Spatial Analysis of Vision Services of Kaiser Permanente Members

by

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To my husband, Michael, for all his patience and support.

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List of Abbreviations

E2SFCA	Enhanced 2 Step Floating Catchment Area
FCA	Floating Catchment Area
FTE	Full-Time Equivalent
HSPA	Health Service Planning Area
HUD	U.S. Department of Housing and Urban Development
IRB	Institutional Review Board
KP	Kaiser Permanente
MRN	Medical Record Number
MSA	Medical Service Area
PHI	Patient Health Information
SDS	Specialist Data Solutions
VE	Vision Essentials by Kaiser Permanente

Abstract

Research has often examined geographical barriers to healthcare accessibility. These examinations, however, are usually focused on primary care and urgent or specialty care. This study focuses on access to vision care and services with the goal of bridging the gap in research for this category of healthcare. Spatial accessibility for Kaiser Permanente members was examined using the Enhanced 2 Step Floating Catchment Area (E2SFCA) method. This method has been used in previous studies to examine spatial accessibility of patients to healthcare services. It examines both supply (the amount of services or providers available to provide services) and demand (patients who may or have used such services). This study also examined the differences between using ZIP codes and Census tracts as the base geography and for understanding how this choice is likely to affect the performance of the E2SFCA method and the final outputs. The analysis showed that the southern region of the Riverside Medical Services Area (MSA) has a shortage of optical services and that members must travel longer distances for these services. Future research should further analyze the accessibility of the members living within the Riverside MSA to vision services offered by Vision Essentials of Kaiser Permanente.

Chapter 1 **Introduction**

Kaiser Permanente is known for the integrated, high quality healthcare that they provide, as well as their superior work environments which aids in their efficiency (McHugh, Aiken, Eckenhoff & Burns, 2016). One part of this healthcare includes optical services provided by Vision Essentials, a department within Kaiser Permanente. All Kaiser Permanente members have access to basic eye exams as a part of their medical benefits. There are supplementary optical benefits available to members that may be purchased in addition to their medical insurance which may, in turn, provide additional funds for eyeglasses or contact lenses. The optometry departments that offer these services, however, are not evenly dispersed and therefore not as easily accessible to all Kaiser Permanente members.

This study examines the spatial accessibility to Vision Essentials optometry department services in the Riverside Medical Service Area (MSA) of the southern California region. The objective is to determine areas of low spatial accessibility to Vision Essential optometry departments using the Enhanced 2 Step Floating Catchment Area (E2SFCA) method. An analysis for the department has already been completed, focused on this area, examining the members that live in this area and which medical centers they are visiting. A comparison between these findings and the findings from this study will be provided as well.

Kaiser Permanente is different from some other medical service providers in that it is both the provider and insurer. Members will most likely only go to Kaiser Permanente facilities, as receiving service from a different provider is considered outside of the insurance network, which may mean that the patient would incur increased out-of-pocket costs. Due to this factor, it is important to identify areas of low accessibility in hopes that new centers can be developed to provide a more even distribution of access to the members.

Vision Essentials is the branch of Kaiser Permanente that provides vision care services to its members. There are 47 optometry departments available to members throughout the southern California region. This is an area that stretches from Kern County to San Diego County; which is divided into 12 MSAs (see Figure 1). The optometry departments are not dispersed evenly through the region, and they are also not available at every Kaiser medical center.

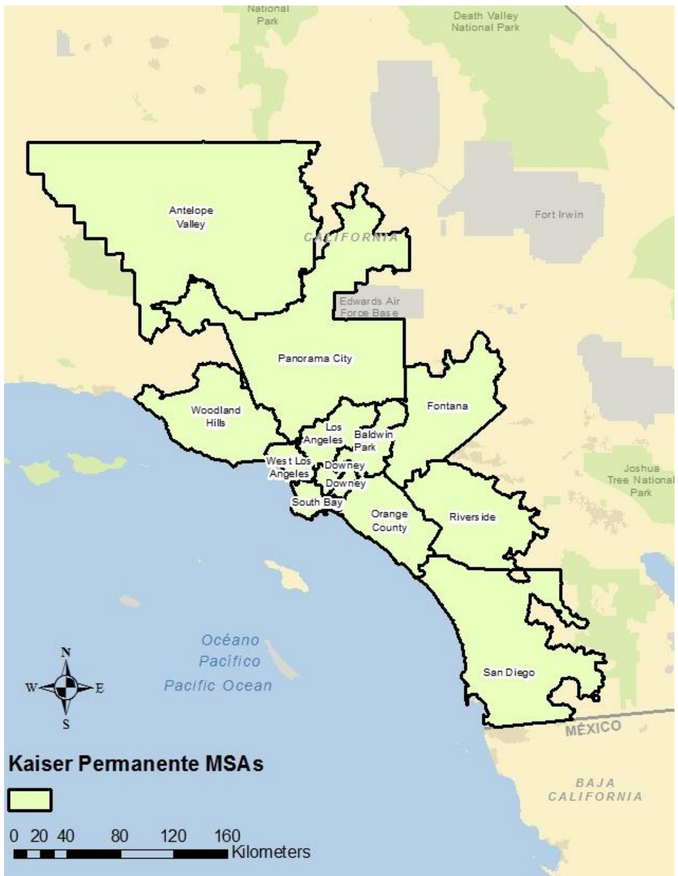

Figure 1: Southern California Kaiser Permanente MSAs

There are three components that must be met in order to provide spatial accessibility. This includes the supply of services or providers, demand for supply, and the distance or time barriers to the healthcare locations (Luo & Wang, 2003; Jamtsho & Corner, 2014; Becker, 2016). When analyzing accessibility as it pertains to healthcare services, there are two possible types identified: revealed and potential accessibility (Khan, 1992; Luo & Wang, 2003). Revealed accessibility relates to services that have been identified as being utilized. Potential accessibility includes the services that may be used but are not guaranteed. This study examined revealed accessibility to vision services. Access has spatial and non-spatial features (Khan, 1992). Spatial access takes into account geographic barriers or facilitators, such as a distance variable, and non-spatial features include barriers and moderators such as income or social class (Khan, 1992; Luo & Wang, 2003).

As stated earlier, Kaiser Permanente is unique in that it is both the insurer and provider. Members will typically not access outside medical services unless a referral is received from their primary care provider. As with other insurance providers, patients are responsible for medical costs that are obtained outside of their network unless a referral has been issued and approval received from the insurance provider. This study focuses solely on Kaiser Permanente members. This simplifies the analysis in that other service providers did not have to be included in the study, as it is most likely that members will not seek outside care for eye exams. This is due to two reasons: (1) the basic eye exam is covered under the primary medical insurance and additional optical coverage is not necessary; and (2) to receive outside provider services would mean out-of-pocket costs for the member. No other population group was examined for this particular study.

The E2SFCA method was used to examine spatial accessibility and health plan service areas (HPSAs) in this study as it is a vector-based method that allowed for the examination of both spatial and non-spatial variables (Jamtsho & Corner, 2014). ZIP code and census tract areas were both used as map units in this study. Analysis examining large service areas, such as counties, are not able to distinguish the detailed spatial variations that may occur when studying spatial accessibility (Luo & Wang, 2003; Luo, 2014). Only ZIP code data was available for both members and optometrists. Membership numbers were available by ZIP code of patient residence; optometrists were linked to the ZIP code of the optometry department in which they provided services. Since only ZIP code data was available the patient membership data was converted to census tracts using the U.S. Department of Housing and Urban Development (HUD) crosswalk file. Weighted centroids of population were created for each census tract and ZIP code. The optometrists and optometry departments were weighted to determine exam room capacity.

The data obtained from Kaiser Permanente included member demographics, optometry and medical center locations, type of vision care services, and additional attributes for each dataset. Once obtained, data was recoded to remove member personal health information to follow all HIPAA requirements. HIPAA requires that personal health information remain private. ZIP code data for members was used in this study and is still considered to be personal health information, although low risk. Approval from Kaiser's Institutional Review Board (IRB) was obtained prior to performing the analysis reported in this thesis.

1.1 **Motivation**

There is limited background research examining spatial accessibility to vision services. This study will work to bridge the gap of research on vision services and to add to the validity of the E2SFCA method. The importance of filling the gap of research for vision services lies with the significance of preventative care. One of the Healthy People 2020 initiatives is to improve the visual health of people through preventative care and early detection and treatment (U.S. Dept of Health and Human Services, 2017). As people age, bodies begin to change and need to be monitored for any adverse effects that could affect health. The eyes are important to monitor as an individual gets older to catch eye diseases at an early stage. There are many types of disease that could occur which include, but are not limited to, presbyopia or far-sightedness, glaucoma, and cataracts.

As people age, the need for optical services for preventative care and/or disease maintenance increases. By 2020, it is estimated that 2.3 billion people will be affected by presbyopia which is but one example of a disease that can develop (NewsRX LLC, 2014). Although most persons over the age of 45 years suffer from presbyopia, more than half are not receiving the care they need to correct the issue (NewsRX LLC, 2014). Disparities in access to vision services prevent individuals from receiving the care they need for correction which includes the elderly population (Umfress and Brantley, 2016). Access to healthcare is promoted by having a provider that is identified within a community (Wyn, Teleki, & Brown, 2000). Riverside County has a population of about 2.4 million with 13.9% being over 65 years old (U.S. Census Bureau, 2016).

Preventative maintenance in health, such as vision care, is important to catch before issues become irreparable. Although many of these studies focus on access to healthcare services such as primary care; there has not been any examining the importance of access to vision services. It is important to monitor vision health as many individuals suffer from some form of eye disease or illness. One study using a small sample size of 152 residents found that only 62% of adults older than 40 years received eye care services in Los Angeles County (Baker, Bazargan, Bazargan-Hejazi, and Calderón, 2009). They also found that having regular providers available was significantly and positively associated with vision care utilization. Although this is a study with a small sample, it is still important to note any consequence that could arise from lack of availability of services.

Of the 47 optometry departments in southern California, three are located within the Riverside MSA. Many patients within this MSA are required to travel more than 30 minutes to receive care from a Kaiser Permanente vision center or must visit a non-Kaiser facility. Neither of these options is convenient for the patient and puts a strain on accessibility for the members.

1.2 **Objectives**

The main objective of this study was to determine the areas of low spatial accessibility to Vision Essential optometry departments for Kaiser Permanente members in the Riverside MSA. This study worked to bridge the gap in research on accessibility to vision services, as well as to provide information to Vision Essentials for future expansion in areas found to be low in spatial accessibility. This thesis also worked to increase the validity and flexibility of the E2SFCA method, as well as provide a comparison of the model results at the ZIP code and Census tract units of analysis.

Through analysis of Kaiser Permanente members and the optical services provided, this thesis examined the spatial accessibility of members using ratios of patients to optometrists and optometrists to members for each catchment. Using distance decay to display a more realistic measure of access, the levels of spatial accessibility per catchment area were created. Without the distance decay, it is assumed that all members found within each of the three zones would have the same kind of access to the services. Estimating the decay as the distance increases mimics the unequal access that the members in different zones would encounter in their everyday lives.

