ANALYSIS OF PEDESTRIAN ACCESSIBILITY AS APPLIED TO SPOKANE CITY PARKS

By

MICHAEL EDMUND WILHELM

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Chair

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APPLIED TO SPOKANE CITY PARKS

Abstract

by Michael Edmund Wilhelm, MSLA
Washington State University
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Chair: Kerry R. Brooks

Environments that accommodate pedestrians (walkers and users of assistive devices such as wheelchairs) are becoming increasingly valuable. Many residents don't have an alternative to pedestrianism while those who do could benefit from the increased physical activity and decreased automobile emissions it offers. Pedestrian access to parks allows many individuals with limited transportation choices, such as children and seniors, to take advantage of the social interaction and contact with nature parks provide. Developing a method to measure the accessibility of any park or location is an important step in making changes to achieve its ideal accessibility. Three methods are evaluated for their value in determining the accessibility of three parks in the City of Spokane, Washington for both walkers and mobility-impaired pedestrians. The three methods are Relative Accessibility, Normalized Patch Shape Index and Pedestrian Route Directness.

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Dedication

This thesis is dedicated to my wife and sons who will

benefit from my work in this area of research

CHAPTER 1 – INTRODUCTION

Interest has been growing lately in a movement to encourage walking and bicycling as an alternative to the automobile. This movement has been catalyzed by issues such as transportation safety, air pollution and inefficient land use. The International Walk to School Day, the Safe Routes to School program (United States), the National Bicycling and Walking Study (United States) and the WALCYNG project (Europe) illustrate the extent of the movement for increased pedestrianism.

There are a wide variety of parameters which make communities pedestrian friendly. A universal recipe for increasing pedestrianism probably does not exist due to differences in culture and infrastructure among communities. Perhaps a list of ingredients does exist, with their corresponding quantities to be decided by individual cities and neighborhoods. Accessibility, or the ability to reach a desired destination, is one of the recipe's basic components explored in this thesis.

Goals

This thesis aims at achieving five goals. The first was to understand the literature surrounding the concept of accessibility. Second, the methods used to measure it were explored and developed upon. Third, spatial data describing pedestrian infrastructure was obtained and developed in such a way that additional attributes support pedestrian modeling. The fourth goal was to model pedestrian access to important community assets, parks, using GIS. Finally, the methods used to model accessibility were evaluated for their ability to measure absolute and relative accessibility.

Objectives

The first objective of this thesis is to compare three different methods of measuring pedestrian accessibility, observing their advantages and disadvantages. The second is to determine the comparative accessibility of three parks in the City of Spokane, Washington to the surrounding neighborhood. The three methods were used to provide a comprehensive view of each park's accessibility.

Document Organization

The organization of this document begins with the concept of accessibility being examined alone and in broader contexts. The portion of Geographic Information Systems (GIS) used to model movement along networks is described. Following is a discussion on why parks were chosen as the location of interest for accessibility studies. Specific parks studied here are then described in detail. The Methodology chapter defines the application of the modeling performed with GIS. Finally the results and conclusions are set forth.

CHAPTER 2 – LITERATURE REVIEW

Introduction

This literature review begins by examining the basic components of walkability. Pedestrian-related frameworks, such as active living, and legislation follow the walkability description. Accessibility as related to pedestrianism is the concentration of the review. The functionality of Network Analyst, a tool within the world of GIS used to perform network-based spatial analyses, is discussed. Reasons for focusing on parks as a destination of interest conclude the chapter.

The purpose of starting out with the general topic of walkability is to illustrate the importance of making it more available. This study started by reviewing works related to walking for recreation purposes but the ideas contained here could be applied to any pedestrian trip regardless of purpose.

Walkability

Definitions, Importance and Trends

Walkability is the extent to which the built environment encourages walking by providing pedestrians a safe, comfortable, convenient and appealing travel corridor (Southworth 2005). In the American Heritage College Dictionary (1993) the term pedestrian is very traditional because it only includes those on foot. However, recent legislation (ADA, ISTEA and TEA-21) has encouraged the definition to include any person on foot or using assistive devices such as wheelchairs, prosthetics, or crutches (Otak 1997; FHWA 2006). This thesis uses the more inclusive definition of pedestrian due to its equity among individuals with differing mobility levels.

The benefits of a walkable community include increased social capital, decreased dependence on automobiles, increased health levels, more equitable transportation, and decreased environmental impact from transportation (FDoT 1995; Putnam 2000; Powell, Martin et al. 2003; Southworth 2005). The following characteristics of a walkable community are detailed below: comfort, safety, convenience, connectivity, path surroundings, path condition and land use patterns (Litman 2004; Southworth 2005; VTPI 2005; PWA 2006).

Comfort

The term comfort can refer to path continuity, suitable temperature, directness of the route, quality of the pathway, or quantity and velocity of traffic on adjacent streets (Jacobs 1993; Litman 2004; Southworth 2005). Many of these attributes are subjective and difficult to measure. For instance, a pathway that has a row of street trees separating it from the roadway might provide comfort to some pedestrians who feel anxious about their close proximity to traffic. Other pedestrians might feel this screening effect discourages a visual connection from passing cars that could inhibit or encourage crime along the pathway.

Attributes contributing to the comfort of a pedestrian which tend to be objective include path continuity, route directness and pathway quality. Path continuity and route directness refer to how well connected the pathway network is, while pathway quality measures how accommodating the surface of the pathway is to pedestrians. These basic characteristics measure the efficiency of a route, especially for mobility-impaired pedestrians.

Safety

The safety characteristic can be easily measured by searching hospital and police incident reports (Ekman 1999). Southworth (2005) suggests that safety is the "best understood and most fully developed aspect of walkability" (p. 250). Of the Federal Highway Administration's five strategic goals, safety is the only area in which pedestrians are mentioned (FHWA 1998). Safety is often a by-product of other attributes such as convenience, connectivity, high facility quality and community support (driver and pedestrian education).

