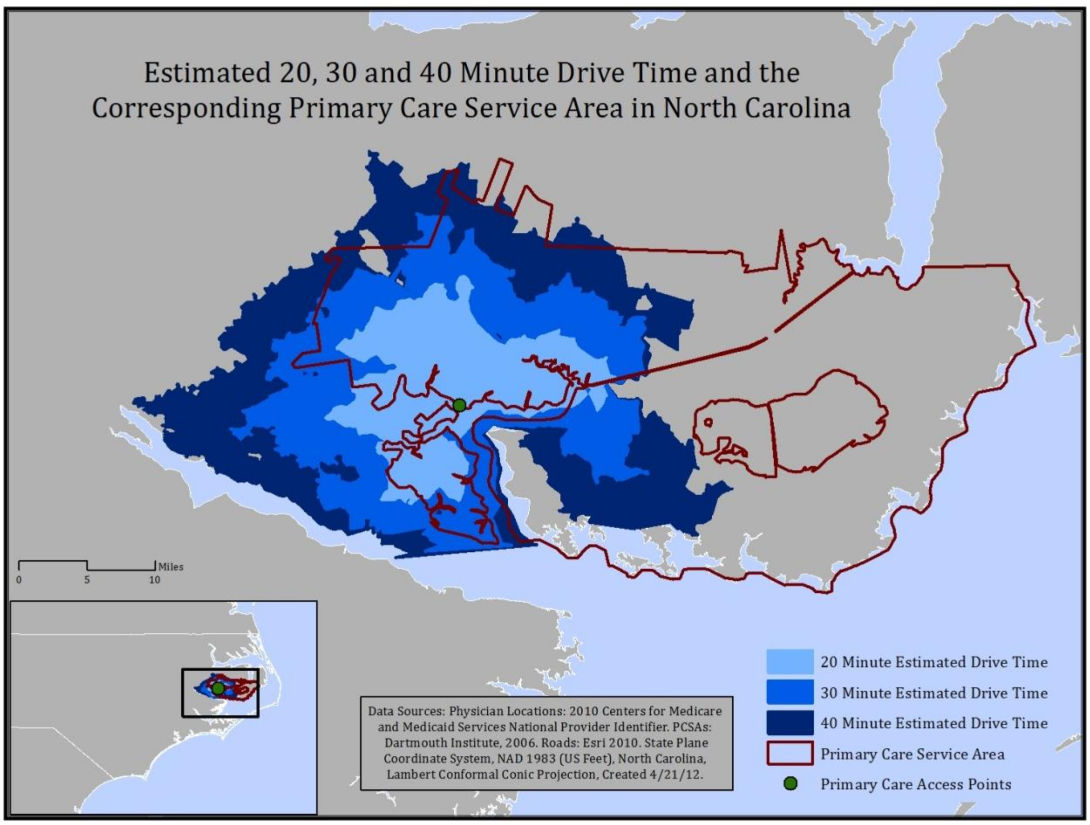

Figure 14: North Carolina focus PCSA with 20, 30 and 40 Minute Estimated Drive Times.

Finally, Figure 15 shows the 4 PCSAs that were included in the additional estimated drive time analysis for Oregon and their corresponding 20, 30 and 40 minute drive time polygons. The PCSA within Oregon that had the highest percentage of the population excluded from the estimated 30 minute polygon (56.22 percent) would have an excluded population of 96.53 percent if considering the 20 minute estimated drive time and only had a decrease of nearly 11 percent if considering the estimated population coverage of the 40 minute drive time polygon. In contrast, the polygon that had an excluded population of 21.4 percent in the 30 minute drive time polygon would have only had an excluded population of less than 5 percent if the 40 minute estimated drive time polygon was considered.