1.3 **Thesis Organization**

The remainder of this thesis unfolds as follows. Related work on spatial accessibility to healthcare services, background on Kaiser Permanente, and gravity-based models used to examine spatial accessibility are reviewed in Chapter 2. Chapter 3 describes the methodology used for this study including the data needs, study area, and data sets that were used. Chapter 4 describes the findings of this study and discusses their significance given the objectives described earlier. The fifth chapter offers some conclusions and ideas for future work.

Chapter 2 **Related Work**

Accessibility to healthcare services is influenced by both physical and socioeconomic factors (Joseph & Phillips, 1984). Socioeconomic influences include a person's ability to afford services or the institution's permitted use of them. Physical accessibility means that the service should be both available for use and easily reached by the individual seeking to use the service. These factors can either create a barrier or facilitate the utilization of healthcare services. There is an importance in identifying these influences. Barriers would need to be overcome to increase accessibility.

There are many different models that have been used to analyze spatial accessibility for local populations. Each of these approaches, seemingly growing off of one another; examines the relationship between supply and demand, taking into account spatial variables that may either impede or facilitate use of services (Jamtsho & Corner, 2014). The development of these approaches will be discussed later in this chapter. The size and type of study area will likely determine which approach would work best in analyzing spatial barriers. Research on accessibility to healthcare services has been examined through regional availability and accessibility (Joseph & Phillips, 1984). Each of these approaches is discussed in more detail later.

Using the Enhanced 2 Step Floating Catchment Area method, this study measured the spatial accessibility of services for Kaiser Permanente members in the southern California region, specifically the Riverside county area.

2.1 **Kaiser Permanente**

Kaiser Permanente has become one of the largest non-profit health plans in the U.S. Established in 1945, the organization became the first of its kind allowing affordable health care services to individuals that would otherwise not receive any. It was developed through the collaboration of Dr. Sidney Garfield and Henry J. Kaiser in which a pre-payment system was created in exchange for medical services to the employees of Kaiser's Shipyard. From this modest beginning, it has grown into an organization that serves more than 11 million members throughout the U.S. (Kaiser Permanente, 2016).

According to their 2015 Annual Report, the organization has 38 hospitals and about 622 medical office buildings throughout the nation (Kaiser Permanente, 2015). It has continuously ranked high among all hospitals in care and satisfaction. Both the northern and southern California regions of Kaiser Permanente have won four-star ratings in overall clinical effectiveness from California's Office of the Patient Advocate for the past 10 years (Kaiser Permanente, 2017). They are the only health plan in California to earn the highest rating possible.

As stated earlier, Kaiser Permanente is unique in that is both the health plan and the healthcare provider. Members will typically not access outside medical services unless a referral is received from their primary care provider. As with other insurance providers, patients are responsible for medical costs that are obtained outside of their network unless a referral has been issued.

2.1.1. Vision Essentials by Kaiser Permanente

Vision Essentials is a department within Kaiser Permanente that provides optical services to its members. There are locations throughout the U.S.; however, this study will focus on the Riverside MSA of the southern California region of Kaiser Permanente. Within this region, there are 47 optical centers from Ventura to San Diego counties. Each optical center provides preventative eye health care through examinations performed by optometrists.

Regular preventative care eye exams are covered under the patient's medical insurance which may help some patients overcome the barrier to services caused by financial stress. The patient would only be responsible for paying the co-pay at the time of service. The co-pays can range from $0 to $60 per visit depending on the type of insurance coverage the patient has. The co-pay may actually be a barrier for some patients who may find it hard to pay any amount; however, this study will focus on spatial accessibility.

2.1.2. Preventative Care in Eye Health

As people age, bodies begin to change and need to be monitored for any adverse effects that could affect health. As an individual gets older, catching eye diseases in their early stages could help in preventing further deterioration from occurring. There are many different types of diseases that could occur which include but are not limited to presbyopia or far-sightedness, glaucoma, and cataracts.

Many individuals are not receiving the preventative care that they need in order to prevent further damage to their eyes. For example, although most persons over the age of 45 years suffer from presbyopia, more than half are not receiving the care they need to correct the issue (News RX LLC, 2014). Disparities in access to vision services prevent individuals from receiving the care that they need for correction (Umfress & Brantley, 2016).

2.2 **Healthcare Accessibility**

Access to healthcare services is reliant on different variables that include availability, affordability, and geographical accessibility (Gao et. al., 2016). Access has both spatial and non-spatial elements (Khan, 1992) and has been measured by the closeness between the provider and the patient (Rosero-Bixy, 2004). Spatial access means that a patient has overcome barriers such as distance and traffic congestion to access services. The non-spatial element refers to barriers such as economic and/or behavioral variables. Even when all of these needs are met, one cannot automatically assume that such services will be utilized. Geographical accessibility has been found to be both a predisposing and enabling factor to whether or not individuals will receive the care they need (Arcury et al., 2015).

There are two different types of accessibility: potential and revealed accessibility (Joseph & Phillips, 1984; Khan, 1992; Gao et. al., 2016). Potential accessibility refers to services that are available for use but does not automatically mean they are used. There would be probable use of services if barriers are overcome. Revealed or realized accessibility are services that have been utilized which means that any barriers deterring the use have been overcome.

2.2.1. Spatial Accessibility

There are three major factors that play into spatial accessibility which include: (1) the supply of available healthcare services; (2) the demand by patients to use these services; and (3) the geographical location of these services (Joseph & Phillips, 1984; Khan, 1992; Jamtsho & Corner, 2014; Becker, 2015). Geographical location, in this sense, refers to how easily the individual is able to get to the services as they may be impeded by time or distance. Supply of healthcare services can be interpreted as supply of healthcare providers. The availability of these resources influences the accessibility and utilization of them (Joseph & Phillips, 1984). The demand refers to the utilization of services by patients.

The approach to be taken to analyze spatial accessibility typically depends on the level of aggregation to be studied (Joseph & Phillips, 1984). Two common approaches are regional availability and accessibility. Regional availability is the simpler of the two approaches and examines the distribution of supply and demand of healthcare services throughout a region. Regional accessibility also examines supply and demand, however, in more detail by looking at the interactions between them. These interactions are analyzed spatially to determine accessibility.

There are problems that arise when using either approach to analyze spatial barriers so these must be taken into account before analysis to determine which model would be the best fit. The drawback of regional availability is that it assumes patients will not visit facilities or obtain services outside of a designated region (Joseph & Phillips, 1984; Luo & Wang, 2003). In other words, it assumes that the boundaries are not permeable. It also makes the assumption that all individuals within a region have equal access to services (Luo & Wang, 2003). Also, with larger levels of aggregation, it is difficult to identify any variations that are occurring at smaller levels.

There are also limitations associated with using the regional accessibility approach. This approach examines regional supply and demand through analysis of centroids in smaller regions; therefore, accessibility is centered at these points within the region (Joseph & Phillips, 1984). Although the regions are much smaller than in the regional availability method, the same problem arises in which it assumes that all individuals within the region have the same access to services. Many models have been proposed to try to rectify this issue including the E2SFCA method which incorporates smaller zones within larger catchments.

2.3 **Spatial Analysis of Accessibility in Health Care**

Different methods have been developed to measure special accessibility to healthcare services such as computation of ratios and distances, gravity-based methods, space-time accessibility techniques, and kernel density methods (Guagliardo, 2004; Jamtsho & Corner, 2014;). Geographical Information Systems (GIS) have been a tool used to analyze need and accessibility in healthcare allowing for researchers to combine both spatial and aspatial variables (McLafferty, 2003). This study used the Enhanced 2 Step Floating Catchment Area Method to examine the spatial accessibility of Kaiser Permanente patients to Vision Essential locations. Many models have been used to examine the spatial accessibility of healthcare, as briefly described below.

2.3.1. Gravity-based Models

The gravity-based method is one method that can be considered the basic formula used in spatial accessibility examining regional accessibility (Joseph & Phillips, 1984; Jamtsho & Corner, 2014). Regional availability recognizes the interactions between supply and demand. Gravity model approaches are used to examine these interactions, taking into account the location of the supply and demand, as well as distance. These two items must be specified when utilizing this approach (Joseph & Phillips, 1984).

The regional accessibility approach differs, and is more complex. Regional accessibility examines supply and demand by creating a ratio between the two variables. This simple examination of accessibility, however, makes a few assumptions: (1) patients only access healthcare services within the boundaries created; and (2) the method does not identify spatial variations that could be occurring in smaller areas (Joseph & Phillips, 1984; Khan, 1992).

A simple gravity-based model was created by Walter G. Hansen when trying to develop a method to determine a pattern between accessibility and residential development in city areas. This model states that the accessibility of location A is influenced by the size of activity in location B, as well as the distance between them (Hansen, 1959). In other words, the more activity around location B and the closer they are, the higher the accessibility of location A:

$$A_{1,2} = \frac{S_2}{T_{1-2}^{x}} \tag{1}$$

where $A_{1,2}$ is the accessibility measure in zone 1 to an activity in zone 2, S_2 is the activity size (such as number of people), and $T_{1\text{-}2}$ is the travel time between the two zones. The exponent is supposed to explain or describe the effects of the travel time. This early model by Hansen only considered the supply side of the equation and not demand. Other models did not take into account the diversity of availability of supply or healthcare providers; for example, some locations may have more providers to offer services or a certain location may offer different types of services.

Joseph and Bantock (1982) applied the gravity model to healthcare accessibility and also tried to capture this diversity by estimating the demand relative to supply by using assumed population utilization for that area. They also used an index of potential physical access to the practitioners. They believed that there are two approaches when analyzing healthcare accessibility, specifically to general practitioners: (1) measures of revealed accessibility through utilization data; and (2) the measurement of potential accessibility which they based off where the patient lives in relation to the services. The formula they used to examine the potential accessibility of patients was:

$$A_i = \sum_j G\,P_j / d_{ij}^b \qquad (2)$$

where A_i is the potential accessibility of location i to the providers, GP_j is the general practitioner at location j within range of location i, d_{ij} is the distance between locations i and j, and b is the distance exponent. They also estimated the demand on doctors since there is a variability of availability of providers in areas with differing population numbers:

$$D_j = \sum_i P_i / d_{ji}^b \qquad (3)$$

where D_j is the demand on the provider at location j, P_i is the population at location i within the range of location j, and d_{ji} reflects the distance between locations j and i (Figure 2).