Time and effort is needed to construct a safe pedestrian network, yet it can be achieved. Many countries in Europe have focused on accommodating non-motorized forms of transportation (Pucher and Dijkstra 2003). Sweden has a high safety record in terms of number of pedestrians injured or killed as compared with other Scandanavian countries (Ekman 1999). Examples of Swedish pedestrian programs include school children wearing fluorescent caps, road level warning lights at road crossings, and painted pre-markings at striped road crossings.

Convenience

Convenience is an attractive attribute in the choice of travel. Travelers tend to take the path of least resistance, which means ease of use and proximity to trip origins and destinations (Farley 2005). Well-designed pedestrian pathway networks enable convenient access to essential goods and services including food, clothing, healthcare, education, employment, social and recreational activities (VTPI 2004; Greenberg 2005). Since many pedestrians do not have the option of using an automobile, convenient pedestrian access to their destinations is necessary (Litman 2004).

Convenience not only plays a role in helping people access vital goods and services, it encourages physical activity. Pedestrian facilities can be the site for recreation as well as provide access to facilities designed for formal physical activity (gyms or fitness centers), depending on its degree of convenience for users (Powell, Martin et al. 2003; Greenberg 2005).

Connectivity

Transportation networks with high degrees of connectivity are favorable to pedestrians because they provide an increased number of route choices. Conversely, developers often prefer sparsely connected street rights-of-way for three reasons. First, residents demand privacy and seclusion from passers-by (Appleyard, Gerson et al. 1981). Second, fewer road intersections promise fewer points of conflict among vehicles and higher automobile safety. Finally, the promise of financial savings due to decreased amounts of infrastructure construction costs is very persuasive(Southworth and Ben-Joseph 1996).

The measurement and analysis of connectivity is an important part of creating a compromise between these conflicting interests. Methods for analyzing connectivity will be discussed in the accessibility related measurements later in this chapter.

Path Surroundings

Pedestrian facilities are commonly located in the public right of way between the street and adjoining property, which contribute much to the experience of passing pedestrians. Attributes such as visually interesting facilities, transparency of building facades and the complimentarity of adjoining buildings all serve to enhance the pedestrian experience (Jacobs 1993). Other attributes include the presence of lighting and a sense of liveliness as displayed by visible human activity (Southworth 2005).

The experience-enhancing items above can be considered not primary for the function of the pedestrian facility. However, if utilitarian attributes such as connectivity, convenience or safety are present, the design and implementation of appealing path surroundings would be next in line toward the goal of walkability.

Path Condition

The pedestrian path network is comprised of many facilities, including sidewalks, trails, curb ramps, grade separated crossings, and traffic calming and control devices (Otak 1997). Sometimes pedestrians use streets because they provide more convenience in reaching their destination or the pedestrian facility is not well maintained (i.e. snow/stormwater issues, litter, crumbling concrete). Similar to roadways, pedestrian network facilities must be well designed, constructed with care and maintained regularly in order to be of value to users (Jacobs 1993).

Each community has pedestrians with varying degrees of mobility, so the design and construction of their pedestrian facilities should cater to those needs (Miller 2000; Muraleetharan 2004). The Americans with Disabilities Act produced standards which should be followed in order to provide path conditions which meet the mobility requirements of nearly all pedestrians.

Land Use Patterns

The automobile has provided greater spatial freedom and has accommodated lower density land use, resulting in sprawling post-war suburban development (Southworth 2005). Low-density land use coupled with inequalities in transportation create needlessly large spatial separation of residents from essential goods and services (Putnam 2000).

Recent trends in development focus on dense land use patterns to discourage reliance on the automobile and encourage greater equity in mobility. Examples include the Pedestrian Pocket concept (Kelbaugh 1989) as well as Transit Oriented Development and New Urbanism concepts (Cervero 1997; Dittmar 2004; Southworth 2005).

As noted, some of the preceding seven qualities of the pedestrian environment are often difficult to measure. Ewing (2006) used a panel of urban design experts to create a composite rating for each segment of pedestrian facilities. This rating was combined with the physical characteristics of the facilities for a final rating. However, the complexity involved in this method of measurement is discouraging for the creation of datasets covering large areas.

Discussion

Travel behavior is a multi-faceted issue and cannot be based solely on the characteristics of walkability as defined above. Realizing the complexity of the issue, some researchers have called for a more careful look at the process of making walking a more viable transportation option (Crane and Crepeau 1998; Boarnet 2001). Giles-Corti (2002) has found that the physical environment plays a secondary role to individual and social environment characteristics in individuals' exercise habits. Although exercise is not a primary reason many use non-motorized forms of transportation, it is an inherent result of walking.

Characteristics of the social environment favorable to pedestrianism include community programs and actions that encourage the use of alternative transportation. Examples are Safe Routes to School (SRTS), heightened enforcement of pedestrian related safety rules, effective education programs for both drivers and pedestrians, or neighborhood beautification programs (PWA 2006). The aim of most of these programs is to increase the safety of pedestrians as they interact with drivers. The last program listed, neighborhood beautification, is directed at improving path surroundings, path quality and comfort of the pedestrian.

Now that the components of walkability have been examined, it will be positioned within four broader contexts: active living, livable communities, universal design and pervasive computing. These are discussed in turn below.

Active Living

Walkability plays a prime role in the concept of active living because it provides a convenient transportation mode that Gauvin (2005) defines as integrating "physical activity into daily routines" (p. 127). The focus of active living is on designing the built environment to support an active lifestyle. Designs should then include all of the aforementioned walkability characteristics because they all encourage walking and in turn, an active lifestyle. One challenge of this approach is that it ignores embedded habits and negative attitudes about exercise encouraged by an automobile centered society (Lavizzo-Mourey 2003).

