2009

Measuring accessibility of regional parks : a comparison of three GIS techniques

Kara Hass
San Jose State University

MEASURING ACCESSIBILITY OF REGIONAL PARKS:

A COMPARISON OF THREE GIS TECHNIQUES

A Thesis

Presented to

The Faculty of the Department of Geography

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Kara Hass

May 2009

SAN JOSÉ STATE UNIVERSITY

The Undersigned Thesis Committee Approves the Thesis Titled

MEASURING ACESSIBILITY OF REGIONAL PARKS:
A COMPARISON OF THREE GIS TECHNIQUES

by
Kara Hass

APPROVED FOR THE DEPARTMENT OF GEOGRAPHY

4 Apr 2009

Richard Taketa, Associate Professor — Date

4/02/2009

Gary Pereira, Assistant Professor — Date

4/1/09

David Drueckhammer, East Bay Regional Park District — Date

APPROVED FOR THE UNIVERSITY

5/5/09

Associate Dean — Date

ABSTRACT

MEASURING ACCESSIBILITY OF REGIONAL PARKS: A COMPARISON OF THREE GIS TECHNIQUES

by Kara Hass

The East Bay Regional Park District (EBPRD) staff would like to know how well they are serving the public with the current configuration of regional parks and where the need for new parks is greatest. Many authors have incorporated accessibility measures to analyze the spatial equity of parks using Geographic Information Systems (GIS). However, the types of accessibility measures are numerous, all previous research was local in scale, and the type of park in question was not taken into consideration. To determine the method that best suits the needs of the park district, three common methods were examined and used to measure the accessibility of the parks provided by East Bay Regional Park District. The results of the comparison reveal the cumulative opportunities measure produced a better geographic representation of regional park accessibility when compared to the least cost and minimum distance measures. When used in an equity analysis, the cumulative opportunities measure did not overemphasize highly populated areas, and it identified locations in the region suitable for conservation and regional recreation facilities. Additionally, in regional analysis, using census block data introduced the potential for errors and misinterpretation in rural blocks, as compared to urban blocks.

ACKNOWLEDGEMENTS

I would like to acknowledge the help and encouragement I received from Dr. Taketa, Dr. Pereira, and my fellow students. In addition, I am grateful for the contributions from my colleagues, supervisor, and managers at East Bay Regional Park District. Lastly, I would like to thank my friends and family for their support.

TABLE OF CONTENTS

LIST OF TABLES

PAGE

LIST OF FIGURES

PAGE

CHAPTER 1: INTRODUCTION

"Accessibility... is a slippery notion... one of those common terms that everyone uses until faced with the problem of defining and measuring it" (Gould 1969, page 64).

Park equity studies use accessibility measures to determine whether the distribution of parks benefit some people more than others. Accessibility measures must therefore determine who benefits and why. While the goal of equity analysis is clear, the methods applied in measuring park accessibility vary. Many methods have been set forth, with no clear standard of which type of method should be applied to measuring accessibility to parks specifically, and how the application to other industries vary. An important issue remaining largely unexplored is how variation in the measurement of access can affect the results of spatial equity (Talen 1997, Talen 1998). Previous research has also not addressed whether the measurement should vary based on the type of parks in question. The goal of this research is to determine which measure should be applied to the accessibility and equity of regional parks, specifically the parks provided by East Bay Regional Park District.

This paper will compare three accessibility measurement techniques to understand how different measures affect the results of an equity analysis of parks on a regional scale: 1) The cumulative opportunities measure, 2) The minimum distance measure, and 3) The travel cost measure. These three measures were selected for their ease of interpretation and frequent use in studies on park accessibility.

Each measure will be used to produce visualizations that park staff can readily assess and answer: 1) Who has access to the parks provided by East Bay Regional Park District? 2) Is the spatial distribution of parks equitable? 3) Which areas have the highest need for new parks? The three techniques will be evaluated and compared in how they answer the preceding questions, and what the trade-offs are to each approach. This research will identify which method provides the best geographic representation of who benefits from the spatial distribution of parks provided by East Bay Regional Park District.

CHAPTER 2: BACKGROUND

East Bay Regional Park District

The East Bay Regional Park District (EBRPD) manages over 97,000 acres of land in Alameda and Contra Costa Counties, including 65 regional parks and 29 regional trails. Along with the conservation of land, the District's other core mission is to provide recreational facilities to the public (East Bay Regional Park District Profile, n.d.). Park staff would like to determine how well they are serving the public with the current location of parks with recreational facilities. This will allow for strategic planning of new facilities in areas where a deficit of parks exists.

Definition of Regional Parks

Parks are categorized based on size and location. The National Recreation and Park Association and the American Academy for Park and Recreation Administration define regional parks as:

> An area selected for its natural and ornamental quality and its suitability for regionally-based recreational activities. Typically, a regional park is 200 to 500 acres in size, although a site as small as 100 acres is acceptable if the quality of the resource provides adequate justification. Its size is based on its capacity to accommodate a variety of activities, preserve its natural character, and provide adequate buffering between activity areas. Access to water bodies suitable for recreational uses is of particular importance during site selection. Recreational activities include swimming, picnicking, camping, boating, fishing, and a variety of trail uses. (Mertes & Hall, 1995)

DiChiara and Koppelman (1982) list more detailed regional park planning standards in the book *Urban Planning and Design Criteria.* Table 1.1 shows a significant difference in the size of regional parks and the radius of area served, as compared to all other park types. Here regional parks are shown to serve a radius of 10 miles.

Table 1.1 Standards for recreational areas (DiChiara & Koppelman, 1982, p. 363)

Type of Area	Acres/1000 Population	Size of Site: Ideal (in Acres)	Size of Site: Minimum (in Acres)	Radius of Area Served (in Miles)
Playgrounds	1.5	4.0	2	0.5
Neighborhood Parks	2.0	10	5	0.5
Playfields	1.5	15	10	1.5
Community Parks	3.5	100	40	2.0
District Parks	2.0	200	100	3.0
Regional Parks	15.0	500-1,000	varies	10.0

Based on Table 1.1, larger park types such as regional parks, serve a larger area than a neighborhood or community park. Using the planning standards in this table, one would conclude that people within 10 miles of a regional park have access, and one could use this as a rule of thumb to measure accessibility. However, based on review of literature, one will find no clear standard to measure accessibility to regional parks, nor accessibility to public services. A variety of methods have been used that range from basic to sophisticated.

Travel to Regional Parks

A recent community survey conducted by Strategy Research Institute on behalf of EBRPD reveals the travel patterns of regional park users (Manross, 2008). Figure 2.1 shows that 78% use automobiles as their normal mode of transportation to get to regional parks. If the primary mode of transportation is driving, than we can assume the routes to access parks can be measured using road networks.

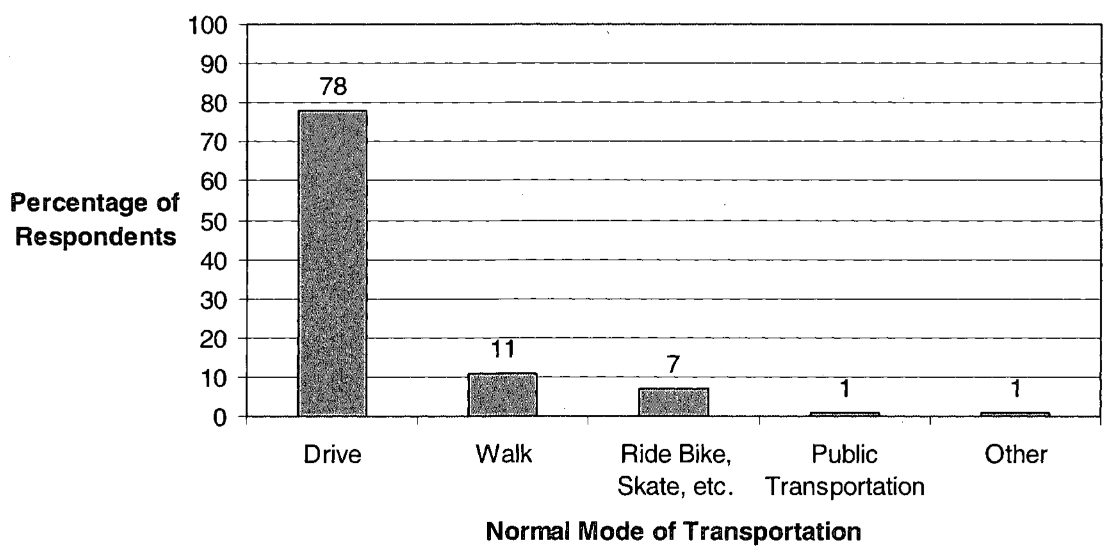

Figure 2.1 Normal mode of transportation to regional parks

The survey also found that 50% of residents are willing to drive greater than 21 miles, shown in Figure 2.2. This supports the idea that people are willing to travel outside of their local community to access the recreational and open space opportunities at regional parks. This also shows that regional parks serve a greater area than neighborhood or community parks, and park accessibility should be measured differently based on the type of parks in question.

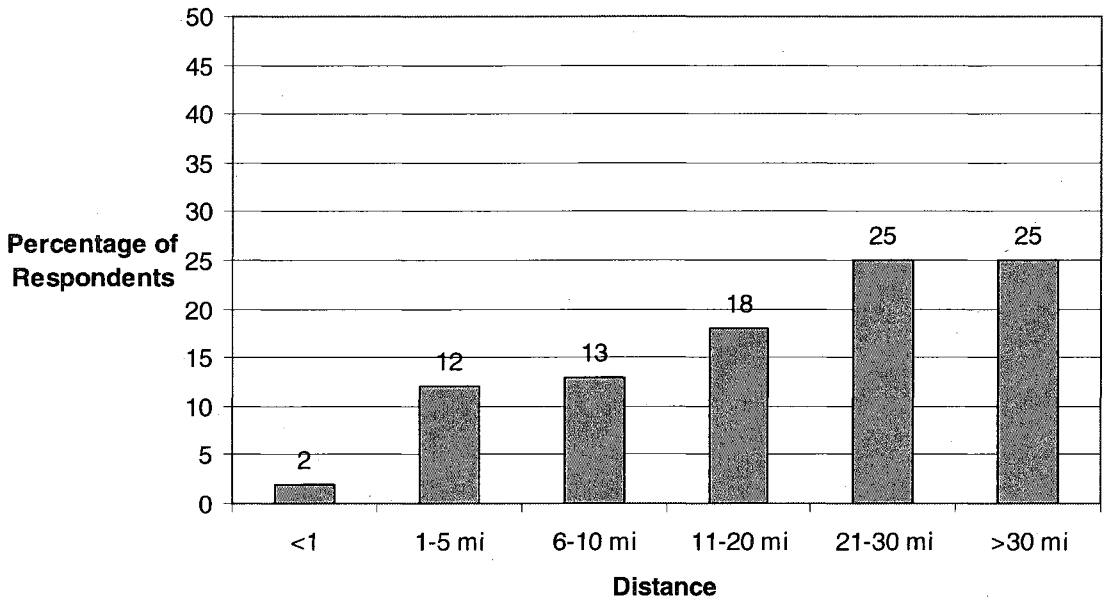

Figure 2.2 Distance willing to travel to a regional park

Definition of Accessibility

The definition of accessibility in *the Dictionary of Human Geography* is "...the ease with which one place can be reached from another. This includes an origin location, mode of transportation, and the location of the destination to which accessibility is being measured" (Johnson, Gregory, Pratt, & Watts, 2000). Accessibility is therefore a measure of spatial opportunities rather than actual usage (Cervero, Root, & Appleyard, 1999). While all accessibility measures have an origin and destination, they vary based on how the mode of transportation (seen as resistance or impedance), and opportunity at the destination (seen as a motivation or attraction) are incorporated into the calculation (Handy & Niemeier, 1997, Kwan, 2003).

Accessibility Measurement Techniques

Accessibility measures found in previous studies can be divided into four general categories, shown in Table 2.1. Here I am specifically focusing on trip-based measures, which only consider one trip type at a time: for example, from home to a recreation area. An alternative option to the trip-based measure is the activity-based measure, which incorporates more complex traveling characteristics such as scheduling and trip chaining (Dong, Ben-Akiva, Bowman, & Walker, 2005).