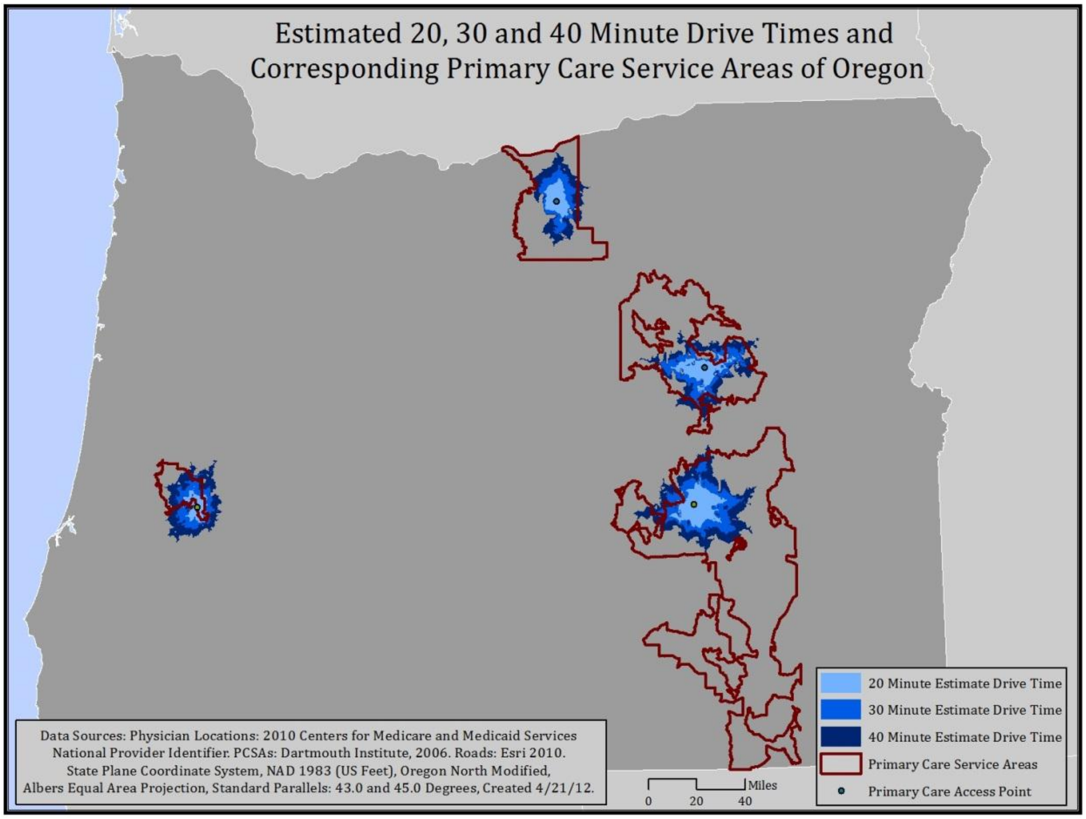

Figure 15: PCSAs in the highest quantile of percent of population outside of the estimated 30 minute drive time and their corresponding 20, 30 and 40 minute drive time polygons.

In summary, an estimated 110,284 people were potentially included in the 47 PCSA populations, but were not included within the estimated 30 minute drive times to the primary care access points within the PCSAs. This is 29.8 percent of the total population of the PCSAs. Thirteen of the 47 PCSAs in the study area did include all of their population within an estimated 30 minute drive time polygon, but 72.3 percent of the eligible PCSAs had populations outside of the estimated 30 minute drive time polygons. While the 40 minute drive time polygons improved the population coverage in each of the 11 cases analyzed, it only improved the coverage by an average of 18.1 percent. While the total area covered by the estimated drive times was greater than the area covered by the PCSAs, there were populations that were not covered within the drive times that were covered within the PCSAs. There was a weak correlation between the population of the PCSAs compared to the population within the PCSAs but outside of the estimated 30 minute drive time polygon.

CHAPTER FIVE – DISCUSSION

Section One – Data Limitations

While this study has clearly demonstrated that there are PCSAs that have populations that may find geographic barriers in access to care based on the PCSA that they are assigned to, there are a few limitations to the data that may affect the results. First, the method used to calculate the number of people within the estimated drive times has been proven to overestimate, and sometimes underestimate, the populations actually within the drive times. Since populations are not evenly distributed within geographies, the assignment of the population based on the geographic centroid may not always accurately include all populations within the estimated drive times and in some cases may include populations within a geography that do not actually reside there. While the severity of this inaccuracy is challenging to quantify, in regards to access to transportation, it has been suggested that the overlay of census polygons can vastly overestimate the population within walking distance to transportation (Biba et al, 2010).

Second, the Dartmouth PCSA analysis was originally conducted utilizing Medicare utilization data from 1996 and 1997. Considering this data, the primary care access points would have been based on registrants from those years most likely using their unique physician identification numbers (UPIN) which have undoubtedly changed since the creation of the National Provider Identifier dataset used to isolate primary care access points for this study. Therefore, the primary care access points in this study should be treated as approximations of possible primary care access points and may not be the same as the providers analyzed in the Dartmouth PCSA project.