Gauvin, Richard et al (2005) explored the establishment of a consistent, reliable method for measuring active living potential. This method incorporates social aspects such as social cohesiveness and disorder, area friendliness, and physical capacities for pedestrians (walkability) and bicyclists. The result, called Neighborhood Active Living Potential (NALP), is defined by Gauvin (2005) as "aspects of the neighborhood that regulate the likelihood of active living in individuals and populations" (p. 127). This study was useful in showing that observers could be trained to reliably record active living parameters.

Livable Communities

The livable community concept is a bold effort utilizing many disciplines to create a social utopia. A livable community has the following qualities: pedestrian access to services and recreation, greater equality among transportation modes, high environmental quality, short commute times, community cohesion, and good health and safety (Dittmar 2004; Litman 2004). The East Bay Community Foundation (2006) distilled many of these characteristics into three categories: environment, economy and social equity. Walkability could fall under two of these categories: environment, because walkability is concerned primarily with the built infrastructure, and social equity because it provides a viable transportation mode to the financially and mobility disadvantaged. Perhaps communities containing all these traits are impossible to form, but following are descriptions of two areas exhibiting a collection of them.

Princen (2005) described the Toronto Islands, a target of automobile conquest for many years, as a remarkable place. Located near the heart of Toronto, Canada in Lake Ontario, the islands are not linked to the mainland by a road, which limits automobile use. The decreased number of automobiles results in decreased pollution, increased pedestrian comfort and safety. Streets on the island are approximately half as narrow as residential streets on the mainland equating to a more dense usage of land. Pedestrianism promotes greater social capital because it allows more personal encounters with others than automobile travel.

Oakland, CA has many transportation hubs that provide pedestrian access to services and recreation. Health and environmental quality are increased by the use of greenbuilding practices, while affordable housing attempts to bridge the gap in social equity (EBCF 2006).

Equitable transportation options are very important to the process of creating social parity. Access to goods and services as facilitated by a highly walkable neighborhood will promote a community that encourages equality among different transportation choices.

Universal Design

The theory of universal design includes the same push for social equity that is found in the livable community concept. Preiser and Ostroff (2001) define universal design as "an approach to design that incorporates products as well as building features which, to the greatest extent possible, can be used by everyone" (p. xxv). This theory seems to be focused on complying with standards that provide basic access. For this reason, the attributes of walkability which apply most here are path condition and safety. The other attributes can be seen as non-essential in order for everyone to use them.

Pervasive Computing

The use of pervasive computing in the built environment is one way to serve a relatively small group of users. Pervasive computing can create smart environments, or places that use electronic devices to increase comfort levels. An example might be using RFID (radio frequency identification) tags to warn pedestrians of route reassignment due to construction or potential dangers such as low hanging signs. A system such as this would certainly increase the safety and convenience for users.

Pedestrian Related Congressional Acts

Americans with Disabilities Act

The Americans with Disabilities Act of 1990 (ADA), often considered a blanket act for the benefit of the disabled, was preceded by a number of civil rights oriented legislative acts. In 1968, the Architectural Barriers Act (ABA) was passed, requiring all buildings that received federal funding to be made barrier-free for the disabled. Other significant pieces of legislation include the Rehabilitation Act of 1973 and the Fair Housing Amendments Act of 1988. The ADA was monumental because it provided for more than just the physically disabled. It helped to remove barriers for people with physical, emotional and mental challenges. Expanding upon the ABA, it required access to the workplace, government facilities (state and local), public commercial facilities, transit vehicles and telephone services. The ADA established the importance of funding facilities intended to assist the disabled.

The Americans with Disabilities Act was a necessary first step in providing mobility equality. However, despite being a great accomplishment for the disabled, this act only begins to solve problems associated with accessibility. Church and Marston (2003) note that it is a standards-based approach unable to focus on the "value or quality of the access provided" (p. 84). The ADA standards require absolute access by at least one route to the destinations listed above.

TEA Family

The Intermodal Surface Transportation Efficiency Act (ISTEA) was passed in 1991 and set aside federal funding for alternative modes of transportation, especially bicycling and walking. This act also required each state to designate a bicycle/walking coordinator and produce a pedestrian/bicycle plan. Planning stage elements in preparation for the next walking-related legislative act, TEA-21, were required.

A re-authorization of ISTEA, the Transportation Equity Act for the 21st Century (TEA-21) was enacted on June 9, 1998. This act provided many funding opportunities for the improvement or creation of pedestrian facilities including sidewalks, crosswalks, signal improvements, curb ramps and traffic calming (Fegan 1999). However, states and metropolitan planning organizations had the final decision in where the funding was applied, which often resulted in the neglect of pedestrians.

The Safe, Accountable, Flexible and Efficient Transportation Act (SAFETEA) was a reauthorization of TEA-21, which expired in 2003. SAFETEA increased provisions for pedestrians such as making funds available for non-construction pedestrian safety projects and pedestrian facilities on bridge structures (FHWA 2003).

The Safe, Accountable, Flexible and Efficient Transportation Act: A Legacy for Users (SAFETEA-LU) signed into law August 10, 2005, regards pedestrianism as an important mode of transportation. Two programs were introduced that aim to improve pedestrian facilities and safety. The Safe Routes to School program will provide increased attention to allowing children to access schools safely. The Non-motorized Transportation Pilot program will fund the creation of a pedestrian/bicycling network in 4 communities (Columbia, Missouri; Marin County, California; Minneapolis-St. Paul, Minnesota; Sheboygan County, Wisconsin) to test the viability of these two transportation modes (Fegan 2005).

The legislation described above has shown a steady increase in policies aimed at promoting pedestrianism. Despite their lack of attention to the importance of dense land use in creating a walkable environment, these acts do promote the improvement of the other six walkability qualities described above: comfort, safety, convenience, connectivity, path surroundings and path quality.

Access

Definitions

Accessibility

The term accessibility is used in many disciplines ranging from geography to communications. Thus it is important to specify which definition of accessibility was used here. Harris (2001) points out the components involved in an accessibility study: "entities" and "actors." Traditionally, two locations represented the "entities", and commonly the "actor" was a human, however in people-based accessibility one location is fixed while the other changes as the location of the "actor" moves (Lowe 1975; Wu 2001; Weber and Kwan 2002; Miller 2005). Thus, accessibility is the ease with which an "actor" can travel between "entities." The connection between two "entities" is evaluated for ease of use.