Table 2.1 Summary of trip-based accessibility measurements

Type	**Approach**	**Definition**	**Source**
Service Area Measures	Container	Number of facilities contained within a given unit.	Talen & Anselin, 1998
	Cumulative Opportunities	Count of the opportunities reached within a given travel time or distance	Handy & Niemeier, 1997
Travel Impedance Measures	Minimum Distance	Distance to the nearest facility	Talen & Anselin, 1998
	Travel Cost	The average distance between each point of origin and all destinations	Talen & Anselin, 1998
Gravity and Potential Measures	Potential	The sum of all facilities (weighted by size) is divided by the 'frictional effect' of distance.	Handy & Niemeier, 1997, Skov-Peterson, 2001

Utility Based Measures	Utility	The probability of an individual making a particular choice depends on the utility of that choice relative to the utility of all choices	Handy & Niemeier, 1997

The *service area measures* use a polygon to count the number of opportunities within the area. The service area could be a jurisdictional boundary or a radius of a given distance around a facility. The travel impedance measures are a continuous measure of the cost, in time or distance, to travel to the nearest or to all facilities. Gravity and potential measures are also continuous measures of cost in time or distance, but they include an impedance function to model the 'frictional effect' of distance. The last, utility-based measures, incorporate an individual's decision alternatives to model attractiveness to a facility.

Of all of the accessibility measures, the *container approach* is the most basic. The container approach involves counting the number of facilities or total facility area within a selected geographic unit, such as a political ward, or census tract (Mladenka & Hill 1977). The equation to calculate the container index is:

$$Z_i^C = \sum_j S_j$$

Where

Z_i^C is the container index for location i

S_j the number or size of the facilities located within the boundaries of *i*

Using this equation to measure park access, one could calculate the number of parks or the park acreage within a selected geographic unit, such as a city, for example. This would assume the population within a geographic unit is considered to have access to all the park facilities in that unit. Talen and Anselin (1998) found that if the selected geographic unit does not match the actual service area of the facility, then this will increase the likelihood of creating a spatially-random pattern of access. Also, park access scores dependent upon arbitrary political boundaries are likely to mask relationships at a finer scale.

Deriving a service area based on one distance, commonly referred to as *coverage*, is a traditional way to visualize accessibility (Kwan, Murray, O'Kelly, & Tiefelsdorf, 2003). A buffer of a critical distance surrounding the facility represents this. The buffer can be a circle buffer with a radius of a critical distance, or a polygon buffer representing a distance on a road network. A buffer is a better approximation of the actual service area of a facility when compared with the container approach, since it does not create a non-random pattern of access (Talen, 98). Using a buffer to represent a service area also allows for spatial externalities outside of a political boundary (Talen, 98). Allowing for spatial externalities is important when measuring park access because a park often serves an area irrespective of a political or arbitrary boundary.

With the service area one can then examine how socioeconomic patterns relate to the accessible area. This technique is commonly used in urban parks planning and equity analysis, where a feature within a half-mile walking distance is considered to be accessible (Lindsey, Maraj, & Kuan, 2001; Nichols, 2001; Nichols, 2003; Nichols, 2004). Tarrants and Cordell also used this method to assess the spatial distribution of recreation sites provided by Chattahoochee National Forest in Georgia and used a one mile service area (1999). Regional parks are larger than urban parks and are often on the perimeter of the city. People are willing to travel farther, and a service area of half a mile or a mile is not an accurate representation. At the time of this study, no existing studies of park accessibility considered using a coverage area of greater than one mile nor how the accessible distance may vary based on the type of park or recreation opportunity provided.

Using a half-mile radius as the service area for all park types assumes that only the population living within that radius has access to the park, as shown in Figure 2.3. The population outside of the half-mile radius does not have access. The studies that use this method to measure park equity show the population within the radius as having no need or the lowest level of need, where the population outside of the radius has high need. This creates a sharp boundary of need, where the area within the buffer is free of need or has the lowest level of need, yet directly on the other side of the buffer may exhibit the highest level of need. This can be seen in recent park equity maps produced by parkscore.com, an interactive tool to show park equity by the Trust for Public Land (2009). The results of this equity analysis show where the highest levels of need are across the landscape, but once a park is placed there, this only covers the population within the given service area radius. A high level of need would still remain directly outside the service area buffer.

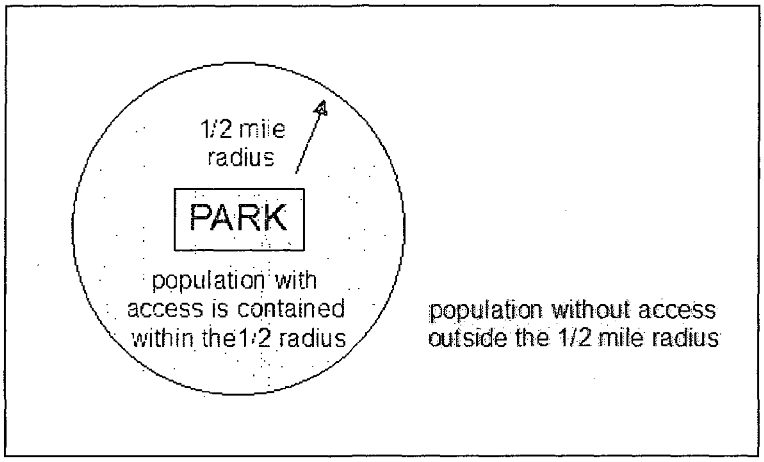

Figure 2.3 Example of a service area using a radius of a half-mile

Talen (1997) used statistical tests to compare the spatial patterns of population characteristics and urban park access in Macon, Georgia and Pueblo, Colorado. To measure park access she used the coverage area measure to calculate the park acreage within a critical distance to each census block, justified by the criteria for park acreage and access standards described by DiChiara and Koppelman (1982) in Table 1.1. The census blocks in both cities were categorized as having low and high access to parks. Census blocks in Macon with no parks within a mile on the road network were considered to have low access, and census blocks with approximately 6 aces to 90 acres (the highest quartile range) within a mile were considered to have high access. In Pueblo few census blocks had zero parks within a mile, so the census blocks with 9 to 16 acres (the lowest quartile range) within a mile were considered to have low access and the census blocks with 24 to 109 acres (the highest quartile range) within a mile were considered to have high access.

Talen (1997) then compared the spatial patterns of access to the seven different socioeconomic variables using the Mann Whitney U test as the test statistic. In general her results revealed that access to parks within the city of Pueblo favored higher income areas, whereas the access to parks tended to favor lower income areas in Macon. Pueblo had a greater number of parks with more park acreage, randomly distributed throughout the city, whereas the area of the city of Macon was larger, with fewer parks, more clustered. The work of Talen shows that accessibility measures are incorporated into equity studies in a variety of ways. In particular she counted the park acreage covered by a one mile service area from each census block to derive accessibility scores and display accessibility patterns. She used the resulting accessibility scores in a statistical test to determine if park access is equitable when compared to socioeconomic characteristics.

Rather than counting the acreage within a service area, one can count the number of facilities within the critical distance of an origin. This is referred to as the *cumulative opportunities measure* (Handy and Niemeier, 1997). The equation for the index of cumulative opportunities is;

$$\mathrm{Acc}_i = \sum_j W_j a_j$$

Where

Acc_i is the index of cumulative opportunities for zone i
a_j is the opportunities in a zone j
W_j equals 1 if $c_{ij} \leq c^*_{ij}$, and 0 otherwise
c_{ij} is the measure of impedance between zone i and j
c^*_{ij} is the pre-determined range within which the activity opportunities are counted

An example of using this measure would be to count the total number of parks within 30 minutes, by driving time, from an origin. Since each opportunity is weighted equally, the results of this measure are easy to compute and understand. It is simply the number of facilities within a critical distance of the origin. However, the results are highly sensitive to the size of the service area (the 30 minute drive time in the example) and how the opportunities (parks) are represented.

Though Handy and Niemeier (1997) listed the cumulative opportunities measure as an option to measure accessibility, I was not able to find a case where this method has been used to measure accessibility to parks in particular. The most commonly used method is to create a service area representing a walking distance, and to examine the population within that service area, disregarding overlapping service areas. Overlapping service areas signify that the population within the overlapping area has more than one park option. This enhances the ability of service area measures to account for additional opportunities.

The service area measures use a discrete area to measure accessibility; the travel impedance, gravity, and utility measures consider accessibility to vary continuously over space. With the travel impedance measures, all trips from the origin to the destination have a travel cost in time or distance. The lower the cost of the shortest route to get to the facility, the more accessible the facility is. Accessibility to a facility is therefore relative to the cost to other facilities and can be measured continuously over space.

The *minimum distance* approach is a measure of the distance between each origin and the nearest facility. The formula is as follows:

$$Z_i^E = \min\left|d_{ij}\right|$$

Where

Z_i^E is the travel cost index for location i
d_{ij} is the distance between location i and each facility j

An example of the minimum distance approach is to consider the nearest park facility to every census block. The accessibility index is the distance from the census block to the closest facility. A low accessibility index for a census block relative to the other census blocks reflects greater accessibility.

The *travel cost* approach is a measure of the average distance between each origin and all possible destination options. The total distance to all facilities or the average distance to all facilities can be used, as long as the number of destinations is the same for each origin. A smaller average distance, or the lower the index value, reflects greater accessibility. The formula to measure the travel cost index is:

$$\overline{Z}_i^T = \sum_j \frac{d_{ij}}{N}$$

Where

$\overline{Z}_i^T$ is the travel cost index for location i
d_{ij} is the distance between a residential location i and a facility j
N is the total number of facilities.

Both minimum distance and travel cost approaches can be understood in simple terms. Both result in scores that equate to distances or time, which are easy to understand and interpret. The difference is that the minimum distance technique only includes the distance to one facility, the closest facility. Whereas, the least cost method includes the distance to all facilities.

Emily Talen described the minimum distance and travel cost measures as options to measures park access in her paper "Visualizing Fairness" (Talen, 1998). She developed a new methodology to visualize park equity for local parks in Pueblo, Colorado. She used the gravity measure to classify areas as high or low access, and then compared these areas to the spatial clustering of selected socioeconomic variables. She showed how the minimum distance and travel cost measures can be used as alternatives to the gravity model. She explained that the decision in the choice of measures is based on how distance between the user and the facility should be characterized. She compared visualizations of all three accessibility measures and found that the results vary significantly based on how access is defined.

The gravity and potential measures are more complex measures found in literature. They also include the distance to all facilities, but incorporate a distance decay function, where increasing distance has an inverse effect on the attractiveness of the facility or possible usage. The potential of an origin can be measured as:

$$P_i = \sum_{n=1}^{j} M_j * f(d_{ij})$$

Where

P_i is the potential accessibility index of zone i
M_j is the 'mass', e.g. population of place j
f() is the distance decay function
d_{ij} is the distance or cost between target i and origin j

In the potential measure, the closer an opportunity, the larger the index value and the more an opportunity is considered to be accessible. With this measure one could incorporate weights for the type of activity found at a park or for the size of the park.

This measure can be used as a more accurate model of human behavior, above the minimum distance and travel cost measures. Yet, the results are not as straightforward and easy to interpret as with the service area and impedance measures. The cumulative opportunities measure can be considered a specific form of the potential measure, one with a sharp threshold where the impedance function is equal to one if the opportunity is within the travel time, and zero otherwise (Koenig, 1980).