Additionally, as is the problem with any national provider dataset, the addresses supplied by the provider are not always the addresses of the practice location. In the case of the CMS UPIN and NPI datasets the provider is asked for a practice location, but the provider may practice at more than one location, may inaccurately provide a home address where they would like payments submitted, or may also provide an address of a facility where payments are processed and no services are provided. These are just a few examples of what may go wrong with provider locations in national and state level provider datasets. Again, it is very challenging to quantify the inaccuracies of any workforce data set, but the inaccuracies of physician counts has been discussed in the literature where 12 percent of pediatricians surveyed were not included in the AMA's Physician Masterfile (Freed et al, 2006).

Section Two – Discussion of Results

The states in this study all contained unique situations regarding the populations that resided in the PCSAs and those that were outside of an estimated 30 minute travel time. Each state provided a different range for these differences with North Carolina having the fewest instances of PCSAs that had populations outside of the estimated 30 minute travel time. Oregon had the largest PCSAs, but they did not result in higher populations excluded from the estimated drive times than Missouri. Missouri had the largest number of PCSAs in the study and also demonstrated the largest range of populations included and excluded from the drive times, but still within the PCSAs.

While North Carolina had the fewest populations excluded from the estimated travel time polygons, it also had the largest average area coverage of the estimated drive times (545.20 square miles). This indicates that further distance can be covered in shorter periods of time. In contrast, Oregon had the smallest average estimated drive time area coverage (274.49 square miles) and also the largest difference in PCSA to estimated drive time areas. It seems that this can possibly be explained by the difference in both topography and the population densities of each of these states. According to the US Census Bureau, Oregon has a population density of 39.9 people per square mile whereas North Carolina has a population density of 196.1 people per square mile (Census Quick Facts, 2010). Additionally, the elevation differences in North Carolina are only 6,664 feet versus an elevation difference of 11,239 feet (USGS).

These two variables may explain how the average drive times differ so greatly between these two states. With Oregon being a more rural and mountainous state than North Carolina, one might expect more roads and higher speed roads in a flatter, more populous state. Therefore, one could potentially travel farther, faster and in more directions in North Carolina compared to Oregon. Missouri on the other hand displays average estimated drive time area coverage of 452.77 square miles, has a population density of 87.1 people per square mile, but an elevation change of only 1,542 feet. While the elevation change may not be the best justification for these differences in the case of

Missouri, the averages correlate with the population density and average estimated drive time distance.

In cases where there were larger percentages of populations excluded from the estimated 30 minute drive times, but included within the PCSAs, at least one of two different phenomena appear to be present. The first of these two different phenomena is the lack of a centrally located primary care access point and the second of the two being relatively small areas for the estimated drive times. In the PCSA that had the highest percentage of population excluded from the estimated 30 minute drive time (94.2 percent in Southern Missouri) both of these phenomena occur. The area of the estimated drive time only covered 203.106 square miles which is the second smallest drive time in the state of Missouri and third smallest of all 47 estimated 30 minute drive times considered in the study. This indicates that the road network may be sparser in this area and/or the road segments cannot be traveled at very high speeds. Additionally, the primary care access point in this PCSA is located near the southern most part of the PCSA and therefore was not very centrally located. At least one of these phenomena, but in most cases both, was present in all of the PCSAs that experienced large percentages of their population excluded from the drive time polygons.

While the correlation between the population excluded from the drive times and the population of the PCSAs was weak in this sample, it was present. However due to the variance of the data sample it was not predicted that this correlation would continue to be as present in the analysis of additional PCSAs and estimated drive times. While the weak, or potential lack of, correlation between these two variables does not help us predict other highly exclusive PCSAs by population size, it does begin to express the fact that there are good and bad performing PCSAs throughout the states and they may be identified by finding those that have high percentages of their population outside of the estimated drive times. These PCSAs may potentially be including higher than average populations that are not seeking services within their limits. Therefore, they may not be a good “area” for the evaluation of primary health care shortages and health outcomes for the population within.

In the documentation for the creation of the PCSAs, the authors did address distance in relation to the distance between the ZCTA centroids and relative size of the PCSAs. They first classified all ZIP Codes into two categories. There were provider ZIP Codes that contained a provider and population ZIP Codes that contained beneficiaries from the Medicare data. The first consideration of distance was given to the percent of patients from the population ZIP Code with a weight on the distance from the provider ZIP Code. In the case where the population in a single ZIP Code sought equal services in multiple provider ZIP Codes, the population ZIP Code was assigned to the nearest provider ZIP Code in relation to the geographic Centroid (ZIP Code to PCSA Assignment, 2006).