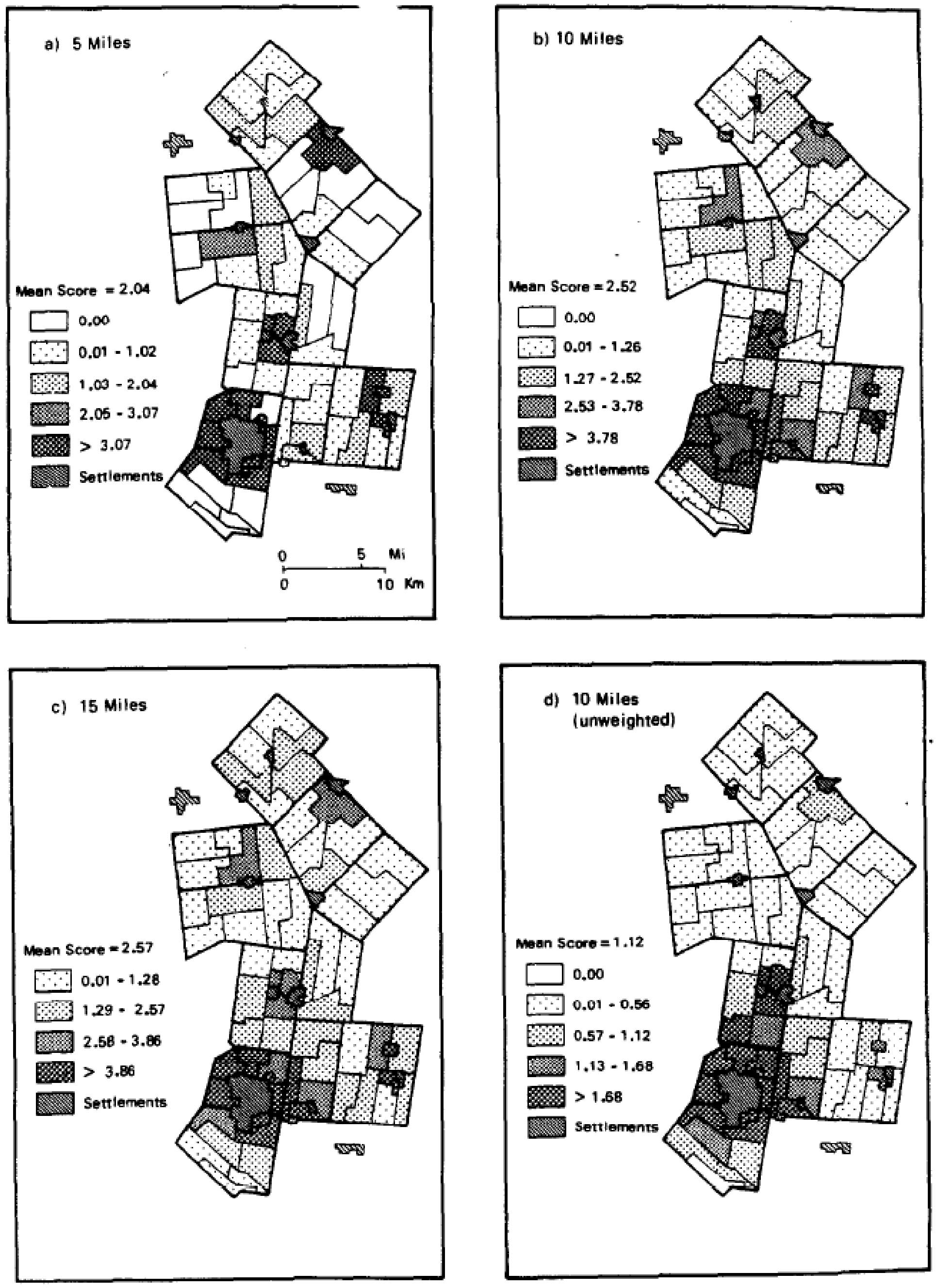

Figure 2: "Demand" – Potential accessibility to general practitioners (Joseph & Bantock, 1982). The scores associated with the four maps refer to the potential physical accessibility measurement with 0.0 representing zero accessibility.

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Although accessibility was being examined from both a supply and demand perspective, it still did not capture the full picture of spatial accessibility. Distance decay and distance ranges were added to imitate the mobility of the population (Khan, 1992). In this gravity model, weighted estimates of potential availability of providers were also introduced.

2.3.2. Floating Catchment Area Methods

The floating catchment area (FCA) methods have been used to measure accessibility as well, but not necessarily in healthcare. Peng (1997) used a version of the FCA to examine jobs and housing for example. In the FCA, boundaries are created around a specific area or point creating catchments. For example, in Peng's (1997) study, catchments were created around each traffic zone, extending out 5 miles. Then jobs and housing were aggregated within each of these catchments to determine the ratio of accessibility. In doing so, it was assumed that each resident would have access to all of the employment opportunities within each of the catchments, however, that is not always the case (Luo & Wang, 2003). When applying this method to healthcare, it does not consider that providers may provide services outside of the proposed area as well and therefore they may not be providing full services to only those residents in the designated catchment areas (Figure 3).

The Two Step Floating Catchment Area (2SFCA) method proposed by Luo and Wang (2003) took the FCA further. It examined both supply and demand in the same analysis instead of just being one sided (i.e., considering supply only) such as in the gravity and early FCA models. In this method, catchments were created around each census tract centroid, as well as the provider location. Travel time was used instead of Euclidian distance to create catchments around each of the centroids. A provider-to-population ratio is used to relate supply to demand.

The providers and residential populations are examined within boundaries with the numerator being the supply such as provider capacity and the denominator being demand which could be the population living near the facility or services (Luo & Wang, 2003; Guagliardo, 2004; Wang & Luo, 2005; Dewulf, Neutens, De Weerdt, & Van de Weghe, 2013). Ngui and Apparicio (2011) even added weights to the provider locations by using the number of providers available at each location.

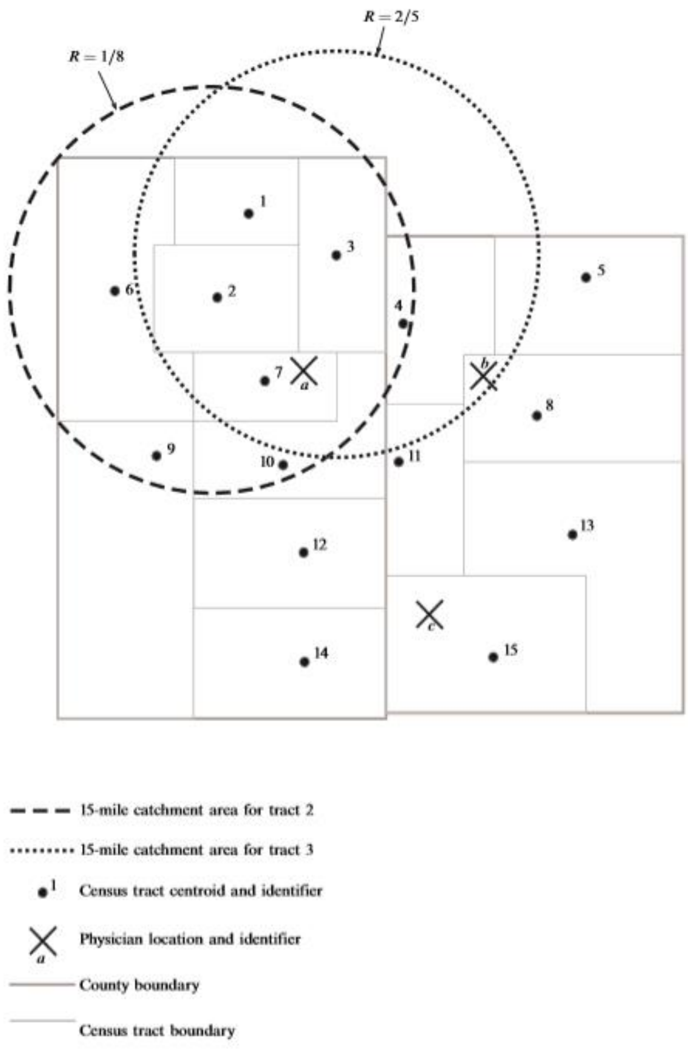

Figure 3: Example of floating catchment area showing the catchment created around the centroids for census tracts 2 and 3 using Euclidian distance (adopted from Luo & Wang, 2003).

For the first step, a catchment is created around each healthcare provider centroid using a specified distance or drive time. The total population found within each catchment is summed up to create the provider-to-population ratio (supply):

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k} \tag{4}$$

where R_j is the provider-to-population ratio at location or catchment j, S_j is the number of providers at location j, d_{kj} is the distance between locations k and j, and P_k is the population within the spatial area such as a census tract or ZIP code.

For the second step, a catchment is created around each population centroid using a specified distance or drive time. The previous ratio of provider-to-population found within each catchment is summed up to create the accessibility index (demand):

$$\mathrm{A_i^F} = \sum_{\mathrm{j}\in\{\mathrm{d_{ij}}\le \mathrm{d_0}\}} \tag{5}$$

$$R_j = \sum_{j\in\{d_{ij}\le d_0\}} \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k} \tag{6}$$

where A_i^F is the accessibility at location i (residential), R_j is the provider-to-population ratio at location j who fell within the catchment of i, and d_{ij} is the distance between locations i and j. See Figure 4 for a visual example of the 2SFCA method. The disadvantage of this method is that it assumes that all persons within the catchments have equal access to service providers and that all service providers have equal access to the residential population (McGrail & Humphreys, 2009). For example, a person living the closest to a boundary line has the same access as the person living near the centroid of the catchment. Also, the measure is dichotomous, meaning that access is either gained or not. There is no variation in the level of access. The Enhanced 2 Step Floating Catchment Area (E2SFCA) method was created in order to combat these problems.

The E2SFCA proposed by Luo & Qi (2009) creates travel time zones within each catchment and assigns different weights to each of these zones in an attempt to address the disadvantage of the 2SFCA method. These zones and weights are to account for the distance decay that occurs as the supply moves away from the population centroid or vice versa. A Gaussian weight was used for each time zone in their study, however, different weights can be used depending on the type of accessibility that is being examined.

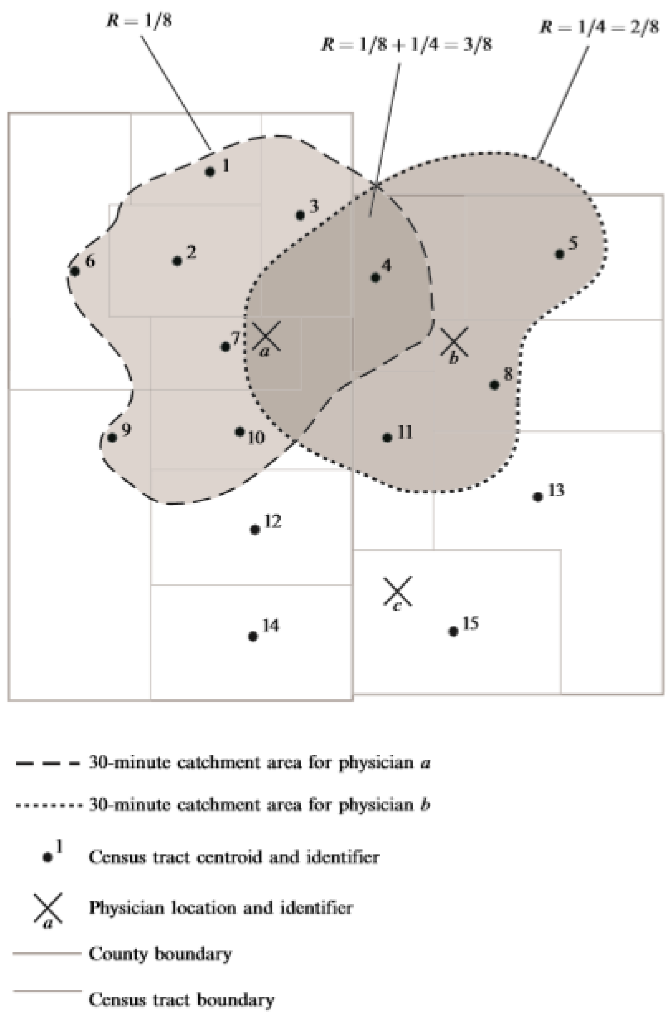

Figure 4: 2SFCA method (Luo & Wang, 2003) showing the catchments created around physician points *a* and *b* using a drive-time of 30 minutes.