In addition to the standard potential measure presented above, and the idea of using a sharp threshold as the distance decay parameter, other modifications include using a power distance decay parameter, and an exponential distance decay parameter. Hans Skov-Petersen compared two different distance decay parameters, the sharp threshold and exponential distance decay parameter, to measure outdoor recreational accessibility in Denmark, using driving time as the measure (Skov-Petersen, 2001). First he estimated distance decay parameters for the sharp threshold, power, and exponential measures using non-linear regression techniques. He found that the exponential function gave the best numeric description of his empirical data. He then compared the results using the exponential function to a sharp threshold of 15 minutes. While the numeric result of the sharp threshold is not as accurate, the values are easier to comprehend and interpret. The value reflects the number of people who can access the forest area within a 15 minute driving distance whereas the values of the exponential distance decay function reflect the number of people who can access the forest area when the exponential function of lambda is -0.049281. He concluded that "The quality of success of the model-results can be judged from two different angles: a) its communicative qualities as in the case of environmental indicators and b) as a quantitative description of phenomena based on empirical data." He argued that the sharp threshold may be more useful for decision making, but if the aim is to describe the phenomena as accurately as possible, then a higher-order decay function can be implemented.

Utility-based measures model the probability of an individual making a particular choice relative to all other choices. An individual assigns a utility to each destination (or mode and destination) choice in a specified choice set, and then selects the alternative which maximizes his or her utility. The formula for the utility-based measure is:

$$A_n = \ln\left[\sum_{\forall \in c_n} \exp(V_{n(c)})\right]$$

Where

A_n is the accessibility index for an individual n

$V_{n(c)}$ is the observable temporal and spatial transportation components of indirect utility of choice c for person n,

C_n is the choice for person n.

Handy and Niemeier (1997) described the equation as:

> The logsum serves as a summary measure indicating the desirability of the full choice set (Small, 1992). The specified utility function includes variables that represent that attributes of each choice, reflecting the attractiveness of the destination and the travel impedance that must be overcome to reach the destination, and the socioeconomic characteristics of the individual or household, reflecting individual tastes and preferences. This type of accessibility measure sometimes takes a form similar to that of gravity-based measures, but has theoretical and empirical advantages.

While many studies have used the utility-based model to measure accessibility of a transportation network, I was not able to find a study that used the utility model to measure park accessibility at this time.

All of the techniques described above can be used to measure accessibility. The measures presented range from basic to sophisticated. The Gravity and Utility-based measures, in particular, incorporate distance decay parameters, weights, and decision alternatives to model more complex human behavior. However, the trade off is that the more sophisticated measures can be difficult to interpret. When choosing a measure, one should consider the type of service or facility, the assumptions of the accessibility measure, and the intended use and audience.

CHAPTER 3: METHODS AND PROCEDURES

Study Area

The study area of this thesis is Alameda and Contra Costa Counties shown in Figure 3.1, also referred to as the East Bay. This is the East Bay Regional Park District's jurisdictional boundary. The Alameda and Contra Costa Counties encompass a 1,623 square-mile area. This area includes dense urban areas with cities like Richmond, Berkeley, Oakland, Hayward, and Fremont located along the San Francisco Bay Shoreline. In contrast to the shoreline area, the eastern areas of both counties are rural, containing undeveloped agricultural and wild land areas, as well as fast-growing cities like Brentwood. A commonly held belief is that as the population in the East Bay grows, people will migrate to the cities in the east, and thus the park district must acquire open space to plan for the growing population. Figure 3.2 shows the population density of the area.

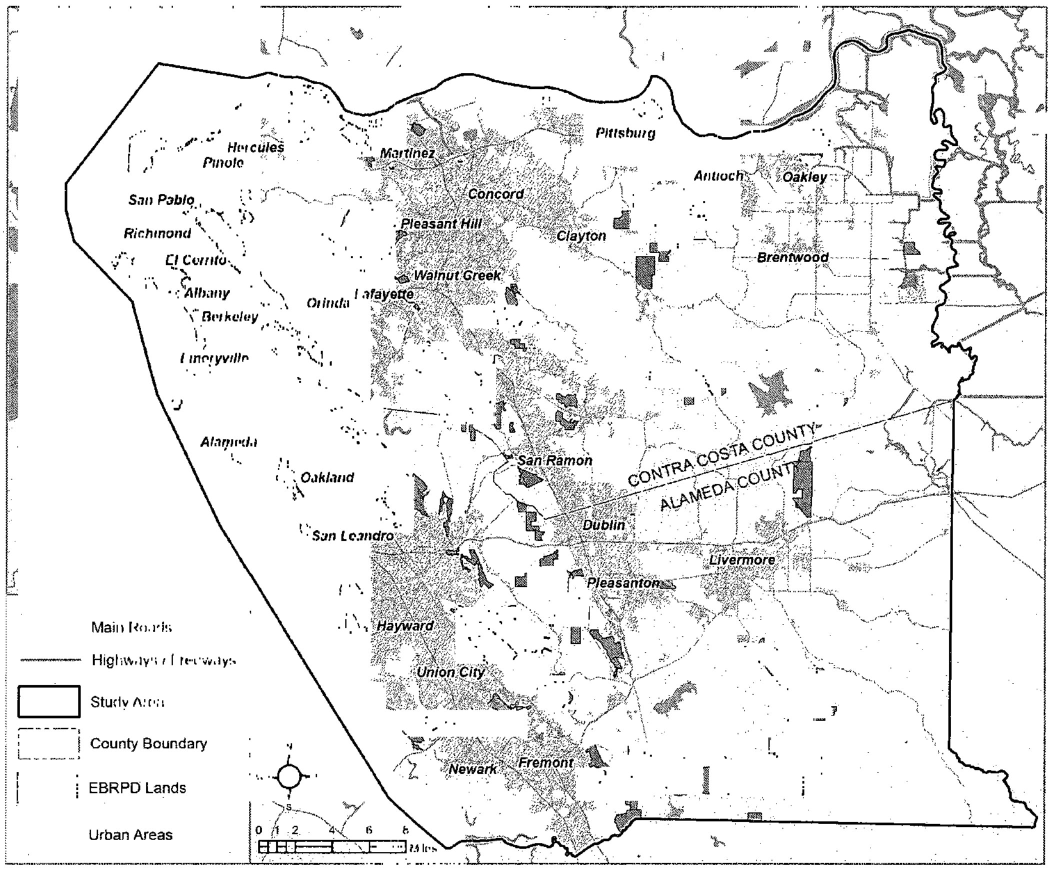

Figure 3.1 The study area: Alameda and Contra Costa Counties.

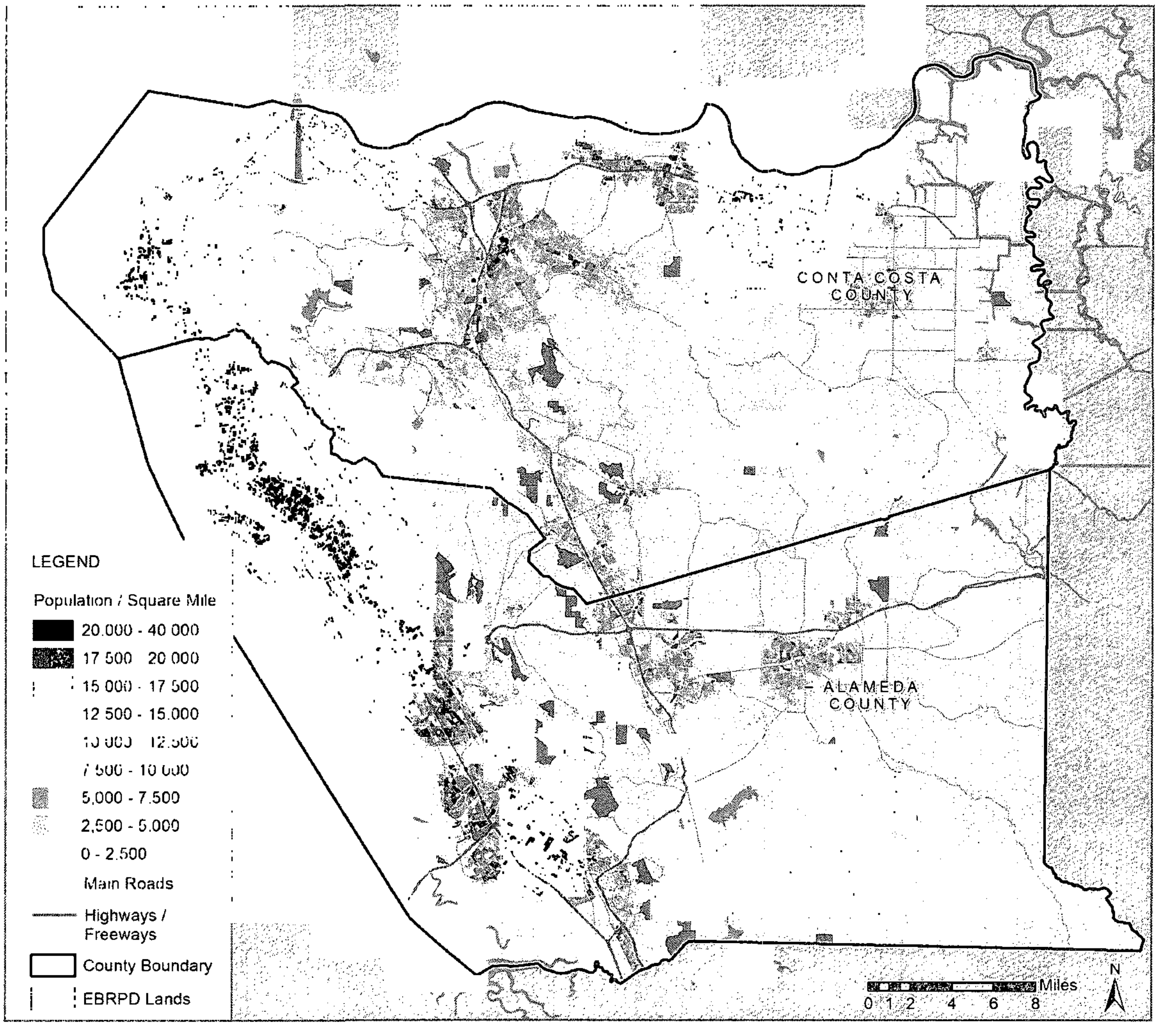

Figure 3.2 Population Density, 2000 Census Blocks

Data

The following layers, shown in Table 3.1, were used in each analysis.

Table 3.1 Data used in analysis

Purpose	Data	Source
Facility Location	EBRPD Park Boundaries	EBRPD
Facility location and Destination	EBRPD Park Entrance Points	EBRPD
Transportation Network	Road Network	TeleAtlas
Origin and Demographic Data	2000 Census Blocks	Census Bureau Website
Origin and Demographic Data	2000 Census Block Centroids	Census Bureau Website

Accessibility is typically measured by zone. A zone represents a group of individuals and households in close proximity. The smaller the zone, the greater the level of spatial disaggregation. Greater levels of spatial disaggregation should result in more accurate estimates for individuals and households in the zone (Handy and Niemeier, 1997). Here I am using the 2000 Census Blocks as the zone because they are the smallest zones readily available with comprehensive demographic data.

The boundaries of census blocks are physical features such as roads, streams, and railroads, as well as portions of political boundaries such as cities, townships, and county limits. The populations of the blocks in the East Bay range from 0 to 3,986 people, and the area of the blocks vary from less than 1 square mile to 18.3690 square miles. In urban areas blocks form small regularly shaped clusters of squares. In rural areas blocks are large and irregularly shaped. In the Census, blocks make up block groups which generally contain between 600 and 3,000 people, with an optimum size of 1,500 people (U.S. Census Bureau, 2000a), and block groups make up tracts which typically range between 1,500 and 8,000 people, with a stated ideal size being 4,000 individuals (U.S. Census Bureau, 2000b). Alternative options of aggregated population data are available, however Census data is the most frequently used, readily available, and free to the public.

Census blocks include population counts and other demographic attributes of the people who reside within each block boundary. I used the unweighted geometric centroid of each block to represent the trip origin of everyone in the block. The potential destination points are the entrance points to each park. Distance from the origin to the destination is based on the road network, and is measured using the shortest path algorithm in ArcGIS Network Analyst. Distance on a road network is considered to be a better approximation of travel time or distance between two locations compared to using a straight line measure (Geertman & Van Eck, 1995). Although travel time is considered to be a more important determinant of travel patterns than distance (Shannon, Skinner, & Bashur, 1973), the measure of impedance in this study is distance. Distance is used rather than trip time, money, or mode of travel, primarily due to the ability to calibrate findings with existing EBRPD surveys on distance traveled or distance wiling to travel to reach a park, described in this chapter.