The second consideration that was given to distance, or area, was the target size of the PCSA. It was intended that no PCSA be larger than 1,256 square miles which would be the equivalent of a radius of 20 miles. However, only 15 states did not have PCSAs that exceeded this land area. Unfortunately the authors did not address the fact that PCSAs are not based on Euclidian distance and estimated travel times were not addressed at all. In a number of the more rural states, Alaska, Wyoming, Montana, Idaho and New Mexico all had greater than 80 percent of their PCSAs exceeding this land area. In the eligible PCSAs for this study in Oregon, 2 PCSAs exceeded this land area, but neither Missouri nor North Carolina had any PCSAs exceeding this area.

Regardless of the number of PCSAs that exceeded this maximum area in the PCSA creation process, it has been shown that many of the PCSAs include populations that are greater than 20 miles from the primary care service access point that fall within the PCSA. This seems to be one of the weakest rules in the creation of the PCSAs as even though they may only cover the equivalent, or much less area than a Euclidian circle with a 20 mile radius, there are many populations that are within the PCSA that cannot reach the access point within an estimated travel time of 30 minutes, which is often equated to 20 miles (Defining Primary Care Service Areas, 2006).

The additional analysis of the 20 and 40 minute estimated drive time polygons was done in consideration of the possible errors in the creation and threshold of an estimated 30 minute drive time polygon. However, in a study on the "Validation of travel times to hospital estimated by GIS" it was shown that in northern England according to a survey of patients perception of actual time traveled, half of the respondents reached the destination within 5 minutes of the estimated travel time (77 percent within 10 minutes) based on analysis from their home address to the hospital (Haynes et al, 2006). There was a symmetrical distribution to the data within this research meaning that there were equal numbers of shorter and longer reported drive times. The longer travel times generally coincided with traffic congestion.

Due to the fact that the majority of the areas within this study were considered to be at least “Small Rural” (see Methods section) it may be considered that there would be relatively low occurrences of traffic congestion and therefore the larger, estimated 40 minute, travel times may be a better proxy for comparison in the present research. However, the previously mentioned study was conducted in northern England and the accuracy of the road network data is not well known. While the same may be said for the accuracy of our road network data it would be an improvement to this research to have some ground truthing, or actual drive times, to compare to how well ArcGIS has estimated the travel times in this study.

Regardless, it was shown that the estimated 40 minute drive times only covered an additional 18.1 percent (24.3 of 42.4 percent) of the population that was not covered by the estimated 30 minute drive times. While this is a clear improvement in the population coverage, there are still a significant number of people that may not have sufficient access to the primary care services within their PCSA. Additionally, if the reverse is true and it is taking populations longer to travel to access points within their PCSA there is a potential of nearly 28 percent more of the total population that cannot access their primary care services within 30 minutes.

While the primary care service access points may have changed from the time the PCSA project was conducted, nowhere in the documentation (Defining Primary Care Service Areas, 2006) does it mention isolating or recognizing the exact location of the primary care access point within the PCSA. This seems to be a very important aspect that was overlooked and may be the explanation for the shortcomings of the poorer performing PCSAs in this study, especially those that tend to cover larger areas. Where the access points are not centrally located there tend to be higher populations that are excluded from the estimated 30 minute drive time. This fact and the admitted results of the authors that only 63 percent of beneficiaries on average for the whole country sought care within their PCSA strongly insinuate that many people are being included within PCSAs that are not actually seeking care within it.

It has been thought that the Dartmouth Institute, creator of the original PCSA project, is planning to conduct the analysis again and rebuild PCSAs based on Census Tract geographies. While it is initially thought and recognized that the use of Census Tracts may reduce error simply due to the fact that they are generally a smaller geography than ZIP Codes or ZCTAs, It is suggested by the results of this study that the consideration of travel time may further reduce inaccuracies in the inclusions of populations that may not access, or be able to easily access, the primary care services within the PCSAs in which they reside.