People-based measures of accessibility are much more sensitive to time constraints that limit access than place-based accessibility measures. Hägerstrand (Wu 2001) introduced the space-time prism (STP) which relates temporal and spatial components and is an integral part of the people-based accessibility concept. One problem with this concept is that despite being sensitive to each person's time constraints, at some point in the analysis the data must be generalized. Another challenge for this accessibility measure is in choosing the actors to be analyzed. Unless the whole population is studied, the representative group studied will display some bias.

Definitions for these "actors" as well as the method of access must be identified in order for accessibility to have significant meaning (Harris 2001). For instance, different modes of transportation present very different accessibility measurements not only due to their abilities, but also their disabilities (certain areas exclude use by pedestrians, cars or bicycles).

The group called pedestrians should be further broken down into differing ability levels, which affect accessibility measures. Those with limited mobility will certainly have a more difficult time traveling the same distance than an ambulatory pedestrian. Wachs (Hanson 2004) refers to this concept as the "friction of overcoming space" (p.141) while others use the phrase friction of distance (Hughes 2001). The attractiveness or capacity of a destination has the ability to minimize the friction of distance. For example, rare services offered by a specific location will encourage users to travel a greater distance than they might for more common services. Hughes (2001) gives an example of traveling further to reach a heart surgeon than to purchase gasoline. The heart surgeon's location has a greater attractiveness or gravity to those who need that service than does a specific, common gas station.

Measures of accessibility along travel corridors can be asymmetrical but are usually symmetrical, or (erroneously) assumed to be. Features such as topography, travel restrictions and weather can make a return trip have a higher travel cost than the first half of the journey. These measures, discussed in detail later, can be defined in many different ways, including distance (Euclidean, Manhattan, network-based) or time (distance multiplied by inversed velocity).

Graph Theory

Real world transportation features can be abstracted to a series of links and nodes (a configuration known as a graph) then analyzed for their structural qualities. Links and nodes, also known as edges and junctions (or vertices) represent paths and intersections. This mathematically based method of abstraction called graph theory uses many complex theorems to evaluate graphs for attributes such as connectivity and flow (Taaffe and Gauthier 1973; Diestel 2005). Graph theory is the basis for routing and network analysis in GIS software (Lee 2001).

Pedestrian infrastructure data can be abstracted and analyzed with the tools of graph theory to obtain insights into the accessibility of the pedestrian network. The abstraction of transportation systems into links and nodes can be valuable if attributes such as travel time, distance and direction are associated with each link and node. Graphs are regarded as undirected if their links are considered bi-directional; and directed if the links are uni-directional.

Graph theory facilitates two important measurements to the study of transportation networks (Taaffe and Gauthier 1973; Dill 2004). The alpha index gauges how many different routes can be used to traverse the network and arrive back at the beginning point. The alpha index is calculated by dividing the actual number of circuits by the maximum number of circuits as shown in Equation 1 (where e = edge and v = vertex).

$$\alpha = \frac{e - v + 1}{2v - 5}$$

Equation 1: Alpha Index for a planar network. Source: Taaffe and Gauthier 1973

The gamma index is simply a ratio of the number of actual links versus the possible number of links that could connect all the nodes. The gamma index is calculated by dividing the actual number of edges by the maximum number of edges that could connect all of the vertices in

$$\gamma = \frac{e}{3(v-2)}$$

Equation 2: Gamma Index for a planar network. Source: Taaffe and Gauthier 1973

the network. Equation 2 defines this relationship with the variable e representing edge and v representing vertex.

These basic measurements can give useful insights into the transportation network, yet require other measurements to fully understand the network. They describe the connectivity of a network, which is discussed in the following section.

Connectivity

Connectivity displays how capable a network is in providing different paths that could be used to arrive at the same location (Handy, Paterson et al. 2003). Connectivity can address the issue of travel distance, which is an integral part of accessibility. A high degree of connectivity will usually result in shorter travel distances which greatly benefit pedestrians, who are considered to have a small mobility reach (400 meters) (Otak 1997). The following discussion on connectivity is given due to the vital role that it plays in accessibility.

Communities within the United States have differing levels of connectivity which can be linked to the era in which they were designed and built (Southworth and Ben-Joseph 1996; Handy, Paterson et al. 2003). Typically, street networks that are in a grid-like form were constructed between the mid-nineteenth and mid-twentieth centuries. These networks display a high degree of connectivity due to the many nodes. Post World War II developments are characterized by three way intersections, curved streets and long block faces. These attributes result in a network that demands relatively long travel distances. However, recent trends in planning have emphasized the need to have good connectivity (Dill 2004).

The advantages typically associated with highly connected street networks are decreased automobile congestion, decreased travel distances for automobiles and pedestrians, increased number of route choices, increased emergency vehicle access and increased utility connection quality. Associated impacts might include increased levels of traffic on residential streets, decreased safety for pedestrians due to increased numbers of intersections, and increased spatial density of development. Appleyard (1981) bases his writing on the conflict between the inhabitant and the voyager. Decreased automobile congestion may lead to even more automobile trips, while decreased travel distances for pedestrians could lower the amount of physical exercise obtained by walking. However, an environment which is more conducive to walking might stimulate an increase in the modal share for pedestrianism.

The connectivity of the street network has been seen as a good metric for analyzing neighborhood design (Dill 2004). Assumptions have been made that high levels of street connectivity equate to high levels of connectivity in pedestrian connectivity (Dill 2004, Handy 2003).

If the definition of street is a transportation corridor providing multi-modal travel, then high street connectivity does equal high pedestrian connectivity. However, many developments built after 1950 do not have adequate pedestrian facilities, requiring pedestrians to either use the street or residential yards (Southworth 2005). Both of these choices lower pedestrian safety due to increased proximity with vehicles or increased difficulty of negotiating the travel surface. The public right-of-way should provide a place for pedestrians to create an accessible, highly walkable corridor.