Cumulative Opportunities Measure

The cumulative opportunities measure uses a critical distance to count the number of facilities within this distance for each zone, in this case a census block. An existing EBRPD survey was used to determine a critical distance to existing regional parks. The survey was conducted by the Strategy Research Institute on behalf of the East Bay Regional Park District in October of 2006 (Manross, 2006). This survey was used to gather public opinion on recreation facilities provided by the park district in the East Bay. I used questions from this survey to determine the distance most people are willing to travel to get to a regional park for the purpose of open space. A cross tab of the two questions "How far would you be willing to travel from your home to use a regional park or trail to participate in a District sponsored activity or program that you perceived as being highly worthwhile?" for the respondents that considered the open space to be a high or medium spending priority within the regional park system.

Figure 3.3 shows the results of the survey with all types of recreational facilities that were considered in the survey. Here I am only using open space as an example from all of the recreation activities considered. This is parkland that is open to the public for the purpose of experiencing open space, which is available at every park. The mode category selected in the survey was 11-20 miles, and after consulting with park staff, we determined that the respondents would travel at least 11 miles to a facility to experience open space provided at a regional park. Therefore, the critical distance was determined to be 11 miles. This distance is also close to the planning standard of 10 miles shown in Table 1.1

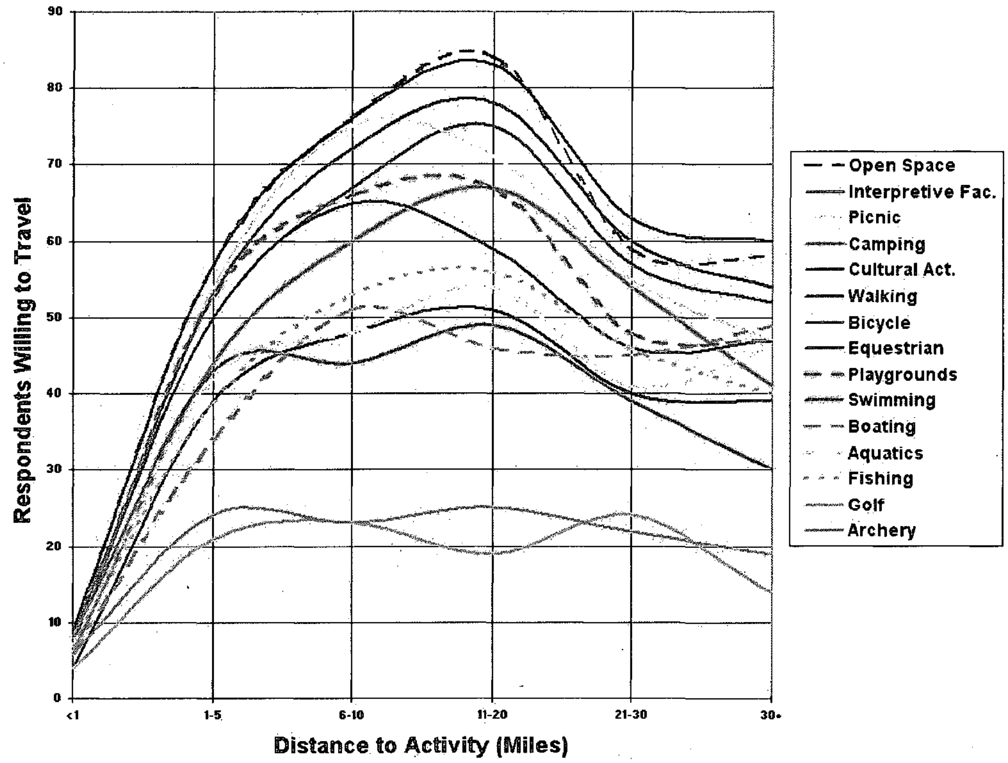

Figure 3.3 Distance willing to travel to park activities.

A public access, or entry point, was collected based on the location where the public can enter the park. A service area was derived for each public access point using the TeleAtlas road network and the Network Analyst extension in ArcGIS. The service areas for each park were merged so that each service area represents access to a park, otherwise each entrance would have been considered a unique facility. Once the park service areas were created, any overlapping service areas were given unique polygons with a count to represent the number of overlapping service areas. The results of this operation appear in Figure 3.4

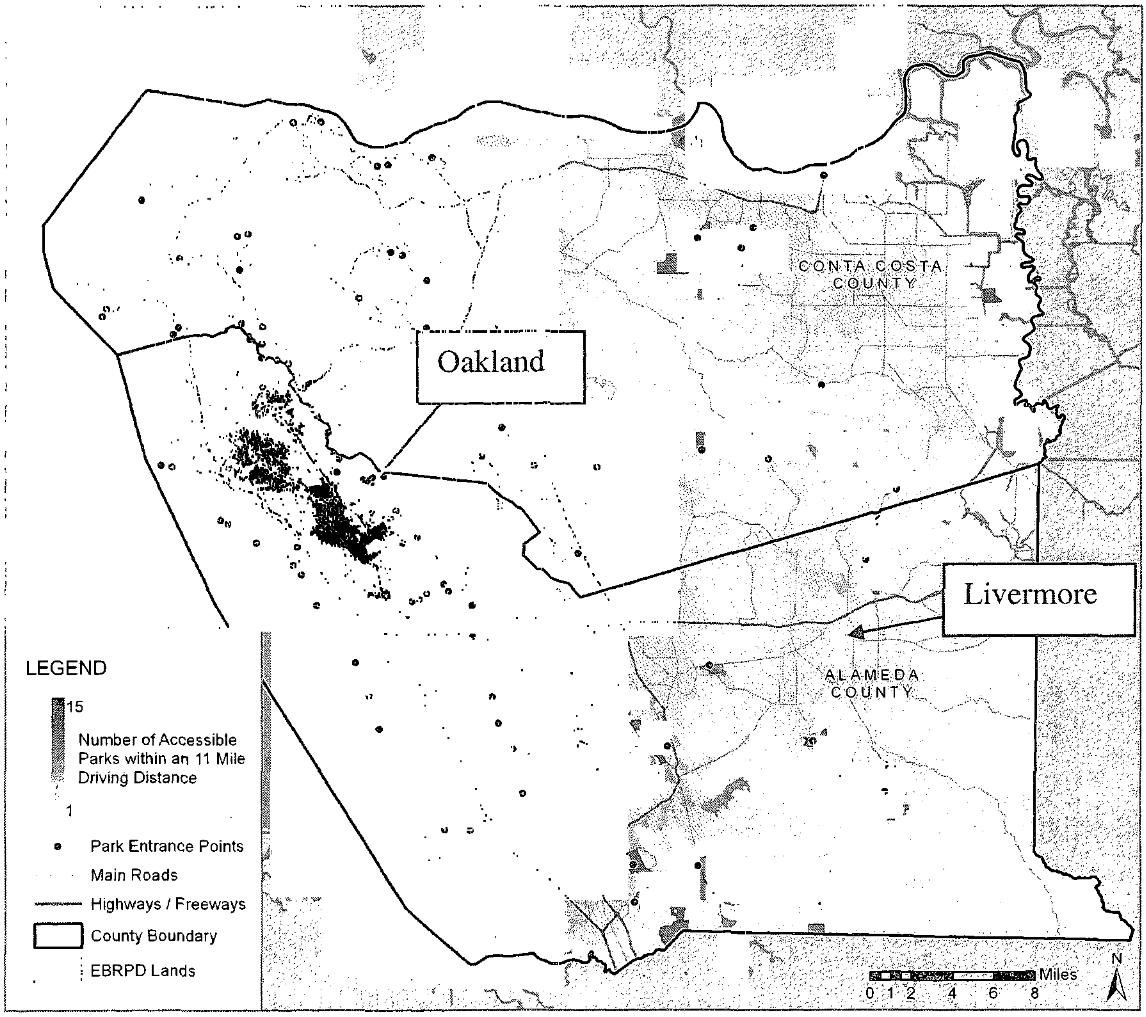

Figure 3.4 The number of accessible parks within an 11 mile road distance.

With this visualization you are able to see areas with a higher number of opportunities within the study area (darkest color), and identify areas that do not have access within the defined service area (lightest color). Areas of Oakland, for example, have access to 15 parks within an 11-mile distance on the road network. Areas of Livermore have access to only one or two parks within an 11-mile distance on the road network. This visualization can be used to answer the questions of who has access to regional parks provided by East Bay Regional Park District. Any area with a yellow to red shade is considered to have access to a regional park within an 11 mile distance on the road network. The rural areas with no accessible regional park within an 11-mile distance on the road network, shown in the lightest cream color, are considered to have no access.

While Oakland may have access to 15 parks, Oakland also has a large population; therefore it is necessary to determine if access is equitable relative to the population size. The 2000 census population density data in Figure 3.2 was incorporated with the accessibility visualization in Figure 3.4. Each Census Block was given an opportunity score based on the number of overlapping service areas (from Figure 3.4) at each census block centroid. This population density at the centroid was divided by the opportunity score to get the ratio of population density to parks for each census block. Creating a simple ratio of population density to the number of park opportunities allows for a comparison among blocks with regard to equity. The results from the analysis are presented in Figure 3.5.

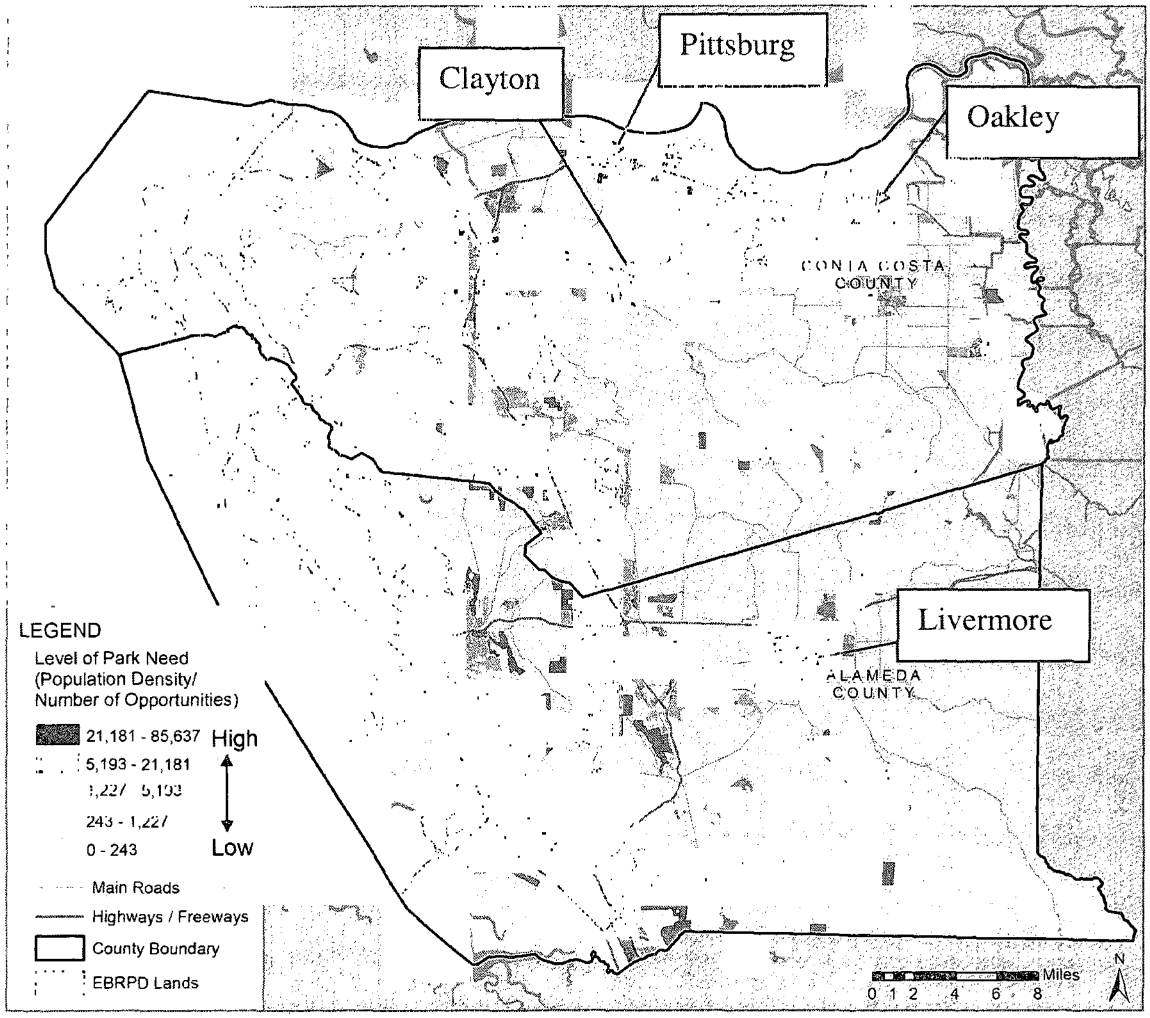

Figure 3.5 Equity visualization using the cumulative opportunities technique.