The difference between the 2SFCA and the E2SFCA method are the zones that are created within the catchment. These three extra zones are created on both the supply and demand sides of the analysis:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_r\}} P_k W_r} = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_1\}} P_k W_1 + \sum_{k\in\{d_{kj}\in D_2\}} P_k W_2 + \sum_{k\in\{d_{kj}\in D_3\}} P_k W_3} \quad (7)$$

where the difference lies in the weighted zones that have been added with the addition of the W_r term. Equation 8, on the other hand, incorportes three zones to simulate the distance decay effect:

$$A_i^F = \sum_{j\in\{d_{ij}\in D_r\}} R_j W_r = \sum_{j\in\{d_{ij}\in D_1\}} R_j W_1 + \sum_{j\in\{d_{ij}\in D_2\}} R_j W_2 + \sum_{j\in\{d_{ij}\in D_3\}} R_j W_3 \quad (8)$$

The Huff model has also been used in within the FCA method as a third step in order to account for the probability that a patient may go somewhere else for services (Luo, 2014). However, for this study this will not be considered as most patients will stay within the Kaiser Permanente network.

2.3.3. ZIP Codes v Census Tracts

The use of ZIP codes for spatial and socio-economic analysis has increased through the years, however, they must be used with caution (Grubesic, 2015). The size of ZIP codes, as spatial units, changes depending on the area under examination. For example, in rural areas the size of ZIP code areas may be larger than those used within urban areas. Riverside is considered a rural area and both ZIP codes and census tracts were examined in this thesis project. There are few studies examining spatial accessibility using ZIP codes spatial units. As the E2SFCA method uses intervals within the catchments, census tract and ZIP codes were both examined to compare any differences that may arise from the choice of spatial unit.

Chapter 3 **Data Sources and Methodology**

This project aimed to identify the spatial accessibility levels of areas in the Riverside MSA for Kaiser Permanente members to Vision Essentials by Kaiser Permanente (VE) optometry departments using the Enhanced 2 Step Floating Catchment Area method. The research design, data sources, area of study, and method used for this of analysis are described below.

3.1 **Research Design**

The service areas for Kaiser Permanente are delineated using the nearest medical service centers. Patients living within the Riverside MSA were the focus of this project. Currently, there are three VE optical centers located within the Riverside MSA in the cities of Corona, Moreno Valley, and Riverside (Figure 5). The E2SFCA method was used to examine spatial accessibility of Kaiser's patients living within the Riverside MSA boundary. The MSA boundary has been predetermined by Kaiser Permanente.

3.2 **Data Sources**

Data on patient visits were gathered through the point-of-sale system called Specialist Data Solutions (SDS) provided by VE by Kaiser Permanente. Appropriate steps were taken to obtain Institutional Review Board (IRB) approval from Kaiser Permanente for the use of personal health information (PHI). The steps taken to ensure protection of PHI will be discussed later. The residential location data was obtained through spreadsheets maintained and made available by VE.

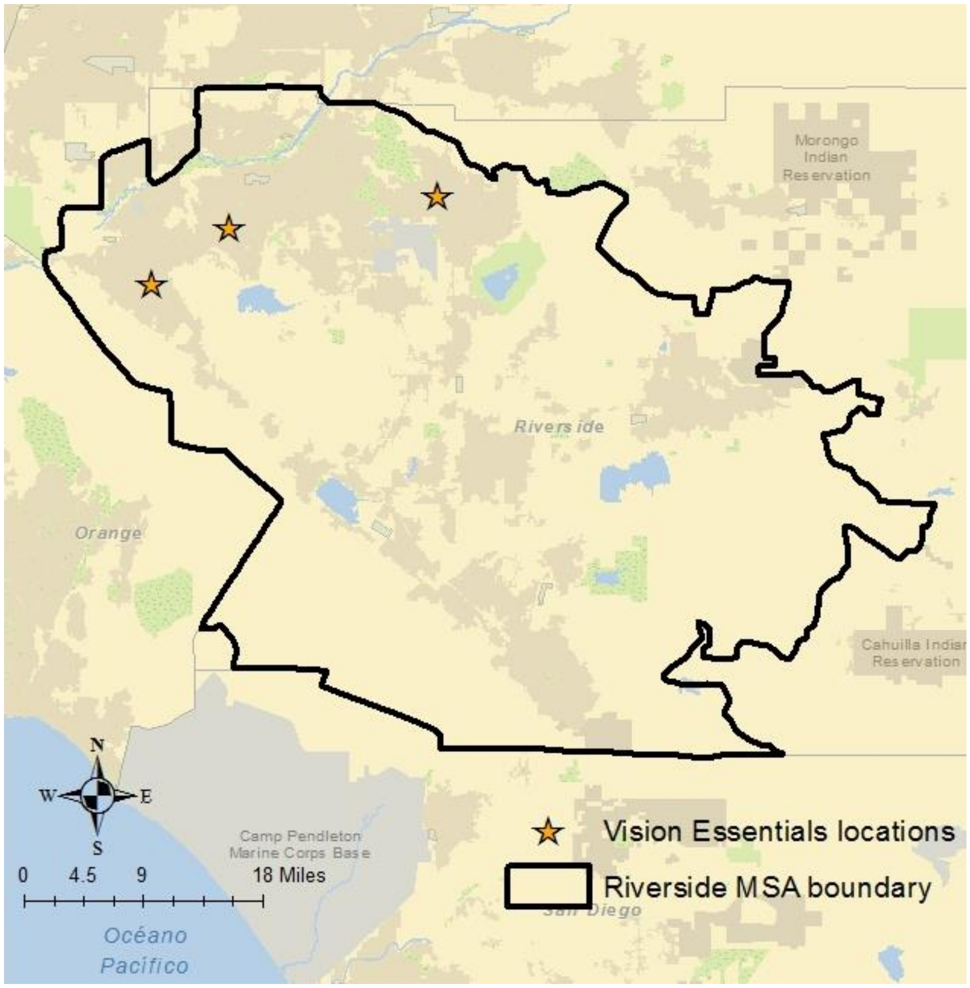

Figure 5: VE Optometry Departments located within the Riverside MSA

3.2.1. Patient Data

The patient visit details were obtained in .xls format and pulled from the VE point-of-sale system called SDS. IRB approval was required before data could be used in this study. The patient's name and medical record number (MRN) are considered unique identifiers and were removed before analysis to protect PHI, as required by law. A preliminary study outline was submitted as a part of the IRB approval process. Additional steps were required to be taken to ensure patient privacy for the protection of the patient's identity which included a second review of data to ensure PHI was removed. ZIP codes and visit details are still considered risky, although minimal, and therefore required IRB approval for usage. This information remained for analysis after approval was granted.

The patient visit detail is a compilation of data that includes date of visit, location of visit, home medical service area, home medical office building or MOB, type of procedure, length of procedure, and the patients' ZIP code in 2016 (Figure 6). This dataset displayed Kaiser Permanente members that have already visited an optical center and therefore represents revealed accessibility. A listing of all members by ZIP code was not approved for use in this study. Therefore, only the members that had already received services at one of the optometry departments were counted. As the patient detail will only provide ZIP codes for members, each was proportionally assigned to census tracts using the ZIP code tabulation area cross-walk provided by the U.S. Department of Housing and Urban Development (HUD) which will be discussed later (Figure 7). The patient visit detail data was provided in .xls format only and therefore was formatted to be added and used in ArcGIS Business Analyst.

3.2.2. Vision Essentials Optical Centers

The addresses for each optical center were provided by VE in .xls format. This dataset includes number of exam rooms for each optical center, as well as the addresses itself. All addresses were geocoded in Esri's Business Analyst, although only the optical centers located in the Riverside MSA were examined for this study (see Figure 2). Optometrist FTEs were used to weight each location.

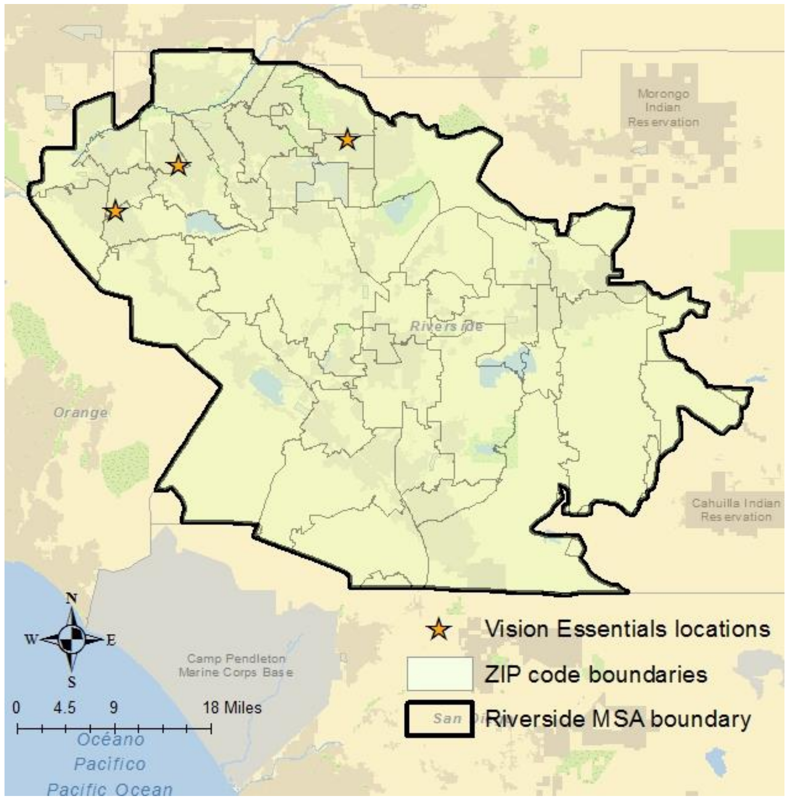

Figure 6: ZIP code boundaries

The FTEs were calculated using exam room availability (see Table 1). For example, an exam room available for 58 hours per week (10 hours per weekday and 8 hours on Saturday) would yield 1.45 FTEs (58 hours / 40 hours for the optometrist = 1.45 FTE per exam room). From this calculation, only 90% will be counted to account for any discrepancies that may occur because of patient no-shows and other problems, leaving the yield at 1.31 FTEs per exam room. This approach was used to generate realistic and conservative outputs in this thesis project. The FTEs per exam room was then multiplied by the number of exam rooms to yield total availability of provider for that location. This calculation was added to the attributes of the provider locations as its own field.