Recently, there have been a number of studies challenging the importance of travel time and travel distance and some have shown that there is a high correlation between the predicted travel time, travel distance and straight line, or Euclidian, distances between geography centroids and hospitals (Boscoe et al, 2012; Jones et al, 2010). However, in the article by Boscoe et al (2012), they did find some exceptions to these correlations along complex coast lines and where large geographic barriers, such as rivers or lakes are concerned. With this in mind, it is possible that in the case of larger interior PCSAs that are free of any of these geographic barriers, a simple Euclidian buffer may be sufficient for assessing accessibility. This would have to be assessed on a case by case basis though, and some of these exceptions can be seen in the small sample used in this study.

In conclusion, this study has produced results that help clearly define some of the poorer performing PCSAs in regards to high percentages of the population potentially not able to access primary care services within a reasonable travel time. While analyzing additional shorter and longer travel times this study sheds some light on the potential variability of these populations with potential need. Also, there are a number of PCSAs that may need to be reconsidered to be properly representative of their populations being served. The analysis of the 40 minute drive times did not prove to completely solve the under service or under representation of the sub sample of the data. The consideration of some travel time, or distance, to services could be a good addition to the PCSA methodology and may reduce the number of PCSAs that contain populations outside of reasonable travel times, or the percent of populations that do not seek primary care services in the PCSA where they live.

CHAPTER SIX – CONCLUSIONS

Section One – Conclusions

Primary Care Service Areas are based on real health care claims data and were the first attempt at creating areas for the analysis of health care indicators and primary care shortages for the entire United States. While these service areas seem to include the populations in many of the PCSAs within the estimated 30 minute drive time polygons, there are a number that have demonstrated significant populations that were excluded from these estimated drive times and these populations are potentially disadvantaged in regards to geographic access to primary care services and potentially misrepresent the populations accessing primary care services within the PCSAs. This indicates a possible misrepresentation of these populations when assessing primary health care outcomes and designating primary care shortages.

While it would have been ideal to analyze the original data used in the creation of the PCSAs, estimated drive times can be used as an initial tests to determine if the PCSAs are including the optimal populations for their purposes. Estimated drive times have provided a proxy of what populations can access the primary care services within a reasonable amount of time and should be considered when assigning primary care service areas for the analysis of health care usage, health care indicators and possible health care shortages.

This research presents two common geographic problems. The first is the zoning problem. The Dartmouth institute has created a fairly unbiased algorithm for assigning patient ZCTAs to provider ZCTAs, but the fact that ZCTAs are being grouped together and have some rules and restrictions the zones (PCSAs in this instance) may not always create the best possible outcome in every situation. Therefore certain cases may need further consideration. The second problem that surfaces in this research is the location allocation problem. As seen in some of the poorer performing ZCTAs, the location of the physician may not be the most optimal, or central, location for serving the entire population of the PCSA. While it isn't common for the policy makers to tell the physicians where to practice, they can provide some financial incentives that encourage additional facilities to be located in more optimal locations.

Though it has been discussed that populations are not always predictable in their access of health care it still seems that consideration of travel time is a good predictor of this and would appear to be one of the most rational ways of assessing potential accessibility to services. Therefore when considering the creation of health care service areas, in this case primary care service areas, it is important to include the consideration of travel time. Since there is currently no perfect method for assigning health care service areas and as data for this process will always be a challenging obstacle, PCSAs may be a good starting point. However, it is recommended that the addition of travel time is a possible way to improve some of the cases of the poorer performing PCSAs.

While the estimated drive time service areas may not be a perfect alternative for new PCSAs, they do give an indication of the population with relatively manageable geographic accessibility to primary care services within their PCSA. The drive time service areas also give an indication as to the population that may be represented better within a different PCSA. Furthermore, estimated drive times may help identify where there may not be enough primary care services to provide for the entire population within the PCSA. This could be an important policy implication for the State or Federal Governments to financially encourage where additional primary care services should be located.

This research has shown that in some cases PCSAs may be including populations that are not representative of the service area in which they reside. While the PCSA project openly admits that this does occur (with only 62 percent of the population seeking care within the PCSA in which they reside), this research may provide a method to help reduce these occurrences and improve the percent of population that seeks care within the PCSA in which they reside. This could lead to an improved PCSA that better represents the population within and could better indicate primary care shortages leading to improved geographic accessibility to primary care services for the entire United States.