In addition, the degree of street connectivity is not accurate in determining pedestrian connectivity due to pedestrian facilities that are not located adjacent to roadways. The pedestrian network usually has a much finer resolution than does the street network. Design elements such as Berkley barriers (Southworth and Ben-Joseph 1996) can result in mid and end-block obstructions to vehicular traffic, creating what Childs (1996) has termed "live end streets" (p. 14). These streets don't affect pedestrian connectivity yet they reduce vehicular through traffic which is seen as a negative side effect of highly connected street patterns. Part of traffic calming strategies, these methods can increase vehicular travel times while enhancing the pedestrian environment by reducing points of conflict.

Connectivity differs from accessibility because it is descriptive of how intertwined the network is, while accessibility is descriptive of how reachable individual nodes (destinations/origins) are. A network may have a high degree of connectivity, yet important origins or destinations may have a low degree of accessibility.

Types of Measurements

Measurements of connectivity, including some proposed in this thesis, come from disciplines such as planning, geography, mathematics, and landscape ecology. Table 1 shows some methods as discipline-specific, however each method can have application in different fields. For example, the alpha and gamma indices listed with the geography and mathematics disciplines has also been used by researchers in landscape ecology (Forman 1986). Each measure has benefits and constraints that require careful application in order to obtain useful measurements. The measures shown in Table 1 are discussed in the following paragraphs.

Table 1: Discipline Referenced Connectivity Measurement Methods as Related to Transportation. Source: Author, based on (Dill 2004)

Discipline	Methods of Connectivity Calculation	Basis of Connectivity
Planning	Block Length	Block
	Block Size	Block
	Block Density	Block
	Intersection Density	Intersection
	Street Density	Street
	Connected Node Ratio	Intersection, Cul-de-sac
	Link-Node Ratio	Street, Intersection, Cul-de-sac
	Grid Pattern	Street, Intersection
	Pedestrian Route Directness	Origin, Destination, Street
	Effective Walking Area	Origin, Parcels
Geography/Mathematics/ Landscape Ecology	Gamma Index	Street, Intersection
	Alpha Index	Street, Intersection
Landscape Ecology	Dispersal Success	Traveler
	Search Time	Travel Stage
	Cell Immigration	Traveler, Arrival Occurence

Simple and intuitive, the Pedestrian Route Directness (PRD) provides a good tool to compare different areas or designs for their connectivity. Randall and Baetz (2001) use the PRD method to compare three different configurations of the same suburban neighborhood for their degree of pedestrian connectivity. It is a ratio of the route length and the Euclidean distance between origin and destination. The PRD measure is the only measure listed here that would show the connectivity measurement of a single route (see Figure 1). This is significant because it has the possibility of focusing on significant destinations such as grocery stores, parks, healthcare facilities, etc. Performed repeatedly, this method could produce an area based on topological distance, termed Pedestrian Accessibility Area (PAA) for the purposes of this study. Within this area, all pedestrians could access the origin, and from the origin any destinations within the defined area due to the symmetrical nature of network travel.

The advantage of the Effective Walking Area (EWA) is that multiple destinations can be evaluated for their accessibility to an origin; the PRD only allows for the evaluation of one destination per analysis. The EWA is similar to the PAA, except that it uses a ratio of parcels instead of a ratio of distance, which can be misleading due to partial access to large parcels. In Figure 1, some of the parcels that would be included in the EWA calculation for accessibility to the origin have very little area contained within the specified service areas. For example, the Euclidean service area minimally covers the oblong parcel to the left of the service area origin, making that entire parcel potentially accessible from the origin.

The remaining methods of connectivity measurement in Table 1 are useful for small scale planning and policy making due to their application over an area and not simply a route. Some of these methods use census data, such as block density, which results in measurements of coarse resolution (Dill 2004; VTPI 2004). Perhaps if fine-scale data were more readily available, some of the methods would be useful for decisions based on large-scale connectivity analyses.