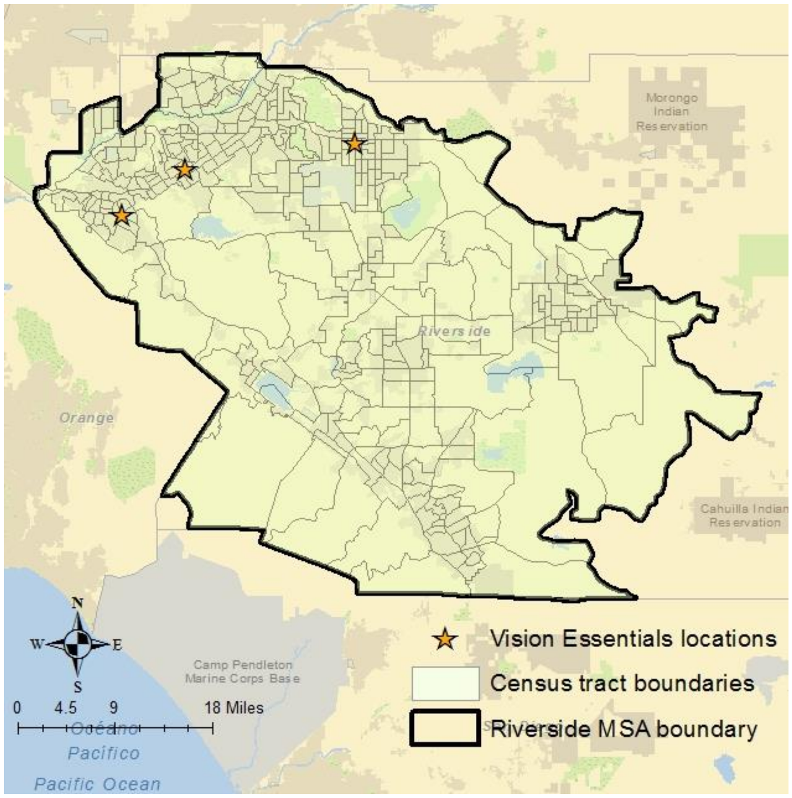

Figure 7: Census tract boundaries

Table 1: Example attributes of U.S. Department of Housing and Urban Development USPS ZIP code crosswalk file

ZIP	Tract	RES_RATIO
92501	030100	0.35244300000
92501	030200	0.28240400000
92501	030300	0.23990500000
92501	030700	0.00330994000

3.3 **The Enhanced 2 Step Floating Catchment Area (E2SFCA) Method**

The Enhanced 2 Step Floating Catchment Area (E2SFCA) Method is a type of gravity-based model (Luo & Wang, 2003). It has been used to examine the level of spatial accessibility that patients have to healthcare services. It takes both supply and demand into consideration when determining accessibility. For this study, the calculated FTEs per location will represent supply and the number of Kaiser Permanente patients that have received care through each VE per ZIP code or census tract will represent the demand.

3.3.1. Zip Codes and Census Tracts

The membership data was available through the patient visit details. This dataset provided ZIP codes for each member which were summed and joined to the ZIP code polygons used by the U.S. Postal Service and obtained from ArcGIS Online. The ZIP codes with membership totals were clipped to the areas within the Riverside MSA. The centroids within each of the ZIP code polygons were created (Figure 8). They were weighted by the VE membership.

Census tract information for membership was not available and had to be estimated using the HUD USPS ZIP code crosswalk file. There were multiple census tracts found within each ZIP code creating a many-to-one relationship. Table 1 showed a snippet of the crosswalk file which shows the corresponding census tract areas for a single ZIP code, along with the ratio of residential population that should be distributed. In order to obtain membership for the census tracts, first the crosswalk file and the patient visit detail files had to be merged. The already clipped ZIP code membership data was exported and then matched to the crosswalk file using MATCH and VLOOKUP. Membership was then calculated for each census tract area using the residential ratio or RES_RATIO using Microsoft Excel.

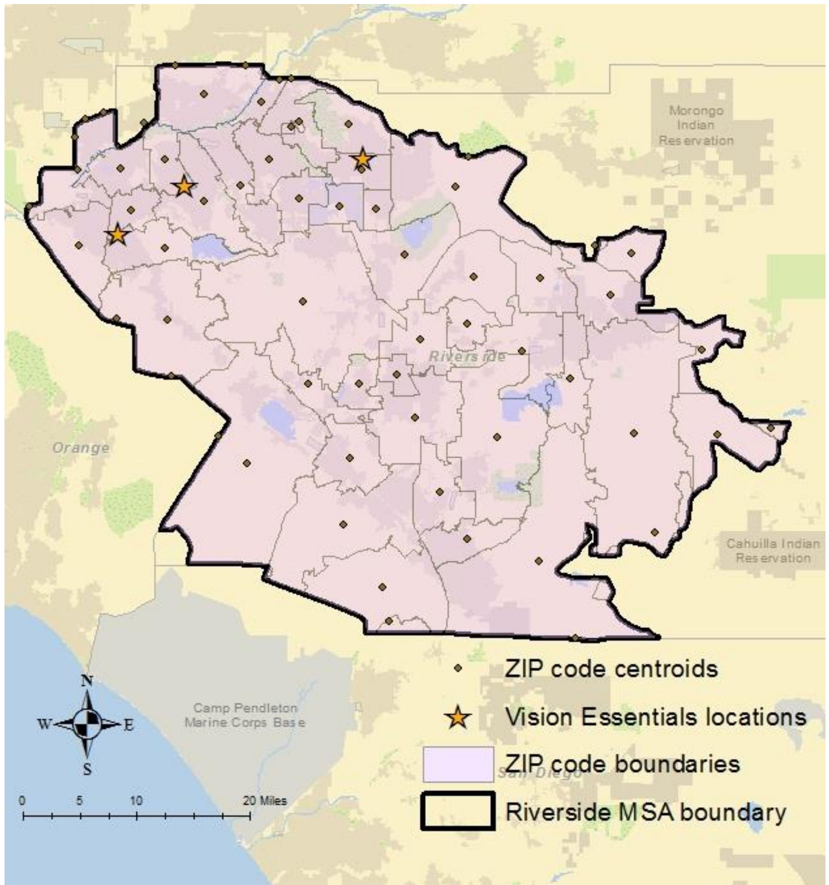

Figure 8: ZIP code centroids

Once the breakdown for membership was obtained it was then pulled into Esri's Business Analyst and joined to the census tract shapefile obtained from ArcGIS Online which was then clipped to the area contained within the Riverside MSA. Centroids were created within each census tract (Figure 9). These centroids were also weighted by the membership.

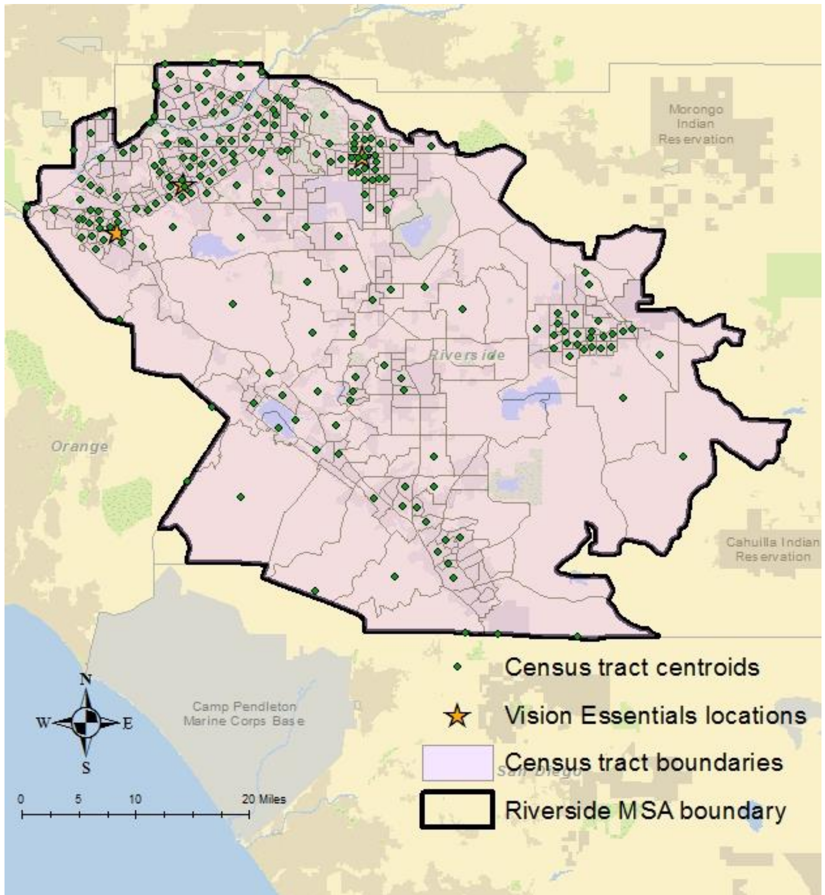

Figure 9: Census tract centroids

3.3.2. Catchment Areas

According to a study of 5,000 adults, people are willing to travel up to about 30 minutes or about 20.4 miles for future non-urgent health care (Yen, 2013). Therefore, zones of 10, 20, and 30 minutes were created around each of the population centroids and optometry offices. For the E2SFCA method, catchments were created for both members and optometrists.

The E2FCA required sub-group catchments representing different time thresholds within the larger catchments. These zones were created in both the ZIP code and census tract analyses. They were split into 10 minute distance increments: 0-10 minutes for Zone 1, 10-20 minutes for Zone 2, and 20-30 minutes for Zone 3. This was to allow for a more accurate examination of spatial variations occurring in spatial accessibility (Luo & Qi, 2009). Each zone was weighted to account for distance decay using the Gaussian function (Luo & Qi, 2009). The Guassian function has a smoothing property where the exponent for distance equals 2 which takes into account the idea of space as well as the movement of populations (de Smith, Goodchild & Longley, 2015; Salze et al., 2011). The time buffers were created using the Trade Area Tool within Esri's Business Analyst.

3.3.3. Data Analysis

The measurement for accessibility is created using the ratio of optometrist to member within each catchment using the 2 step approach described below. The ratio of optometrist to membership for the first step was calculated by summing up all points found within each zone or buffer around the optometrist locations using:

$$R_j = \frac{S_j}{\sum_{i \in (d_{ij} \in D_1)} P_i W_r} = \frac{S_j}{\sum_{i \in (d_{ij} \in D_1)} P_i W_2 + \sum_{i \in (d_{ij} \in D_2)} P_i W_2 + \sum_{i \in (d_{ij} \in D_3)} P_i W_3} \quad (9)$$

where R_j represents the provider-to-membership ratio found within catchment locations j, P_i is the population total within each census tract or ZIP code that is found within catchment j, S_j is the total providers/calculated FTEs at each location j, d_{ij} is the distance between locations i and j, and W_r represents the weight of each zone using the Gaussian function.

Once the zones were created around each of the provider locations, the provider-to-population ratio was calculated by completing a spatial join between the zones and the centroids of both census tracts and ZIP codes, separately. In the tool, a one-to-many relationship was established in order to pull each individual centroid that falls within each of the zones. A new field was created to perform the calculation of FTE with distance decay divided by the membership to give us the provider-to-population ratio.