The population density per park opportunity scores are shown for 25,271 census blocks. The values range from 0 to 85,637, with a mean of 1,492, a median of 981, and a mode of 0. The distribution of the results shows a positive skew with a long right tail, and 20% of the records equal to zero. To highlight changes in the middle and extreme population density per park opportunity values the Geometric Interval or Smart Quantile classification scheme was used (Environmental Systems Research Institute, Inc., 2008).

This classification scheme is considered to be a compromise method between the Equal interval and Quantile method, where the values are placed into five classes based on the natural grouping of data values. Since the distribution is positively skewed the equal interval classification method would have highlighted the most extreme values without showing variation in the middle values, and the quantile method would have highlighted the middle values without showing variation in the most extreme values. In this visualization the geometric interval classification method produced visually appealing results and balanced the need to highlight the middle and extreme values.

Figure 3.5 shows that the spatial distribution of access is not equitable. This visualization highlights areas where there is a deficit of accessible open space facilities relative to population density, particularly in Pittsburg, Clayton, Oakley, and Livermore. Identifying these areas as having the most need allows for strategic planning of new facilities in areas where there is a deficit of parks with recreational opportunities. This visualization can also be used as a baseline for future analysis: proposed facility entrances can be incorporated as park access points to show how the level of need changes.

With the cumulative opportunities measure it is possible to produce a visualization to show regional park accessibility and equity. The results can then be readily assessed by park staff to answer: 1) Who has access? 2) Is access equitable? 3) Where is the greatest need for new parks at the East Bay Regional Park District?

A distinguishing feature of the cumulative opportunities measure is that a discrete number, or critical distance representing an accessible range, is used to the measure the number of opportunities within this distance. The other measures are considered to be continuous measures, and therefore the number of possible opportunities cannot be incorporated. Another distinguishing feature is the critical distance can be adjusted based on the type of facility that is being studied, or adjusted to perform a sensitivity analysis of the critical distance. Literature and surveys can be used to verify and calibrate the critical distance. One of the disadvantages is that the measure is based on the assumption that only facilities located within the critical distance are accessible; therefore the measure does not take into account the spatial externalities outside of the critical distance, or how the critical distance may vary based on the facility.

In summary, I was able to use an existing survey to determine the critical distance. The survey showed that most people were willing to travel at least 11 miles to access a park. With 11 miles as the critical distance one can see the areas with the most opportunities for access, and the areas with the highest deficit of access based on the equity visualization.

The cumulative opportunities measure assumes that parks have a consistent sphere of influence, and the population within the critical distance will benefit from the park. Anyone outside this area does not benefit. Each additional park within the critical distance results in additional benefits. From a planning perspective, the objective is to locate parks where there is the greatest need, which would be the areas with the smallest number of options and the highest population. Park users benefit more from additional accessible opportunities, therefore the cumulative opportunities measures the important characteristic of potential opportunity.

Minimum Distance Measure

Rather than counting the number of parks within an accessible distance, the object of the minimum distance measure is to calculate the distance from each origin (census block) to the nearest destination (park entrance) to produce an accessibility index. This measure creates a continuous scale of accessibility, where the census blocks that are closer to park entrances have greater accessibility to parks.

Census block centroids were used to represent the origin of everyone who resides in the census block. ArcGIS Network Analyst was then used to calculate the distance from each block centroid to the closest facility, or park entrance. Note that the locations of the census block centroids were relocated to the nearest road in order to perform the closest facility operation. Results of this analysis are shown in Figure 3.6.

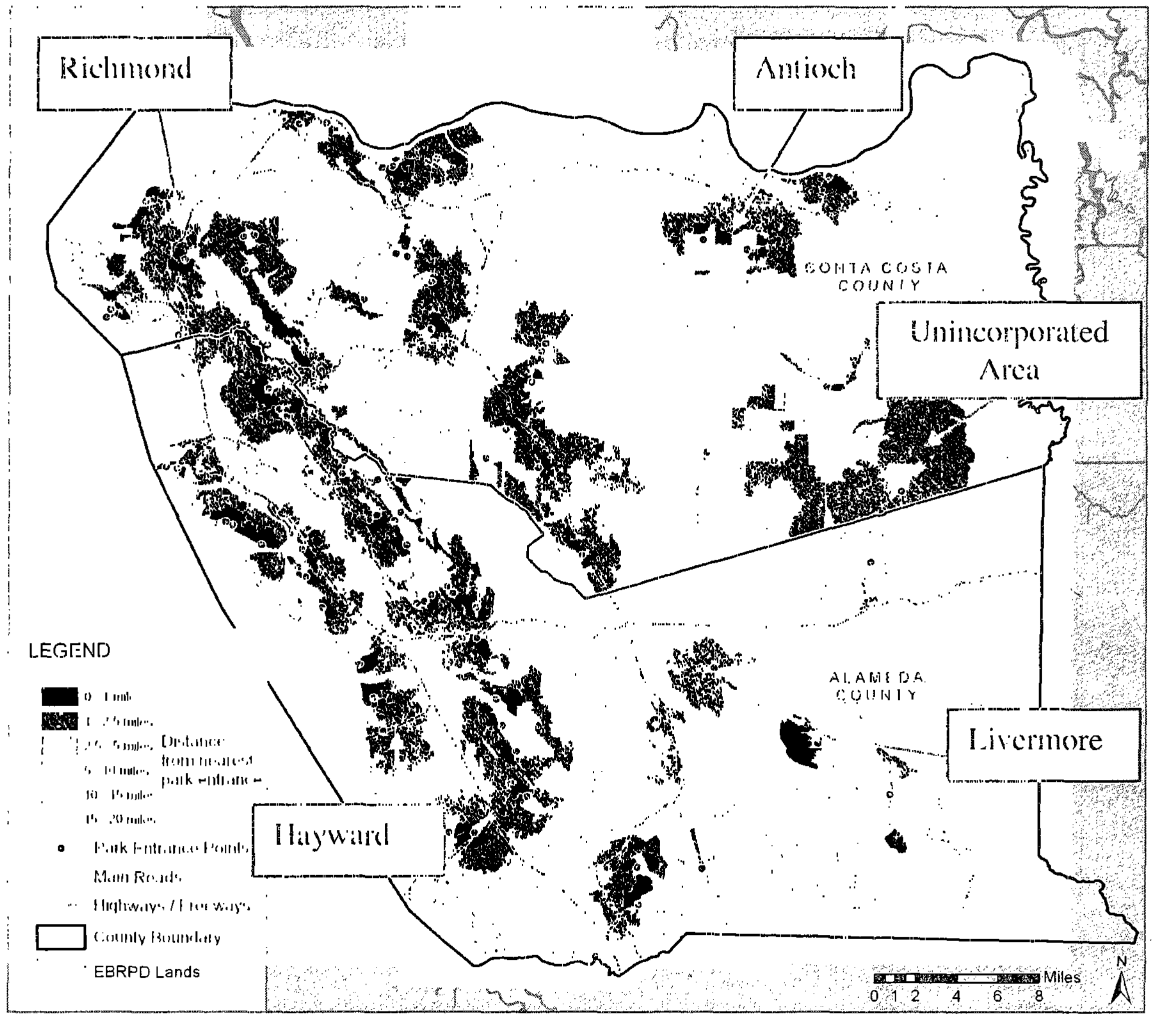

Figure 3.6 Minimum distance to nearest park entrance.

In Figure 3.6 the census blocks with the higher saturation of red are closer to a park entrance and have a lower minimum distance score. The red census blocks are located within 1 to 2 miles of a park entrance, whereas the yellow blocks in eastern Alameda County are 15 to 20 miles away. The visualization can be used to answer the question of who has access to regional parks provided by East Bay Regional Park District. The populations in the census blocks closer to a park entrance relative to the other census blocks have more access. Parts of Richmond, Antioch, Hayward, Livermore, and unincorporated areas have the most access, just to name a few.

In Figure 3.6, one can also see the problems with using the census blocks as the zones in rural areas. Census blocks are much larger in rural areas as compared to urban areas. Values representing the centroid of the block will lead to misinterpretation in rural areas in a choropleth map. For example, the unincorporated area in Figure 3.6 is shown to have a high level of accessibility, because the centroid of this block is within 0 to 1 miles of the park entrance. This creates the potential for *ecological fallacy* (O'Sullivan & Unwin, 2003) where we inaccurately assume that the level of accessibility is the same across the census block. The accessibility scores are dependent on the arbitrary block boundaries and corresponding unweighted centroids in rural areas. This creates a Mo*difiable Areal Unit Problem*. "If the spatial units in a particular study were specified differently, we might observe very different patterns and relationships" (O'Sullivan & Unwin, 2003). One must take into account the potential for misinterpretation when comparing urban census blocks to rural census blocks in a choropleth map.

The visualization presented in Figure 3.6 does not consider the population affected by the travel distance. To determine the total distance traveled if every person traveled to the nearest facility, Brabyn and Gower (2004) suggest multiplying the population of the census block with the shortest distance to the nearest facility. If you normalize this total distance traveled by the census block area you can compare blocks to one another to see regional differences, shown in Figure 3.7.