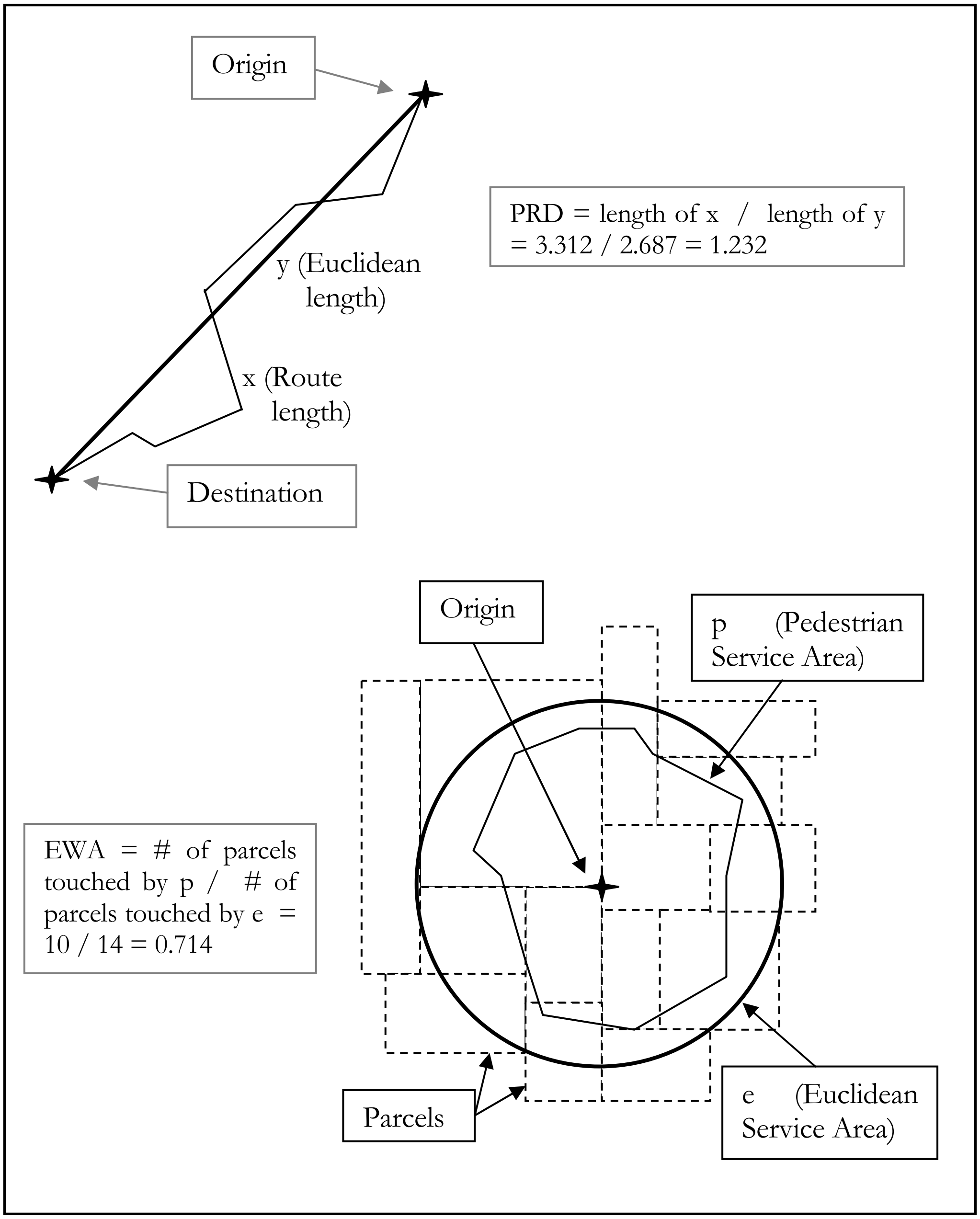

Figure 1: Pedestrian Route Directness (left) and Effective Walking Area (right). Source: Author

Time, Distance, Individual and Zone Based Measures

Measurements of accessibility can range from very simple distance based methods to complex methods involving time. Most methods can be put into one of the two categories described below; individual and zone (or place) based accessibility (Berglund 2001; Miller 2005). The two basic components of accessibility measures are travel cost and opportunity (Berglund 2001). Travel cost could be represented by time or distance, while opportunity signifies the measurement of demand at specific destinations within the accessible area.

Place

Parameters that must be defined in a study of place-based accessibility include aggregation/disaggregation of population data, spatial extent (or origin/destination specification), destination attractiveness measurements and travel impedance estimations. Using population data in the measurement of accessibility introduces what has been referred to as the modifiable areal unit problem (MAUP) (Miller 2005). This problem addresses the fact that as the spatial extent of each data unit of population data is altered, the population data attributes change. Often, census data is used for accessibility analyses, which may generalize or mask important population characteristics. Generalized population data has the potential to ignore minority populations that might be the thrust of many accessibility studies. For example, if the boundaries of each census unit were aligned in a manner that isolates mobility-impaired individuals, those individuals might be ignored because of their representational dilution. In politics, this concept is termed gerrymandering. Whether this manipulation technique is intentional or not, using population data has the aforementioned inherent risk. Although effects of this problem cannot be entirely solved, well designed spatial units of disaggregation can help to mitigate errors.

The location of origins and destinations must be chosen carefully so as not to introduce a substantial amount of bias due to varying levels of accessibility across networks (Handy and Niemeier 1997). Defining accessibility with a service area, or area approachable from a central origin within an allotted time or distance, eliminates the bias of assigning destination locations. This bias can be somewhat moderated by performing accessibility analyses from more than one origin which have overlapping service areas.

Subdivisions of Place-Based Accessibility

Place or zone based measures can be subdivided into four major categories: distance, topological, attraction-accessibility and benefits. Distance-based measures, the most basic gauge of accessibility, can be expressed in Euclidean (or geographic), Manhattan or network-based distances. Accessibility measurements based on place necessitate choosing specific destinations and origins (Handy and Niemeier 1997). Origins have commonly been the home and destinations have been workplaces, stores, parks and other facilities. Given a right triangle with the longest side connecting these origin and destination points, the Euclidean distance would be the hypotenuse, while the Manhattan distance would be the sum of the legs or catheti (Miller and Shaw 2001). The Euclidean distance measure ignores any obstacles that might stand in a traveler's way, while the Manhattan distance assumes that the destination can be reached on a grid-like network. Network-based distances go a step beyond Manhattan distances by defining the actual transportation network and summing the lengths of each section along the route. Dykstra's algorithm is a mathematically developed method to calculate the least cost path (the route with the least travel impedance or total cost) between two points. It determines the travel cost associated with every route between the two points and returns the route with the lowest total travel impedance as the answer.

Topological measures examine the connectivity between nodes via links in a network. It expands upon the previously described network-based distance by associating a weight with each link within the network that favors or discourages each link's use. The issue of direction can be looked at within this method by assigning two different weights to each link dependent on the direction of travel. For instance, return trips in the network-based method would require simply switching the origin and the destination. The topologic measure can incorporate features such as one way travel corridors, peak travel times resulting in congestion, elevation changes resulting in varying travel costs and other factors affecting travel time and distance (Weber and Kwan 2002).

The mode of transportation influences the weight that each network link should be assigned. For example, topography influences automobiles less than bicyclists and pedestrians, while one way streets don't affect pedestrians as much as automobiles. Thus, networks should have mode-dependent impedances for each link to be an accurate representation of travel cost (VTPI 2004). In addition, impedance values could be assigned for every user group having differing capabilities, such as visually-impaired pedestrians, hearing-impaired pedestrians, mobility-impaired pedestrians, etc. Modal transfers introduce yet another complexity due to waiting for, entering and exiting transit, not to mention transit delays (Miller 2005).