The data were next joined back to the VE locations using Join and Relate creating a new shapefile containing the ratio. The second step was used to sum up the number of providers found within each catchment around the membership centroids as shown in the following equation:

$$A_i^F = \sum_{j\in(d_{ij}\in D_1)} R_j W_r = \sum_{K\in(d_{ij}\in D_1)} R_j W_1 + \sum_{j\in(d_{ij}\in D_2)} R_j W_2 + \sum_{j\in(d_{ij}\in D_3)} R_j W_3 \quad (10)$$

where A_i^F is the accessibility to providers for members found within location or catchment i, and d_{ij} is the distance between locations i and j. The Gaussian weights, represented by W_r, were used in step 2 as well. For this step, after the zones were created around each of the membership centroids (census tracts and ZIP codes were handled separately), a spatial join was used to connect with the new shapefile created in the previous step. A many-to-one relationship was created in order to pull in each centroid that falls within the zones. Once joined, the spatial accessibility index was calculated by summing up the provider-to-member ratio that was obtained in the previous step.

Chapter 4 **Results**

This chapter reviews the results obtained through the examination of spatial accessibility using the Enhanced 2 Step Floating Catchment Area Method in the Riverside MSA. The spatial accessibility of Kaiser Permanente (KP) members to optometry departments were analyzed using tabulations of members by ZIP code and census tract.

4.1 **Membership and FTEs (Exam Room Availability)**

Both the centroids for the census tracts and ZIP codes and the optometry locations were weighted in order to create provider-to-population ratios that would become the spatial accessibility index. The patient visit detail data contains a total of 707,216 KP members that have received VE services within the southern California region. There are 2,029 patients who have visited this region but live outside of the area. Of all the patients, 78,741 members live in the Riverside MSA. There were 63 ZIP codes in the Riverside MSA and of these, 62 were occupied by patients that had visited at least one of the Riverside MSA VE locations during 2016. The membership data was joined to the ZIP code shapefile to create the weighted centroids (Figure 10).

Membership was not available by census tracts and therefore was redistributed using the U.S. Department of HUD's fourth quarter 2016 USPS ZIP crosswalk file as described earlier. The redistribution was then joined to the census tract shapefile for which weighted centroids were then created (Figure 11). All 78,741 members were able to be distributed into the census tracts provided by the crosswalk. However, once clipped, the census tract membership lost 19,308 members due to those that lived outside of the Riverside MSA boundary. Figure 12 shows how the census tracts matched up to the Riverside MSA. There was a total of 59,434 members that were retained within the MSA, and a total of 333 census tracts that were counted.

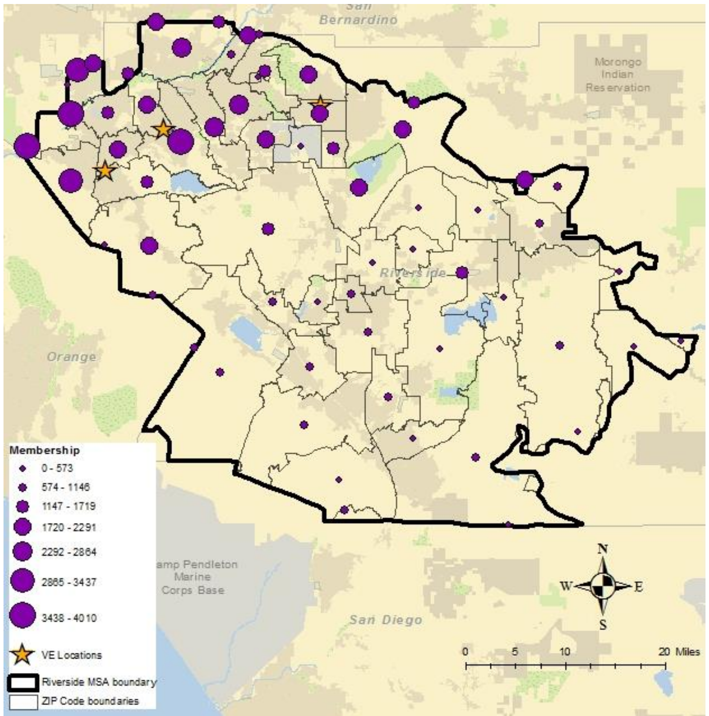

Figure 10: ZIP code centroids and the weights used to represent VE membership

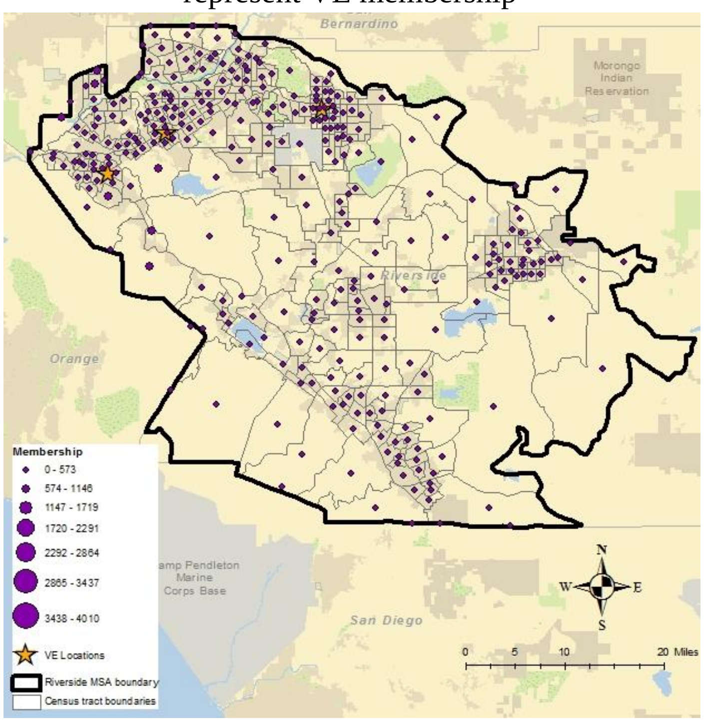

Figure 11: Census tract centroids and the weights used to represent VE membership

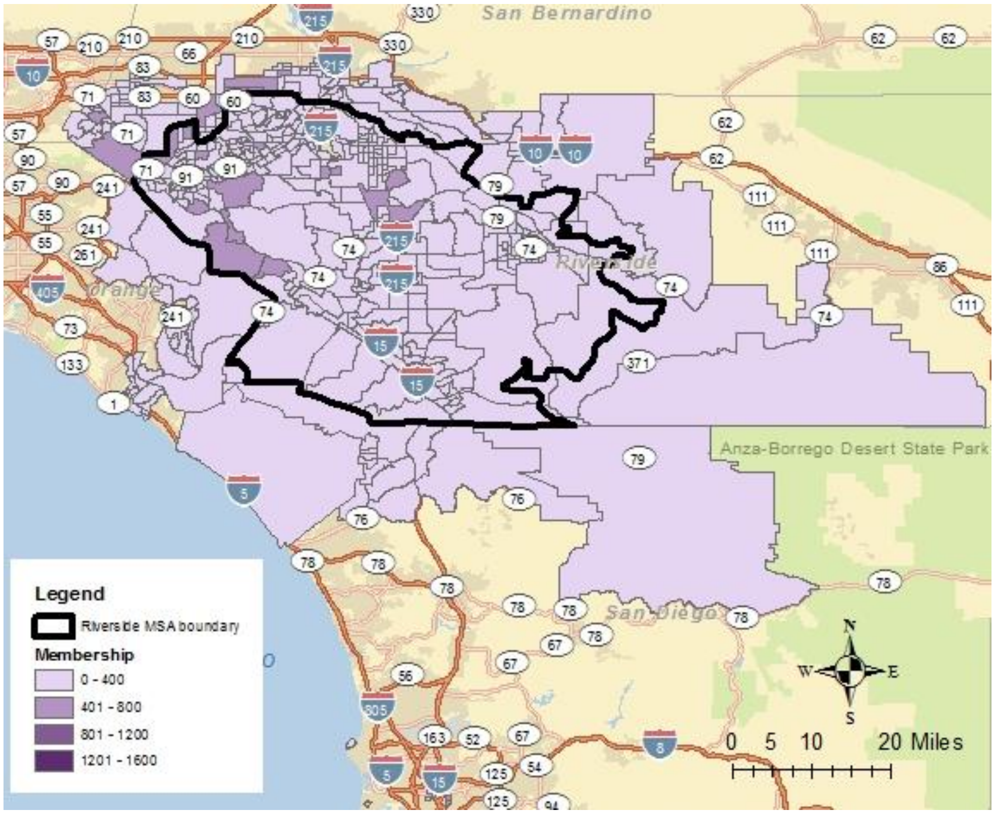

Figure 12: Display of how the census tract is mismatched with the
MSA boundary and ZIP code polygons.

The membership was joined to the clipped census tract boundaries to create the weighted centroids.

The weights for the optometry locations were created by calculating FTEs through exam availability. A full time optometrist works 40 hours per week which is equal to one FTE. The hours of operation determined the number of hours per week an exam room was open. The weighted FTE for each location was calculated at a 90% utilization rate for each exam room. Table 2 shows the breakdown of room numbers for each location, as well as the number of hours they are open per week. The Corona location had a weighted yield of 9 FTEs, the Moreno Valley location had 4.5 FTEs, and the Riverside location had 13.1 FTEs available.

Table 2: Calculations used to estimate FTEs per VE location

Location	# of Exam Rooms	# of Hours/Week Open	Full-Time Optometrist (Hrs)	Utilization (%)	FTE	Weighted FTE
Corona	8	50	40	90	1.13	9.0
Moreno Valley	4	50	40	90	1.13	4.5
Riverside	10	58	40	90	1.31	13.1

4.2 Drive Time Zones

Drive time zones in 10 minute increments (i.e. 0-10, 10-20, and 20-30 minute intervals) were created around the optometry locations and the membership centroids of the census tracts and ZIP codes and clipped to the Riverside MSA boundary (Figures 13-15).