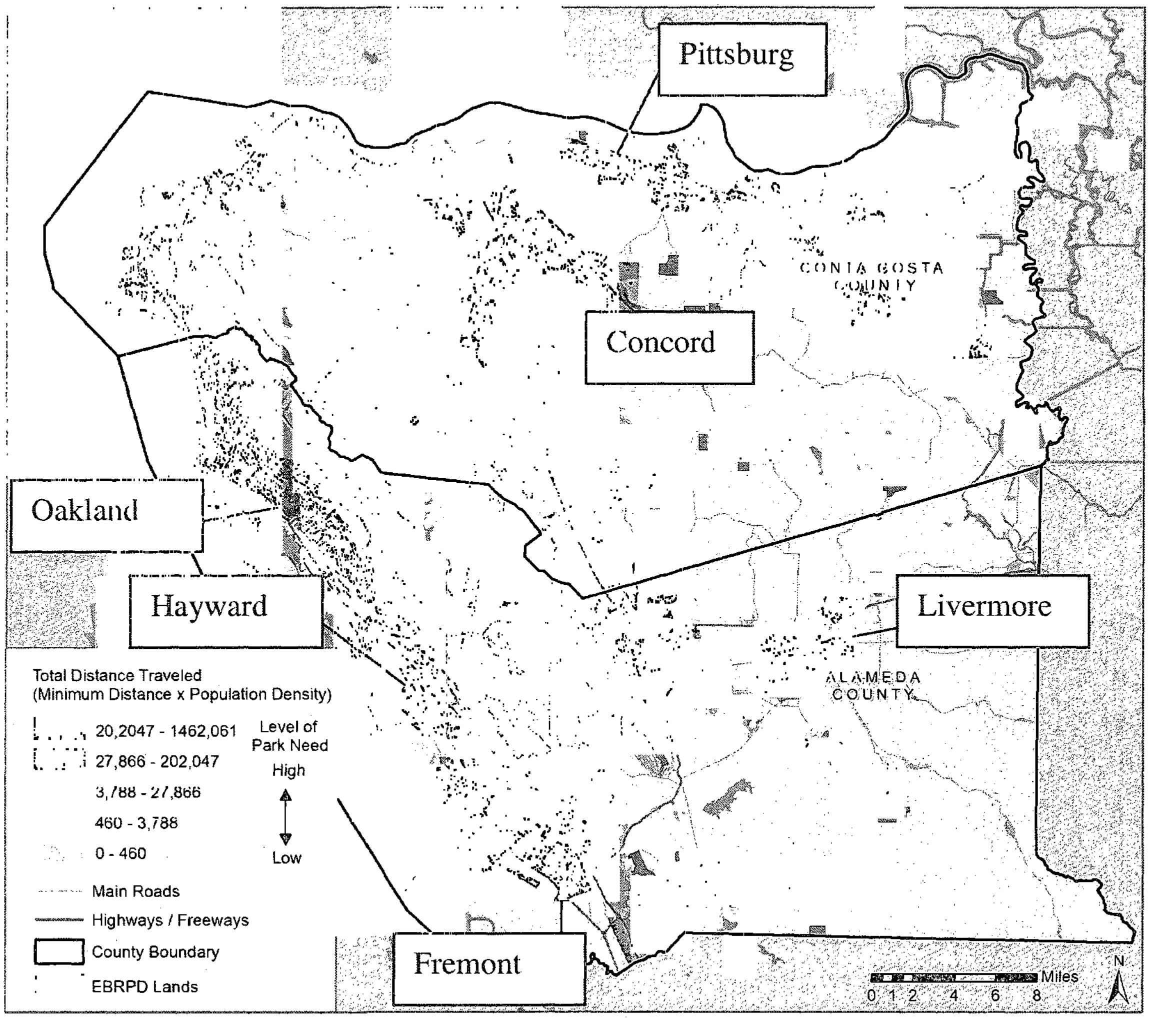

Figure 3.7 Equity visualization using the minimum distance technique

Figure 3.7 shows the relative accessibility for the population. The data is classified into categories using the geometric interval described in the previous section. This visualization reveals that the spatial distribution of access is not equitable. The areas with a relative deficit of parks are shown in red. Here Oakland, Hayward, Concord, Pittsburg, Livermore and Fremont have the highest need for parks. In order to focus on the areas with a lack of access, Brabyn, and Gower (2004) suggest that one could display the census blocks located more than a critical distance way from a facility. If you did this for regional parks, you could use the critical distance of 11 miles from the cumulative opportunities measure in the previous section, however, as you can see in Figure 3.6, very few blocks are located more than 11 miles away from a park entrance, therefore only a few census blocks would be displayed.

An advantage of the minimum distance measure is that it is easy to comprehend; it's simply the shortest distance to the nearest park. Here the accessibility measurement is also continuous. The disadvantage is that this measure only considers the nearest park. The nearest park may not be the park that people want to visit, and the measure does not consider the location of additional facilities.

The assumption of the minimum distance measure is that accessibility to an individual is based on relative distance. Here people are only going to benefit from one park, the nearest park. Areas that are the furthest away from any park have the least amount of access. When used in an equity analysis for planning purposes, the object would be to minimize the distance between origin and destination, specifically in areas that have the greatest travel cost and population size. Regional park users are not highly localized. For this reason, this measure may be better suited for local parks.

Least Cost Measure

As with the minimum distance, the least cost measure is considered a travel cost measure. The least cost measure is the average distance from the census block centroid to all parks entrances. This was calculated using the cost matrix operation in the ArcGIS Network Analyst extension which calculated the distance from each census block centroid to all possible park facility entrances. The distances were then summed for each centroid and divided by the number of park entrances to get the average distance from the census block centroid to all park entrances. The results are shown in Figure 3.8.

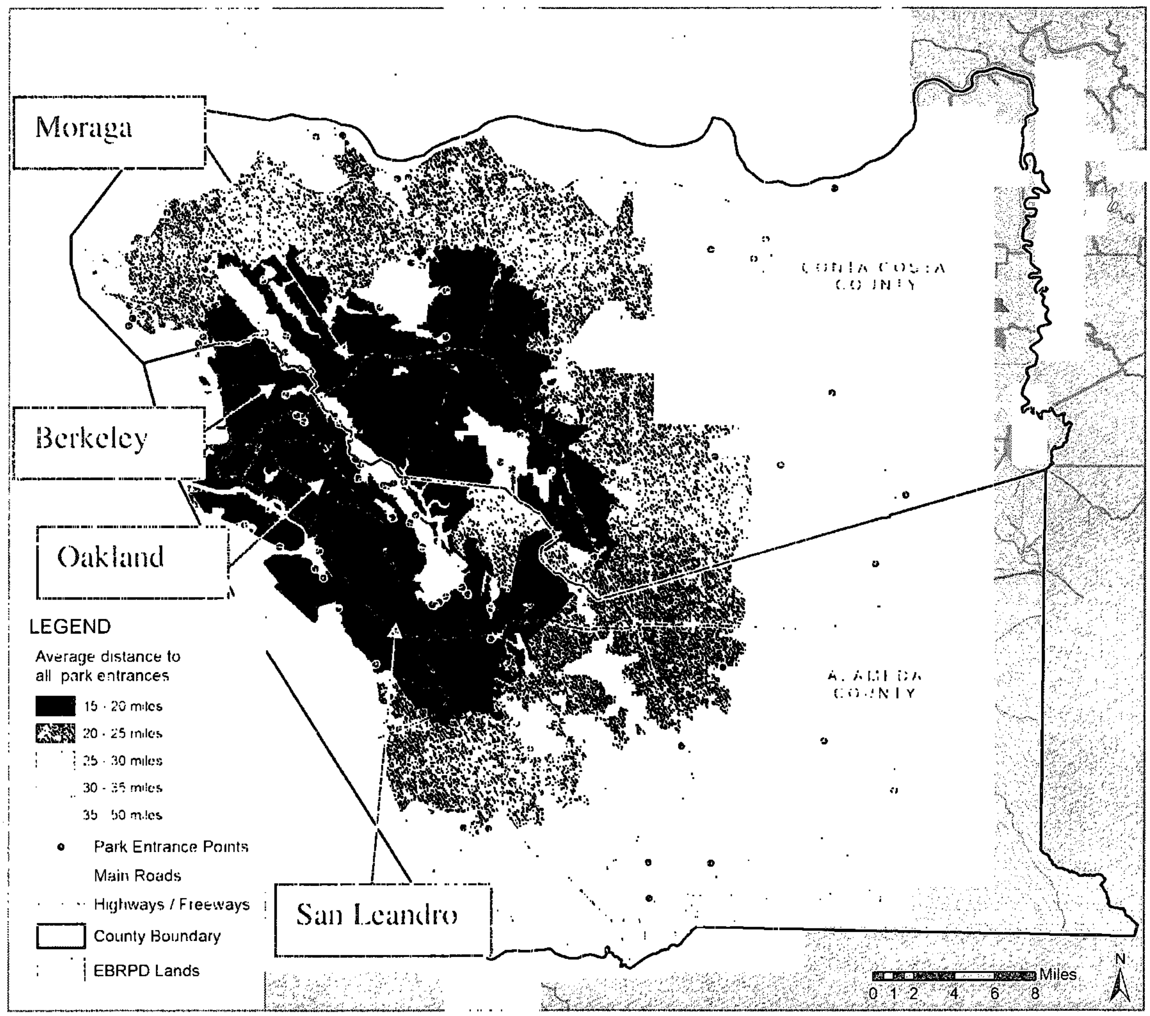

Figure 3.8 Average distance to all possible park entrances

As you can see from Figure 3.8, the western sides of Contra Costa and Alameda counties are shown to have greater relative access to the parks provided by East Bay

Regional Park District, or a shorter average distance to all park entrances. Berkeley, Oakland, San Leandro, and Moraga, have a particularly high concentration of access. The areas that have a greater average distance to park entrances are the eastern county areas, shown in orange and yellow.

Just using the average distance can be misleading because it does not consider the population affected by this variation in accessibility (Brabyn & Gower, 2004). A region may have a high average travel distance but a low population. Therefore to determine if the access is equitable Brabyn and Gower (2004) suggest multiplying the average distance to all park entrances by the population for each centroid. You can then divide this by the census block area in order to compare the measures regionally.

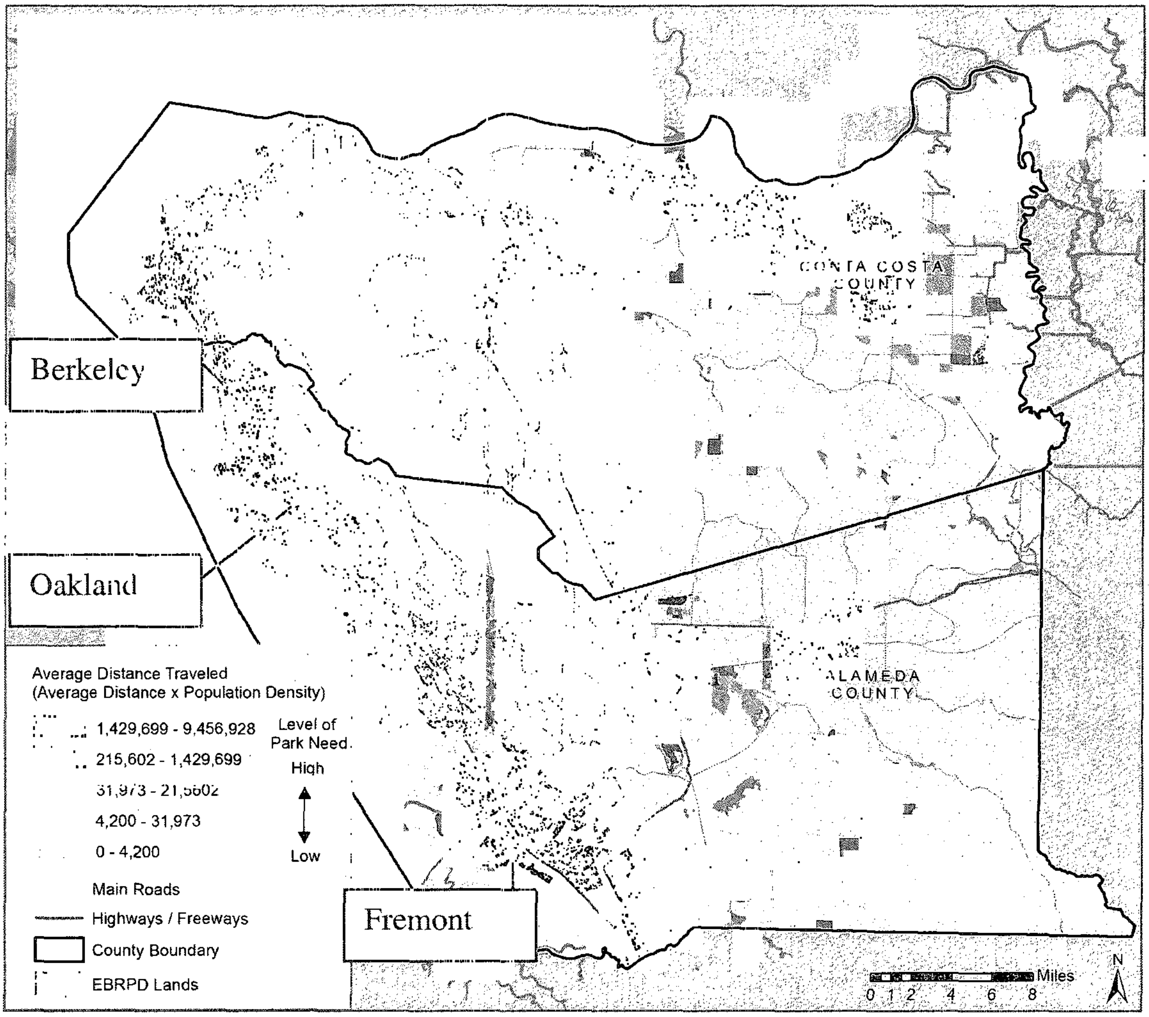

Figure 3.9 Equity visualization using average distance to all entrances

Figure 3.9 shows the relative accessibility for the population. The data is classified into categories using the geometric interval, described in the cumulative opportunities section. This visualization reveals that the spatial distribution of access is again not equitable when using this measure. The areas with a relative deficit of parks are shown in red. Many of the urban areas have the highest need for parks. If you use this map to determine the highest need for a regional park, it would be the dense urban areas of Berkeley, Oakland, and Fremont.