A service area defines the accessible spatial extent from an origin along network links, making it a topological measure of accessibility. The Effective Walking Area (EWA) mentioned in Table 1 uses the idea of a service area in its formula (number of parcels accessible by walking a quarter mile from the origin divided by the total number of parcels within a quarter mile of the origin). The EWA has a coarse resolution because it doesn't represent actual accessible service area, but accessible parcels. Service areas are discussed in more detail later.

Attraction

Attraction-based measurements, also called gravity-based measures, predict trip distribution based on the perceived and real value of each destination (Handy and Clifton 2001). The attraction that destinations have to individuals differs with each destination's capacity, square footage, age, variety of goods, and familiarity and convenience to users. A destination is assumed to have an inverse relationship between its utility and individual's distance to it. Just as a large planet has a greater pull on surrounding objects than smaller planets, large, complex facilities have the tendency to attract users from far away. The attraction method can be subdivided into additive measures, which show all accessible destinations or maxitive measures which show the preferred destination (Berglund 2001; Hanson 1995). Miller (2005) uses the Weibull framework to transform this measure into the benefit measure.

Relative Access

Relative access can show the difference in how accessible activities are to a disabled person compared with an ambulatory person. Church and Marston (2003) have shown that this ratio could be applied to many accessibility measures to display disparities in accessibility between pedestrians with various physical abilities. Relative accessibility (RA) is calculated by simply dividing the area of the mobility-impaired pedestrian service area by the area of the ambulatory pedestrian area (see Figure 2). A RA value of one indicates that any barrier would equally impede both groups of pedestrians. The RA value of one represents the ideal of equality that the aforementioned legislation has been attempting to achieve.

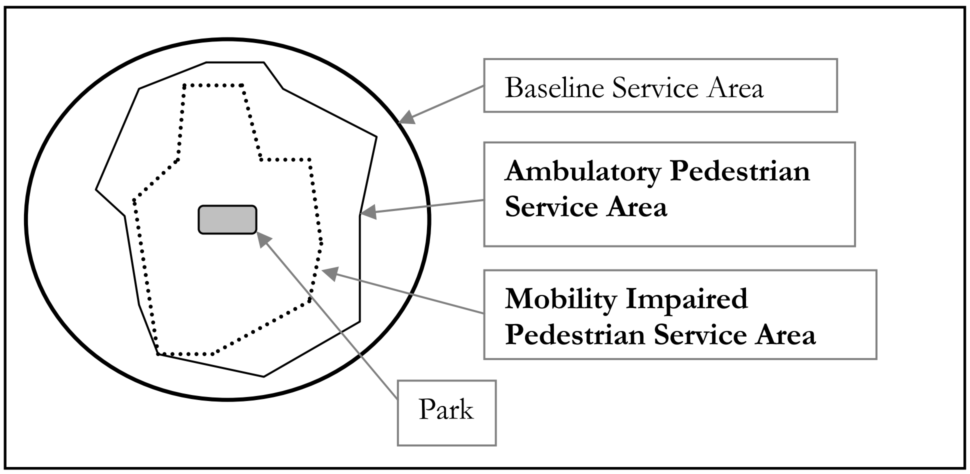

Figure 2: Relative Accessibility Measurement Components (noted in bold text) Source: Author

Proposed Access Measurement: PSI

The concept of the Patch Shape Index (PSI) as mentioned by Forman (1986) was used to measure another "equity" aspect of accessibility. The PSI is a measure of how close to circular the patch is as it radiates from a specified center origin (see Figure 3). The maximum PSI index value is one, which indicates the absence of barriers. In other words, there are no impedances when traveling away from the origin. However, traditional street grid layouts change this ideal accessibility number due to constraints on any surface transportation. Routes of travel through a grid, along the x and y axes, are evaluated through the concept of the

Manhattan measure of accessibility, as stated earlier. The ideal shape of a service area based on a single origin point is a diamond centered on the origin. Neighborhoods that have curvilinear streets and cul-de-sacs produce a variety of service area shapes.

The PSI can be calculated for service areas to measure the equality of pedestrian facilities surrounding an origin (Forman 1986). Described in Equation 3, the PSI has the following variables: D is the index of the patch shape; P is the perimeter of the patch; and A is the area of the patch.

$$D = \frac{P}{2\sqrt{A\pi}}$$

Equation 3: Patch Shape Index. Source: Forman 1986

PSI is a good measure of how close to circular (the shape with the most area per perimeter) a polygon is (see Figure 3). This metric needs some modification in the case of multiple origins contributing to a cumulative service area. For instance, a service area originating from two offset points having optimal accessibility would appear as two overlapping circles. The PSI value for this service area would indicate that it does not have the best possible accessibility because it is not a perfect circle. Therefore a PSI value which has been normalized, here referred to as the NPSI, would be of greater value.

The normalization of the PSI was performed by dividing the PSI value of the combined service areas from all related origins by the PSI value of the optimal combined service areas from the same origins. This is symbolized by Equation 6 in the Methodology chapter. Although slightly less accurate, the NPSI could be calculated by using the result of a buffer of the polygon of interest.