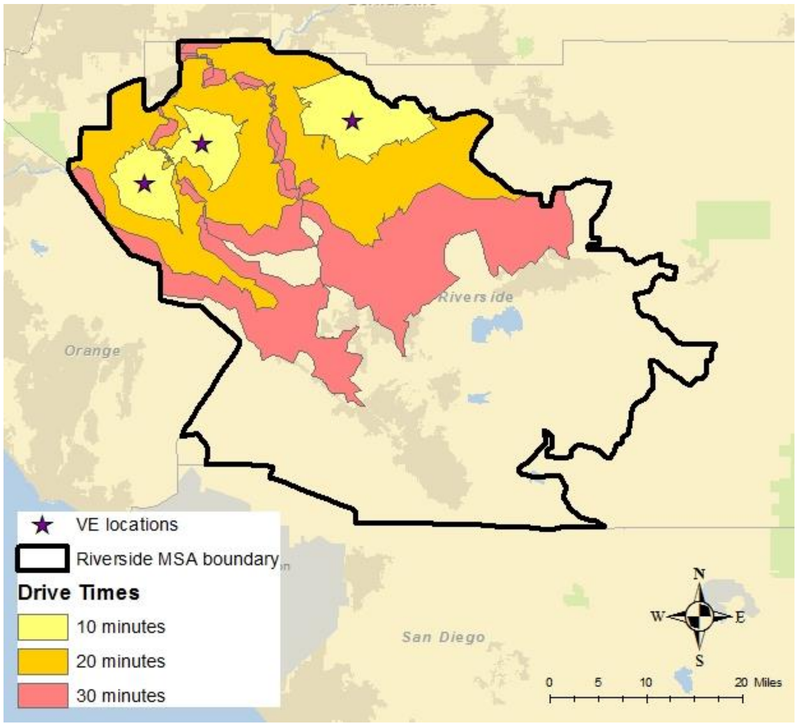

Figure 13: Drive-time zones of 10, 20, and 30 minutes around VE providers

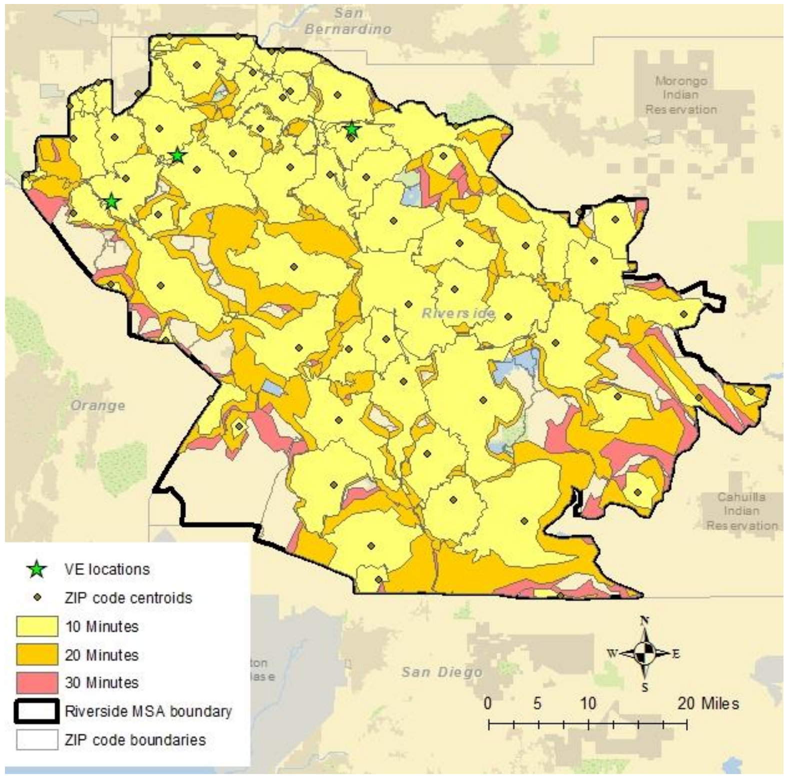

Figure 14: Drive-time zones of 10, 20, and 30 minutes around ZIP code centroids

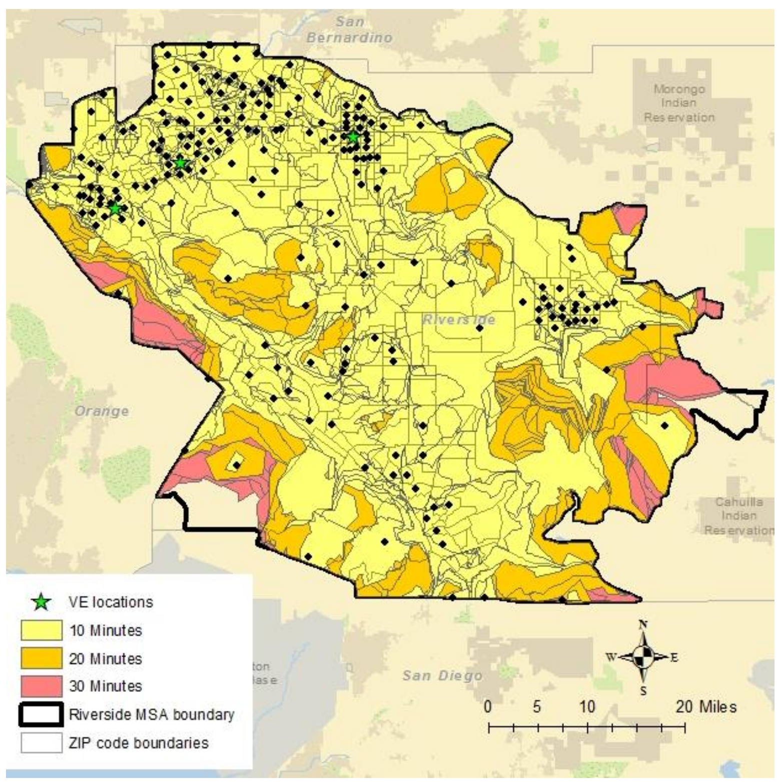

Figure 15: Drive-time zones of 10, 20, and 30 minutes around census tract centroids

The zones were created using the Trade Area tool within Esri's Business Analyst. Weights were given for each drive zone (zone 1: 1.0; zone 2: 0.6; and zone 3: 0.2) in order to account for distance decay which was based off the Gaussian decay function. These weights were used as they created a slower distance decay (Luo & Qi, 2009). Riverside has more rural areas throughout the MSA and therefore distance may not be as much of a hindrance for patients as they will need to do some traveling for services anyway. So the slower distance decay would not create drastic changes in accessibility as the distance increases away from the provider locations.

4.3 The E2SFCA Method Predictions

The E2SFCA model runs and the subsequent analysis for ZIP codes and census tracts were completed separately.

4.3.1. ZIP Codes

The first step of the E2SFCA method, after the creation of the catchments and drive-times around each of the service providers and population centroid locations, is to find all the population centroids that fall within each of the service provider drive-time zones. A spatial join was used to "catch" all of the population centroids. There were centroids that were counted more than once when they fell into multiple zones. For instance, all the centroids that fell within the 0-10 minute drive-time zone also were counted again in the 10-20 and 20-30 minute drive-time zones. Table 3 displays the total numbers of centroids counted per zone, as well as the number of centroids when removing the overlaps. Similarly, the number of members served per drive-time also were double counted, however, the totals in Table 3 reflect the actual numbers per drive-time zone without overlap. There was a combined estimated total of 76,825 members served and their distribution across each of the drive-time zones is reported in the last column of Table 3.

Table 3: Step 1 – Supply Availability, ZIP Code Centroids within Provider Drive Time Zones

Step 1: Vision Essentials - Supply Availability

Drive-Time Zones	**No. of Zip Code Centroids**	**Within Single Zone (No Overlap)**	**Estimated No. of Members Served**
0-10 Minutes	7	7	15,518
10-20 Minutes	27	20	37,014
20-30 Minutes	39	12	24,293
Totals	**73**	**39**	**76,825**

Once the membership was added to the provider zones, the provider-to-population ratio had to be calculated. A new field called Prov_POP was created and calculated by dividing the provider availability, which reflects the distance decay, by the membership that fell within that drive-time zone. The spatial accessibility ratio ranges from 0 to 1 with 0 meaning no access and 1 being full access. When looking at the spatial accessibility ratio, however, the actual totals are far less than 1. This is due to the fact that there is a small number of providers that provide service to a large number of members. To obtain a 1 would mean that there is exactly 1 provider that is available for services for every 1 member. The provider-to-population was then joined to the provider location centroids.

In step 2, the provider-to-population ratio (Prov_POP) was joined back to the VE location centroids. A spatial join relationship was then created to capture all provider locations within each of the ZIP code drive-time zones. Table 4 displays the number of ZIP code polygon drive-time zones in which a VE location was captured. There was a total of 81 times that a VE location landed within a zone without the overlap of drive-times. The provider-to-population ratio calculations were summed for each ZIP code boundary that a provider fell into. This ratio was then joined to the ZIP code boundary shapefile for display. Figure 16 shows the spatial accessibility for members

Table 4: Step 2 – Demand, ZIP Polygons containing VE location within Member Drive-Time Zones

Step 2: KP Members -Demand (3 Locations)

Drive-Time Zones	Total No. of Times VE locations Caught in Zone	Within Single Drive-Time Zone (No Overlap)
0-10 Minutes	8	8
10-20 Minutes	41	33
20-30 Minutes	81	40
Totals	**130**	**81**

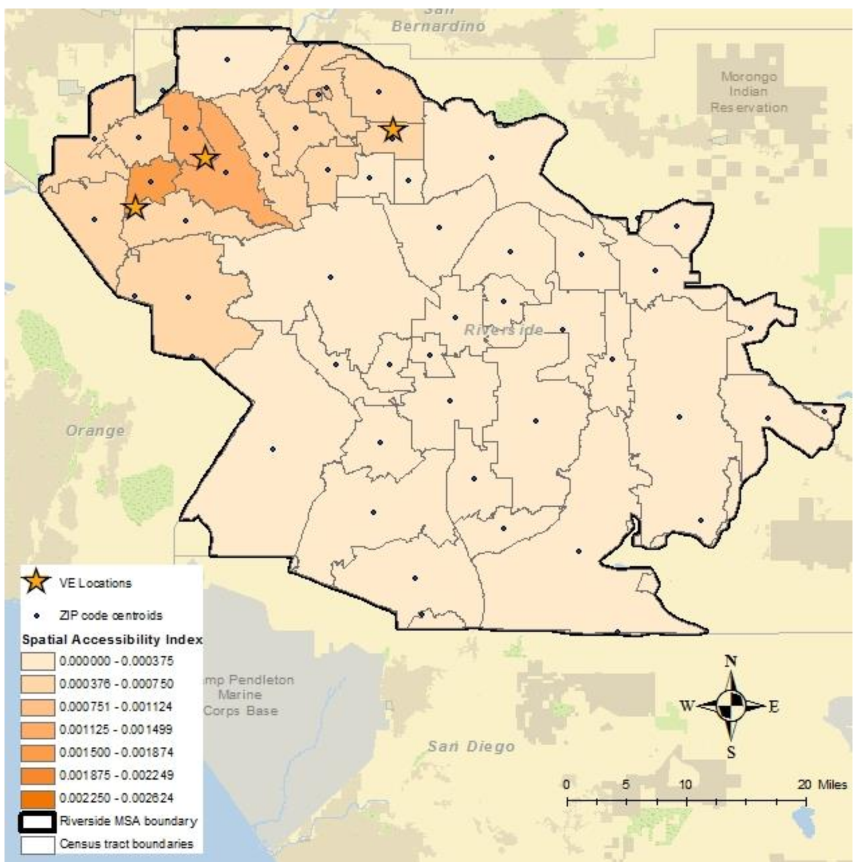

Figure 16: Spatial accessibility index of VE members by ZIP code

within each ZIP code boundary. Members located in the southern region of the MSA have no spatial accessibility to any VE location while members living in the northern half of the Riverside MSA have greater but varying degrees of spatial accessibility.

4.3.2. Census Tracts

The analysis for the census tracts followed the same steps used when analyzing the ZIP code spatial accessibility using the E2SCFA method. The first step was to count all census tract centroids that fell within each of the provider drive-time zones. Table 5 displays the number of centroids that was captured within each zone. Similar to the ZIP code analysis, census tract centroids fell into more than one of the drive-time zone when they were closer to the provider location. For example, a centroid that fell within zone 1 (0-10 minutes) would fall into every drive time zone. There were a total of 240 centroids, without overlap, that fell into any one of the drive-time zones. There was an estimated number of 50,456 members that were served within 30 minutes of drive times. This estimated number does not include members that may have landed in more than one drive-time zone as they are only counted once.