With the minimum distance and least cost measure it is possible to produce visualizations to show regional park accessibility and equity. The results can then be readily assessed by park staff to answer: 1) Who has access? 2) Is access equitable? 3) Where is the greatest need for new parks? The primary difference between these measures and the cumulative opportunities measure is that they measure accessibility in relative terms.

The advantage of the least cost measure is similar to the minimum distance measure. The measure is the average distance to all park entrances, so it is easy to comprehend. The unique feature is that the least cost measurement is continuous, and includes the distance to all parks within the jurisdictional boundary. The assumption is that park users can travel to any facility, though distance is a deterrent and they are less likely to travel to further locations. The benefit of the parks is viewed as a complete package of public goods. It does not take into account how far people may actually travel, or are likely to travel, but considers the entirety of the parks provided by the park district. When used in planning, the areas with the greatest need for new parks are the furthest away from all parks, with a relatively high population size.

All three accessibility measures were used to produce visualizations that park staff can readily assess. With the visualizations, park staff can interpret who has access to the regional parks and see where the greatest need for new parks is, based on the relative equity. However, the results of all three accessibility measures varied.

The purpose of an accessibility analysis is to see if public goods are distributed equally. A review of the unique features, the advantages, and disadvantages of each measure shows how and why each measure differs from the others. The differences reveal assumptions about access in each measure. One must understand the unique characteristics of regional parks and how users benefit in order to choose which measure represents the accessibility and equity of regional parks. To aid in this understanding the results of each measure will be discussed.

CHAPTER 4: RESULTS

The goal of this research is to identify which accessibility measure should be applied to measuring the equity of regional parks, specifically the parks provided by East Bay Regional Park District. Each measure produced a set of accessibility and equity visualizations that the audience, park staff, can readily assess and answer: 1) Who has access to the parks provided by East Bay Regional Park District? 2) Is the spatial distribution of parks equitable? 3) Which areas have the highest need for new parks? In order to determine which method provided the best geographic representation of who benefits from the spatial distribution of parks provided by East Bay Regional Park District, the characteristics of regional park accessibility and how they compare to the visualizations produced by each method will be discussed. Of prime importance is the issue of how the accessibility measures affect the results of the equity analysis.

To analyze accessibility one needs to determine who benefits from regional parks and why. Figure 3.3 shows that most people would be willing to drive at least 11 miles to access the open space provided by EBRPD. This means that regional park use is not highly localized, thus people are traveling from other cities in the region to access the park facilities. This distance also allows some to benefit from multiple park facilities. The cumulative opportunities visualization in Figure 3.5 best represents this characteristic of regional park access. This is different from the minimum distance measure, which represents accessibility as being greatest in areas adjacent to the park facility, and the least cost method, which considers the distance of the origin to every park within the jurisdictional boundary.

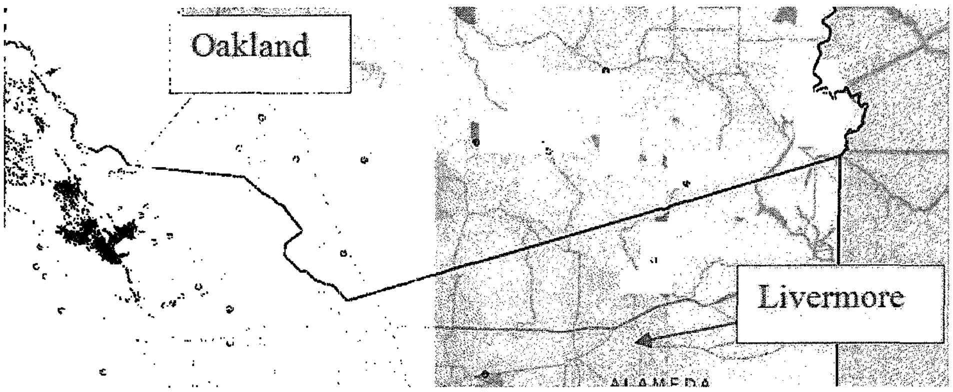

Figure 4.1a Sample of the cumulative opportunities accessibility measure

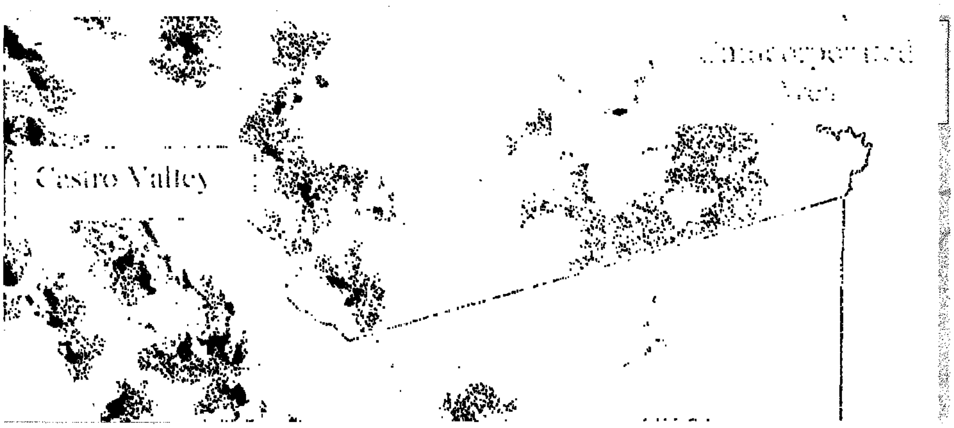

Figure 4.1b Sample of the minimum distance accessibility measure

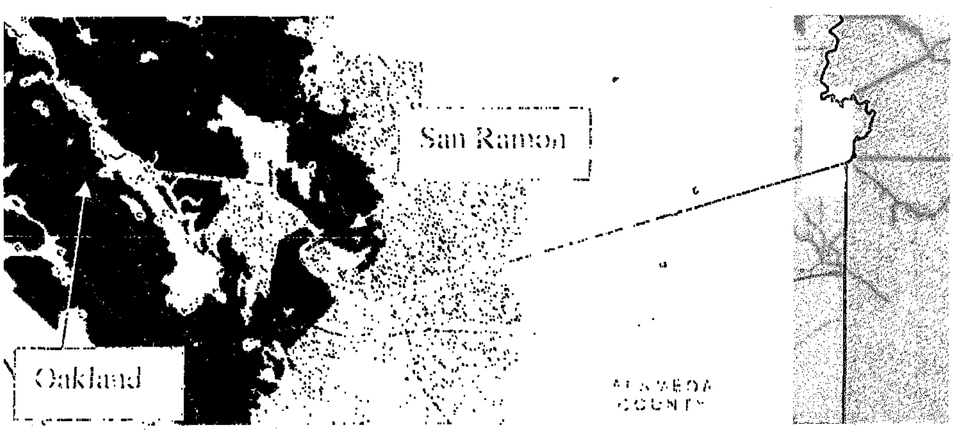

Figure 4.1c Sample of the least cost accessibility measure

A comparison of the Figures 4.1a to 4.1c reveal how the results of the accessibility measures differ. The cumulative opportunity visualization (Figure 4.1a) clearly shows the Oakland area as having the most access. The area benefits from being surrounded by a variety of natural features such as a mountain range, the San Francisco Bay shoreline, and multiple lakes. The first regional parks were established in this area to protect the ridgeline. If you compare Oakland in this Figure to Livermore, for example, Livermore has only 2 options for parks within the 11 miles driving distance, Del Valle and Shadow Cliffs, both containing lakes. Therefore one would accurately conclude from this assessment that the people of Livermore do not have as much access to regional parks.

The minimum distance visualization, Figure 4.1b, shows the census blocks surrounding the park entrances to have the most access. The minimum distance measure falls short of representing regional park accessibility because it assumes that people who live the closest to the park entrance benefit more. People are willing to travel to access the unique natural and recreational facilities available at regional parks, so this measure does not correspond with visitor's travel behaviors. Parcels in the most rural areas, such the unincorporated areas adjacent to a park, are given accessibility scores that are equivalent to Castro Valley, which has three parks surrounding the town. This measure fails to represent additional accessible opportunities.

The least cost measure Figure 4.1c, shows large general areas of Oakland and San Ramon with equivalent levels of accessibility. The number of parks that people are willing to drive to visit in Oakland may be different than the number of parks people are willing to drive to visit in San Ramon. Since the accessibility index is the average distance to all parks in the two county area, all parks are considered to be part of the public good, not a representation of the parks people are likely to visit. The parks included in the analysis are more a function of the jurisdictional boundary rather than the accessible range. Since the average distance to all parks are considered, this method produces generalized results. A more accurate way to measure accessibility would be to incorporate a more specific measure to determine the distance that people are actually willing to drive, such as in the cumulative opportunities method.

These accessibility measures directly affect the result of the equity analysis. An equity analysis incorporates population statistics and geographic accessibility to measure and compare the population's accessibility to a public good. The population density (Figure 3.2) and the score shown in the accessibility visualizations determine the population's need. A comparison of the equity analyses show how the results vary based on the accessibility measures, when the population statistics (Figure 4.2a) remained constant.

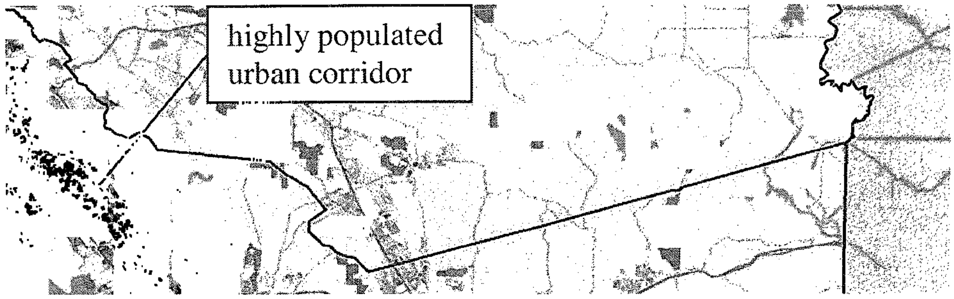

Figure 4.2a Sample of Population Density

Figure 4.2b Sample of cumulative opportunities equity analysis

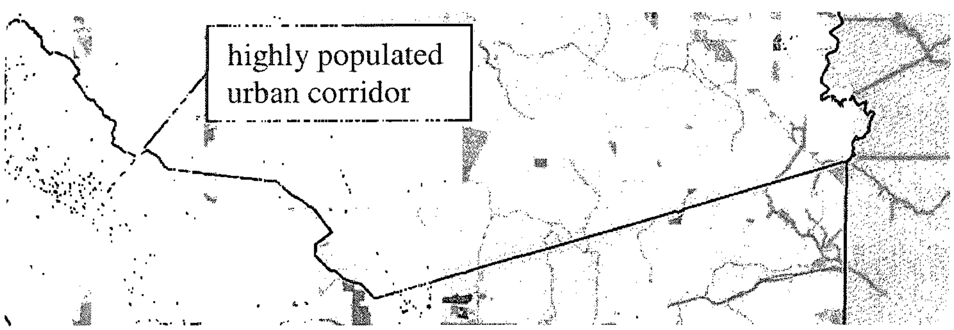

Figure 4.2c Sample of minimum distance equity analysis

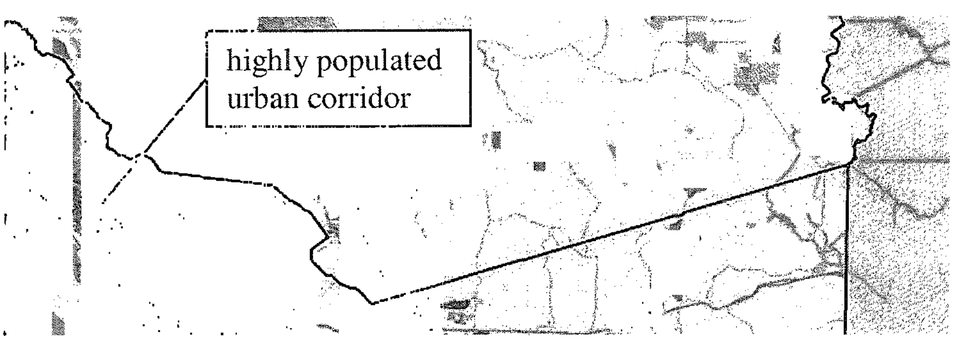

Figure 4.2d Sample of least cost equity analysis

In the minimum distance measure, the relative accessibility was considered to be greatest in the immediate area surrounding the park entrances. Parks are located where natural features are, such as lakes and mountain ranges, so in the minimum distance measure the areas with the most access are often less populated areas. In the equity analysis shown in Figure 4.2c, the urban areas are shown to have the greatest inequity or need for new parks. Comparing this to population density shown in Figure 4.2a demonstrates that the area of greatest need corresponds to the densely populated urban corridor. This equity analysis overemphasizes population. Measuring the equity of regional parks using the minimum distance measure does not appear to be an appropriate application to this method. A better application would be in transportation planning, to determine transit stop need. Transit stops are needed most in high-density areas, because transit stop use is highly localized.