Section Two – Future Research

As mentioned in the previous section. Future research may want to look into the zoning and location allocation problems further. It may be a good way of finding solutions to some of the poorer performing PCSAs in order to assess more optimal locations for additional services and perhaps better divide the geographies used in order to have the most optimal zones, or PCSAs . If the Dartmouth Institute is considering the recreation of PCSAs based on Census Tracts it would be interesting to apply a travel time, or distance, element to the access point data they choose to utilize. This could be done in order to test the effectiveness of the consideration of travel time in the creation of PCSAs based on the smaller geographies. The application of a travel time, or distance, element to the PCSA study could identify Census Tracts that have their centroids within an estimated travel time of 30 minutes. This would allow the application of a preference weight to those Tracts so identified, in addition to the plurality weight that is already applied to patients from those census tracts.

Additionally, it would be interesting to evaluate the ability of road network based travel times as analyzed in ArcGIS to predict actual travel times. This study would either take extensive ground truthing of actual drive times along the road networks from the outer edges of the estimated travel time polygons, or could be modeled after the evaluation methods used in the study mentioned in the work from Northern England by conducting a survey of primary care patients at primary care access points and comparing the reported travel time to the estimated travel time from their home address to the access point.

Also, with the quickly growing body of research comparing road network distances, travel times, and Euclidian distances, it would be an interesting to compare Euclidian distance buffers to estimated travel time service areas to see how different the coverage of population really is and if there are equally strong correlations between the two.

Note: In a personal communication with a researcher at the Dartmouth Institute it has been learned that the recreation of PCSAs is currently underway and due to be completed by the end of May (Chang, Personal Communication, 2012). This research has been submitted to the Dartmouth Institute and it is understood that they are already considering the application of some sort of distance or travel time to services areas in order to make the larger PCSAs more representative of the populations that are seeking services within them and as a means for PCSAs to be a better basis for evaluating health care indicators and designating primary health care shortage areas.

REFERENCES

REFERENCES

Biba, S., Curtin, K. M., Manca, G. (2010). A New Method for Determining the Population With Walking Access to Transit. *International Journal of Geographic Information Science,* 24(3):p347-364.

Borders T. F. et al (2000). Why Rural Residents Migrate for Family Physician Care, *The Journal of Rural Health*, 16(4): p337–348.

Boscoe, F. P., Henry, K. A. Zdeb, M. S. (2012). A nationwide Comparison of Driving Distance Versus Straight-Line Distance to Hospitals. *The Professional Geographer*. 64(2): p188-196.

Carr, B. G. and Addyson D. K. (2010). Geographic Information Systems and Emergency Care Planning, *Academic Emergency Medicine*, 17: p1274–1278.

Census Quick Facts (2010). http://quickfacts.census.gov/qfd/index.html

Chang, C. (2012), Personal Communication, Email, April 27, 2012.

Curtis, S. E. (1982).Spatial analysis of surgery locations in general practice. *Social Science & Medicine*, 16:p303–313.

Dartmouth, Primary Care Service Area Shape File (2003). http://pcsa.dartmouth.edu/index.html

Defining Primary Care Service Areas (2006). http://knox.dartmouth.edu/pcsa/downloads/Defining_PCSAs.pdf

Dijkstra, E. W. (1959). A Note on Two Problems in Connection with Graphs. *Numerische Mathematik* 1: p269–271.

Esri. ArcInfo 10.0, ArcGIS 10 Online Help. http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html.

Fiedler, J. L. (1981). A Review of the Literature on Access and Utilization of Medical Care with Special Emphasis on Rural Primary Care. *Social Science & Medicine. Part C: Medical Economics.* 15(3): p129–142.

Freed, G. L., Narhra, T. A., Wheeler, J. R. C. (2006). Counting Physicians:

Inconsistencies in a Commonly Used Source of Workforce Analysis. *Academic Medicine*81(9): p847 – 852.

Four Category Rurality Classification. http://depts.washington.edu/uwruca/ruca-maps.php

Goodman D. C. et al (2003). Primary Care Service Areas: A New Tool for the Evaluation of Primary Care Services, *Health Services Research*, 38(1): p287–309.

Guagliardo, M.F. (2004). Spatial Accessibility of Primary Care: Concepts, Methods and Challenges, *International Journal of Health Geography,* 3: p1–13.

Haynes, R., Jones, A. P., Sauerzapf, V., Zhao, H. (2006). Validation of Travel Times to Hospital Estimated by GIS. *International Journal of Health Geographics.*5: p40 – 47.