Table 5: Step 1 – Supply Availability,
Census Tract Centroids within Provider Drive Time Zones

Step 1: Vision Essentials -Supply Availability

Drive-Time Zones	**No. of Census Tract Centroids**	**Within Single Zone (No Overlap)**	**Estimated No. of Members Served**
0-10 Minutes	80	80	16,004
10-20 Minutes	186	106	25,129
20-30 Minutes	240	54	9,322
Totals	**506**	**240**	**50,456**

Step two was completed by joining the provider-to-population ratios to the VE location points and then catching all of provider locations that fell within any one of the three drive-time zones for the census tract centroids. Table 6 displays the number of census tract polygons that the VE locations fell within the different drive-time zones. Without overlap, there were 507 census tracts that were touched by the VE locations.

Table 6: Demand, Census Tract Polygons containing VE location within Member Drive-Time Zones

Step 2: KP Members -Demand (3 Locations)

Drive-Time Zones	**Total No. of Times VE locations Caught in Zone**	**Within Single Drive-Time Zone (No Overlap)**
0-10 Minutes	93	93
10-20 Minutes	286	193
20-30 Minutes	507	221
Totals	**886**	**507**

The spatial accessibility index was again created by summing up the provider-to-member ratios during the second step. As mentioned earlier, the ratio between provider and members will be small given that there are few providers compared to the thousands of members. The final map was then created by joining together the census tract boundaries and the spatial accessibility ratios (Figure 17). Members residing in the southern region of the MSA have no spatial accessibliity to any VE services located within the Riverside MSA boundary and northern residents once again have varying degrees of accessiblity.

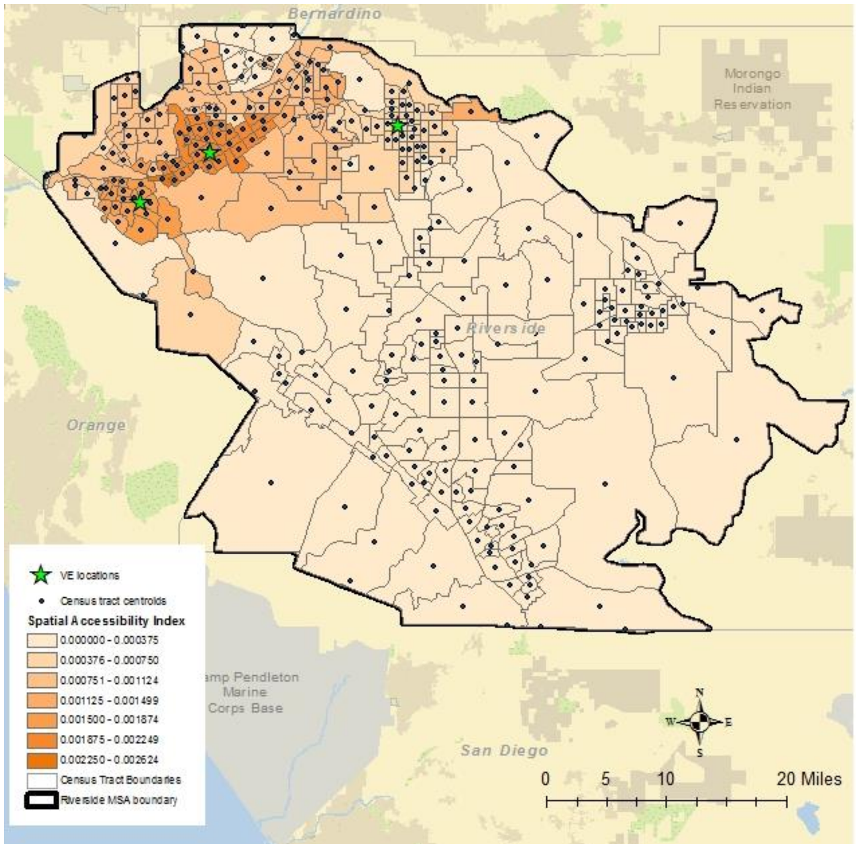

Figure 17: Spatial accessibility index of VE members by census tract

Chapter 5 **Discussion and Conclusions**

The spatial accessibility of the KP members is not evenly distributed among KP members throughout the Riverside MSA. It is evident that the northern region of the MSA has much greater access to VE providers than the central and southern parts. The results from this analysis coincided with some analysis completed within the VE department. This MSA has been an issue for the department because many of the KP members lack access to VE services and have to travel to other MSAs to receive needed care.

It was estimated during VE in-house analysis that 16.3% of the patients residing in the Riverside MSA seek services outside of the MSA. Many of these patients live within the southern region. This region contains 20% of the total patient population in this MSA. The MSAs that patients are traveling to for services include the Fontana, San Diego, and Orange County MSAs; with a small percentage traveling to various other MSAs. This poses difficulties and issues for the providers since it could mean a cut in the funds and/or services provided. This study was completed in order to support the original findings completed by the department in a preliminary study and although it did not examine the patient's path to where they are receiving services, it does identify those areas with service deficits.

5.1 Census Tracts v ZIP Codes

This study compared the results obtained from examining both census tracts versus ZIP codes as the unit of analysis. Although ZIP codes are not a preferred unit of analysis, it was important to examine them in this study because the patient data collected by Kaiser Permanente is available by ZIP code only. Currently, Kaiser Permanente does not keep census tract or block group information for its membership database. Therefore, exploring the differences between the two could determine whether it is appropriate to use ZIP codes for this type of analysis of spatial accessibility in future Kaiser Permanente studies.

One thing observed in this study was the difficulty of redistributing KP patients into census tracts from ZIP codes using the HUD crosswalk file. The results in the previous chapter showed that KP members were lost, notwithstanding the use of 2016 membership data, ZIP code boundaries, census tract boundaries, and the HUD crosswalk file. An accurate join between the members within the MSA and the ZIP code boundaries was obtained, however, the ZIP codes, once clipped, did not match the clipped census tract boundaries perfectly. There was a total of 19,308 members that were lost due to this incompatibility. Figure 12 shows the distribution of census tracts that hold the same numbers of membership that was distributed among the ZIP codes but fall outside of the Riverside MSA boundary. The loss of large numbers of patients affected the comparison of the two units of analysis. However, the analysis was still completed to compare the distribution of the population throughout the MSA, as well as the distribution of spatial accessibility as follows.

In both the ZIP code and census tract membership distribution, it is evident that the majority of the population resides in the northern region of the Riverside MSA. There are a few more clusters of membership in smaller areas of the southern region when looking at the census tract distribution because denser settlement patterns will produce smaller census tracts.

When examining spatial accessibility, both maps show that the members living in the southern regions of the Riverside MSA have no spatial accessibility to VE services provided within the Riverside MSA boundary. However, the census tract boundaries provide a little more detail in showing the distinctions between levels of access. This could have been caused by a few factors: (1) the units are small enough to provide the extra detail or (2) the loss of membership from the distribution could have altered the data and created larger provider-to-population ratios in selected areas. The latter is likely the better explanation since the spatial accessibility index values for the census tract analysis were larger on average because of the loss of KP members due to the problems with the crosswalk noted earlier.

With the E2SFCA method, using a Gaussian distance decay as suggested by previous studies (Luo & Wang, 2009) did have a modest effect on the calculation of spatial accessibility after joining with both the census tract and ZIP code polygons. Due to the distance decay, looking at both census tracts and ZIP codes, a gradual decrease in spatial accessibility can be seen as distance increases between the member locations and the VE service locations. Although it does allow for a gradual decline in spatial accessibility, and avoids designating access or not, the approach still gives all individuals within a polygon the same spatial accessibility. This is more evident in the ZIP code analysis than in the census tract analysis because the latter units were much smaller.

5.2 The E2SFCA Method

Since total membership data was not available, realized data was used which means that the data only containted patients that had already been seen by a service provider. For future studies, total membership could be used along with realized accessibility in order to calculate a more specific distance decay surface to support the analysis. For this study, slower decay weights were used for distance decay under the assumption that KP members living in rural areas would still need to travel for service despite the distances involved. However, there may be underlying reasons or situations that change the decay speed. The development of distance decay relationships using the data available in-house to Kaiser Permanente could help to reduce the guess work incorporated with this step.

This study also did not take into consideration that patients may leave the Riverside MSA to receive services elsewhere, whether with Kaiser in a different MSA or with an outside provider. Per the analysis done within the department, it is known that patient's from the southern parts of the Riverside MSA, such as Temecula, do go outside of the Riverside MSA for services. However, examining the potential of using services outside of a MSA is not considered during analysis conducted by Kaiser Permanente as each MSA functions almost as its own entity. Further analysis using a buffer that reaches outside of the Riverside MSA; as well as including the VE locations within a 30 minute drive-time could provide a more accurate assessment of spatial accessibility of VE services in the future because members are able to leave the MSA to receive care.

The total Kaiser Permanente membership was not used in this study as it was not permitted. Only a small portion of the membership was able to be used. With the total membership, a more realistic idea of distribution of membership throughout the Riverside MSA would be obtained. From the use of total membership, a better distance decay could be calculated to be used for future analysis.

Another thing noticed during this study was the overlapping catchments which meant some patients were captured multiple times. This topic was not discussed in the previous studies. Luo and Wang (2003) vaguely skimmed the topic when discussing the transition from the FCA method to the 2SFCA method in which Euclidian distances were used for catchments. In order to account for this overlap, separate drive-time zones for both providers and membership centroids were created. This allowed for the breakdown and analysis of each zone separately. These special steps had to be taken in order to avoid counting centroids more than once in the totals. Any future exploration will need to take extra steps to avoid this outcome as well.

5.3 Final Remarks

As stated earlier, ZIP codes are not the preferred unit of analysis. Many researchers have reviewed the units and found many issues when using them. They are not discretely bounded areas and could lead to modifiable area unit problems in which data and patterns may be distorted (Grubesic, 2008). However, when using Kaiser Permanente data, ZIP code distributions are what is available for analysis. Finding a proper way to redistribute this membership to census tracts or other small units of analysis would be beneficial to any future spatial analysis. It may be beneficial for healthcare providers to obtain census tract data on patients from the outset so no redistribution needs to take place. More steps added to any procedure increases the risk of corruption and/or error. A better analysis can be performed on the smaller census tract spatial units and is thought to be more manageable for estimating travel time and analyzing accessibility (Luo, Wang, & Douglass, 2004). This type of analysis may be something Kaiser would want to explore in the future.

For future analysis, the research should examine all VE locations within a certain distance of the KP members living in a specific MSA. This may reduce the loss of patients that occurred when patients were redistributed to census tracts; as well as provide a better idea of the true accessibility of the members since they are not physically bound by the MSA in which they reside. The full membership, including patients that have used services as well as those that have not, should also be used for future analysis to determine an accurate distance decay that would reflect the member behavior and provide a more complete and accurate picture of spatial accessibility as well.

Examining the distribution of membership and spatial accessibility suggested broad similarities in the outputs for both ZIP codes and census tracts. Although this study was a preliminary analysis to test the effectiveness of using ArcGIS for spatial analysis, it helps to point to areas in need of additional services. The visualization of the service accessibility using GIS can assist in making the case for additional funds and services to underserved areas.

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