The equity results of the least cost method, shown in Figure 4.2d, are similar to the equity results of the minimum distance measure. Since the least cost method is a measure of the average distance to all parks, all parks are considered to be accessible. As a result the accessibility index is generalized, not geographically specific, and the range of accessibility scores is narrow. When used in an equity analysis, the population density is overemphasized. It is not clear when this measure should be applied instead of the minimum distance measure.

Figures 4.2c and 4.2d reveal that the minimum distance and least cost measures emphasize inequity in populated areas. This directs service to highly populated areas, and not necessarily where there is a lack of access in the region, or where it is possible to put regional parks. The mission of EBRPD is to serve the region, and not specifically urban areas, therefore the minimum distance measure and least cost measure should not be used to measure equity for regional parks. A regional park is "an area selected for its natural and ornamental quality and its suitability for regionally-based recreational activities" (Mertes & Hall, 1995). Regional parks aim to protect natural areas, require enough space for outdoor recreational facilities to be located, and serve an area of at least a 10 mile radius.

The cumulative opportunities model, shown in Figure 4.2b, best geographically represents the areas of greatest need for regional parks. It identifies census blocks in the region with the lowest number of park opportunities available within 11 miles relative to the population density. These are areas such as Livermore with significant population size and lack of accessible parks when compared to the Oakland/Berkeley area. Additionally this visualization shows where you can put parks; near developing cities with adequate open space and natural beauty. Since the mission of EBRPD is to serve the region by conserving land and providing large-scale recreational facilities, the cumulative opportunities measure is the best measure to use.

Regional Accessibility

Previous studies on park equity used census blocks to measure accessibility in urban areas at a local scale. A regional study, such as this one, includes both urban and rural areas. Census blocks in rural areas are large and irregular in shape compared to the small and homogeneous urban blocks. There is a greater potential for misinterpretation in rural areas because the population is not uniformly distributed. Issues of ecological fallacy and the Modifiable Areal Unit Problem need to be considered in regional studies using census blocks.

One possible solution to reduce misinterpretations in rural areas would be to use a dasymetric population grid, instead of census block aggregated data. A dasymetric grid method uses a 30 meter grid to represent the distribution of the population within block groups (Sleeter, 2004). Sleeter compared census block level data to dasymetric mapping distributions in the San Francisco Bay Region and found that "the dasymetric mapping method produced more accurate population distributions than the choropleth method relative to the census block" (Sleeter, 2004). Using the 30 meter dasymetric grid to calculate equity can overcome the disadvantage of the census block arbitrary areal unit.

Rural census blocks may not contain roads or may have a population of zero. This created unforeseen errors and inaccuracies in this study. The un-weighted geometric census block centroid is used as the location of origin for trips to regional parks, the accessibility index calculated at this point represents the entire block. Some census blocks are bounded by roads, but do not contain any roads. When the census block centroids were relocated to the nearest road to calculate the distances in the minimum distance and least cost measures, some of the centroids were relocated to roads in adjacent census block. Therefore, the accessibility index for some rural blocks actually represents a point of origin in a different block. Using network analysis to calculate distances on roads from rural census blocks was problematic. Additionally one equity analysis used the ratio of the number of park opportunities within 11 miles per population density. The population in a select number of rural census blocks is equal to zero.

Having a ratio where the denominator is zero created errors when determining park equity in rural areas. Future studies on park equity should consider the potential errors when using census block population data and road networks in rural areas.

CHAPTER 5: CONCLUSIONS

Existing studies examining park accessibility and equity did not consider the unique characteristics of regional parks. Regional parks are located on the perimeters of cities, 78% of visitors drive to regional parks, and 50% of the visitors are willing to drive at least 21 miles to get to a regional park (Manross, 2008). Regional parks are considered to serve a 10 mile radius (DiChiara & Koppelman, 1982) and are typically 200 to 500 acres in size (Mertes & Hall, 1995). Parks of this side accommodate a variety of activities and are intended to preserve natural resources. Previous studies clumped all park types together and consistently used a half-mile radius from a park boundary to represent accessibility to a park.

This study compared cumulative opportunities, minimum distance, and least cost accessibility measurement techniques to understand how the different measures affect the results of an equity analysis on a regional scale. All three measures produced visualizations that park staff could use to readily assess and answer: 1) Who has access to the parks provided by East Bay Regional Park District? 2) Is the spatial distribution of parks equitable? 3) Which areas have the highest need for new parks? The results of all three equity visualizations were different.

The least cost and minimum distance accessibility measures produced relative accessibility scores that overemphasized population density once used in equity analysis. The cumulative opportunities measure enabled incorporating public opinion into the determination of the service area of regional parks and allowed counting other possible opportunities within this service area. Once incorporated with the population density, the equity visualization showed the areas in the region that have the lowest number of accessible park options but still have significant population size in areas such as Clayton, Pittsburg, Oakley, and Livermore. The ability of the cumulative opportunities measure to highlight areas of the region with the most need, without overemphasizing population, leads to the conclusion that this is the best accessibility measure to analyze regional park equity.

The cumulative opportunity visualization represents the population density per number of park opportunities within an eleven mile distance measured on the road network. Conceptually, this measure balanced the need to identify areas where regional parks will serve people and where there is a lack of other opportunities. The results enable EBRPD to serve the two-county region and place parks where it is possible to conserve land and provide recreational opportunities, as stated in the mission. Additionally, using a straight-forward accessibility measure and presenting the equity analysis in a visual form make the results easy to comprehend and interpret.

REFERENCES

Anselin, L. (1995) . Local indicators of spatial association- LISA. *Geographical Analysis,* 27, 93-115.

Brabyn, L., & Gower, P. (2004). Comparing three GIS techniques for modeling geographical access to general practitioners. *Cartographica,* 39(2), 41-49.

Cervero, R., Rood, T., & Appleyard, B., (1999). Tracking accessibility: employment and housing opportunities in the San Francisco Bay Area. *Environment and Planning A*, 31, 1259-1278.

DiChiara, J., & Koppelman, L., (1982). *Urban planning and design criteria.* New York: Van Nostrand Reinhold Co., Inc.

Dong, X., Ben-Akiva, M., Bowman, J., & Walker, J. (2005). Moving from trip-based to activity-based measures of accessibility. *Transportation Research Part A: Policy and Practice.* 40(2), 163-180.

East Bay Regional Park District Profile. (n.d.). Retrieved March 19, 2007, from http://www.ebparks.org/dropdown/aboutus.htm

Environmental Systems Research Institute, Inc. (2000). ArcGIS Desktop 9.3 Help. Retrieved March 21, 2009 from http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?id=3996&pid=3986&topicname=Data_classification

Geertman, S. and Van Eck, J.R.R., (1995). GIS and models of accessibility potential: An Application in Planning. *International Journal of Geographical Information Systems.* 9 (1), 67-80.

Gould, P. (1969). Spatial Diffusion, Resource Paper No. 17. Washington, DC: *Association of American Geographers.*

Handy, S.L., & Niemeier, D.A., (1997). Measuring accessibility: an exploration of issues ad alternatives. *Environment and planning A.* 29, 1175-1194.

Johnson, R. J., Gregory, D., Pratt, G., & Watts, M., (2000). *The dictionary of human geography.* Blackwell Publishing.

Koenig, J.G., (1980). Indicators of urban accessibility: Theory and application. *Transportation,* 9, 145-72.

Kwan, M.-P., Murray, A., O'Kelly, M., & Tiefelsdorf, M. (2003). "Recent advances in accessibility research: Representation, methodology and applications." *Journal of Geographical Systems,* 5(1), 129.

Lindsey, G., Maraj, M., & Kuan, S. (2001). "Access, equity, and urban greenways: An exploratory investigation." *The Professional Geographer,* 53(3), 332-346.

Mertes, J., & Hall, J. (1995). *Parks, Recreation, Open Space, and Greenway Guidelines.* National Recreation and Park Association.

Mladenka, K., & Hill, K. (1977). "The Distribution of Benefits in an Urban Enviornment". *Urban Affairs Quarterly,* 13(1), 73-94.

Manross, G. (2006). [Updating the East Bay Regional Park District Park and Trail Map: Benchmark Scientific Survey of Residents and Voters.] Unpublished survey.

Manross, G. (2008). [East Bay Regional Park District 2007-2008 Community Survey: Benchmark Scientific Survey.] Unpublished survey.

Nicholls, S. (2001). "Measuring the accessibility and equity of public parks: a case study using GIS." *Managing Leisure,* 6, 201-219.

Nicholls, S. (2003). "Measures of Success: Measuring park accessibility using GIS." *Parks and Recreation,* 38(8), 52-55.

Nicholls, S. (2004). "Measuring accessibility and equity in a local park system: The utility of geospatial technologies to park and recreation professionals." *Journal of Park and Recreation Administration*, 19(4),102-124.

O'Sullivan, D., & Unwin, D., (2003) *Geographic Information Analysis.* New Jersey: John Wiley & Sons, Inc.

Shannon, G., Skinner, J., & Bashshur, R. (1973). "Time and distance: The journey for medical care." *International Journal of Health Services,* 3(2), 237-44.

Skov-Petersen, H. (2001). "Estimation of distance-decay parameters - GIS-based indicators of recreational accessibility". Scandinavian Research Conference on Geographical Information Science.

Sleeter, R., (2004). "Dasymetric mapping techniques for the San Francisco Bay region, California" Urban and Regional Information Systems Association, Annual Conference, Proceedings, Reno, Nevada, November 7-10, 2004.

Small, K. (1992). *Urban Transportation Economics*. Toronto, Ontario: University of Toronto Press.

Talen, E. 1997. "The social equity of urban service distribution: An exploration of park access in Pueblo, Colorado, and Macon Georgia." *Urban Geography,* 18, 521-41.

Talen, E. (1998). "Visualizing fairness: Equity maps for planners" *Journal of the American Planning Association,* 64(1), 22.

Talen, E., & Anselin, L. (1998). "Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds." *Environment and Planning A*, 30, 595-613.

Tarrant, M. A. and H. K. Cordell (1999). "Environmental justice and the spatial distribution of outdoor recreation sites: an application of geographic information systems." *Journal of Leisure Research,* 31(1), 18.

East Bay Regional Park District Profile. (n.d.). Retrieved March 19, 2007, from http://www.ebparks.org/dropdown/aboutus.htm

Trust for Public Land. (2009). *Parkscore.* Accessed from http://www.parkscore.org/ on February 1, 2009.

U.S. Census Bureau (2000a). Census Block Groups: Cartographic Boundary Files Descriptions and Metadata. Retrieved October 4th, 2008, from http://www.census.gov/geo/www/cob/bg_metadata.html

U.S. Census Bureau (2000b). Census Tracts: Cartographic Boundary Files Descriptions and Metadata. Retrieved October 4th, 2008, from http://www.census.gov/geo/www/cob/tr_metadata.html