HPSA (Health Professional Shortage Areas) Designations, Guidelines for Primary Medical Care/Dental HPSA Designation, http://bhpr.hrsa.gov/shortage/hpsas/designationcriteria/medicaldentalhpsaguidelines.html

Hunter, J. M., Shannon, G. W., and Sambrook, S. L. (1986). Rings of Madness: Service Areas of 19th Century Asylums in North America, *Social Science Medicine*, 3(10): p1033–1050.

Johnson, S. (2006). *The Ghost Map*. The Penguin Group. New York, NY.

Jones, S. G., Ashby, A. J., Momin, S. R., Naidoo, A., (2010). Spatial Implications Associated with Using Euclidian Distance Measurements and Geographic Centroid Imputation in Health care Research. *Health Services Research,* 45(1): p316-327.

Joseph, A. E., & Phillips, D. R. (1984).*Accessibility and utilization geographical perspectives on health care delivery*. New York: Harpers & Row.

Joseph, A. E. and Bantock, P. R. (1984). Measuring Potential Physical Accessibility to General Practitioners in Rural Areas: A Method and Case Study. *Social Science and Medicine*. 16(1): p85–90.

Konrad, T. R. (2009). County-Level Estimates of Need for Mental Health Professionals in the United States, *Psychiatric Services*, 60(10): p1307–1312.

Lou, W. and Wang, F. (2003). Measures of Spatial Accessibility to Health Care in a GIS

Environment: Synthesis and a Case Study in the Chicago Region, *Environment and Planning B: Planning and Design*, 30: p865–884.

McGrail, M. R. and Humphreys, J. S. (2009). Measuring Spatial Accessibility to Primary Care in Rural Areas: Improving the Effectiveness of the Two-Step Floating Catchment Area Method, *Applied Geography*, 29: 533–541.

Olden, M. et al (2010). House Calls Revisited: Leveraging Technology to Overcome Obstacles to Veteran Psychiatric Care and Improve Treatment Outcomes, *Annals of the New york Academy of Sciences*, 1208: p133–141.

Panchansky, R. and Thomas J. W. (1981).The Concept of Access. *Medical Care*, 19(2): p127–140.

Parker, E. B., Campbell, J. L. (1998). Measuring Access to Primary Medical Care: Some Examples of Geographical Information Systems, *Health & Place*, 4(2): p183–193.

Patel, A. B., Tu, J. V., Waters, N. M., Ko, D. T., Eisenberg, M. J., Thao Huynh, T., Rinfret,S., Knudtson, M. and Ghali, W. A. (2010). Access to Primary Percutaneous Coronary Intervention for ST-Segment Elevation Myocardial Infarction in Canada: A Geographic Analysis. *Open Medicine,* 4(1): p13–21.

Pedigo, A. S., and Odoi. (2010). Investigation of Disparities in Geographic Accessibility to Emergency Stroke and Myocardial Infarction Care in East Tennessee Using Geographic Information Systems and Network Analysis, *Annals of Epidemiology*, 20:p924–930.

Phillips, R. L., et al, (2000). Using Geographic Information Systems to Understand Health Care Access, *Archive of Family Medicine*, 9: p971–978.

Richards, T. B. (1999) Geographic Information Systems and Public Health: Mapping the Future, *Public Health Reports*, 114: p359–353.

Rushton G. (2002). Public Health, GIS, and Spatial Analytic Tools, *Annual Review of Public Health*, 24: p43–56.

Sandhu, J. (2012). Personal Communication, Email, April 25, 2012.

Shannon, G. W., Spurlock, C. W., Gladin, S. T., & Skinner, J. L. (1975). A method for evaluating the geographic accessibility of health services. *Professional Geographer*,27: p30–36.

USGS. Elevations and Distances in the United States.

http://egsc.usgs.gov/isb/pubs/booklets/elvadist/elvadist.html

ZIP Code to PCSA Assignment (2006).
http://knox.dartmouth.edu/pcsa/downloads/ZIP_Code_Assignment.pdf

CURRICULUM VITAE

Sean Corrigan Finnegan graduated from Perry Lecompton High School, Perry, Kansas, in 1998. He received his Bachelor of Science in Geography from the University of Missouri, Kansas City 2005. He was a geography intern at the National Geographic Society in 2006 and remained working for them through 2008 after which he worked for Discovery Communications and has spent the last 4 years doing work as a geographic information specialist for Population Action International from 2009-10 and the American Academy of Family Physicians from 2010 to the present. He will plan to graduate from George Mason University with his Masters of Science in Geographic and Cartographic Information Systems in the summer of 2012.