Nodal Access

Taaffe and Gauthier (1973) describe one measurement of nodal accessibility called the degree of a node which is measured by how many links a node is connected to. It should be noted that this simple measurement does not take into account the quality of each of those links. They also describe matrix multiplication that shows how to define accessibility between nodes through multiple routes. The Accessibility Matrix or T matrix sums up the linkages between nodes to find which node is most accessible. A distance decay relationship (the more linkages you use to get to your destination, the less accessible it is) is introduced through the use of a scalar. The multiplication procedures described above as well as the shortest path matrix (removes

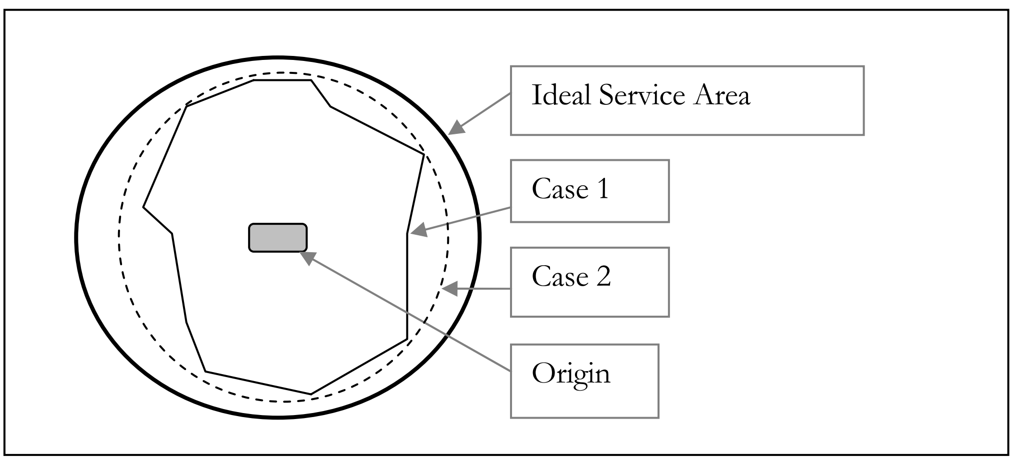

Figure 3: Patch Shape Index Measurement Components Source: Author

redundancies) are only concerned with the number of linkages. Shimbel pioneered the shortest path matrix concept in 1953. Valued graphs define network accessibility by taking into account the cost of travel between nodes (i.e. distance and time). Taaffe and Gauthier (1973) hints towards accessibility being strongly linked to the density of nodes.

Individual or People Based Accessibility

Individual or people based accessibility measurements are highly specific, containing time and distance constraints which zone-based measures ignore (Berglund 2001; Wu 2001; Weber and Kwan 2002; Miller 2005). This method uses individual temporal and spatial locations to construct an index of accessibility to destinations. It treats time as invaluable by looking at not only convenient distances to travel to a destination, but also the possibility of visiting those destinations in spite of time constraints.

This high degree of specificity is difficult to represent in a meaningful way without aggregating the results for individuals, thus reducing the value of the measurement. Berglund (2001) suggests merging two components of the individual based measure: mandatory travel patterns and detailed population data, into zone-based measures.

Berglund's path-based accessibility is targeted at measuring accessibility to places that aren't an individual's primary destination (work or home). In other words, path-based accessibility measures the ease of access for a secondary destination between trip origin and destination. Miller (2005) takes into account destinations which must happen in a specific location (fixed activity) or in a number of locations (flexible activities). These activities constrain other destinations by spatially and temporally limiting the individual. Paths and stations plotted spatially and temporally illustrate well the relationship between geographic space and temporal space (see Figure 4).

Weber and Kwan (2002) don't use individuals' time and location schedules in the same manner as previously described. Instead they measure congestion on transportation networks and use this data to more accurately represent conditions affecting travel time. Integration of the effects of congestion overcomes one weakness with traditional space-time geography (Miller 2005).

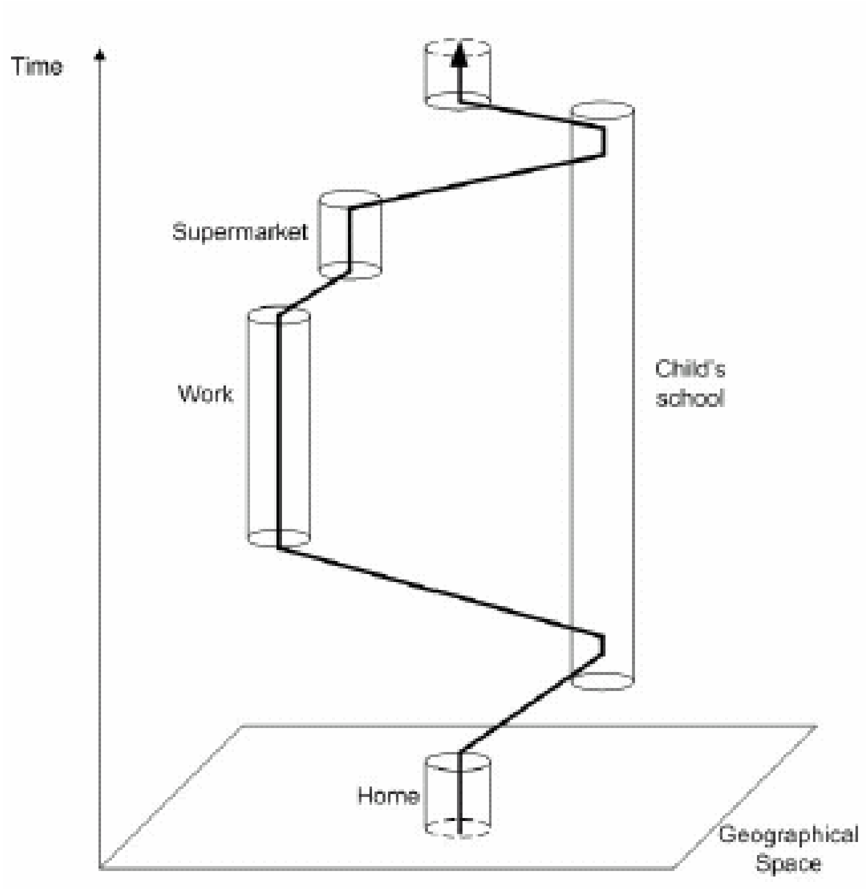

Figure 4: Individual's spatial and temporal locations. Source: Miller 2005

The problems associated with individual based measures of accessibility include the large amounts of data that are needed. Travel time data, congestion data, and individuals' spatial and temporal locations can all combine to make a huge amount of data. This output data must be aggregated in order to make any reasonable conclusion. Privacy of the individual is another challenge with this method (Miller 2005; Omer 2006). These problems dissuade usage of individual based measures for areas where this data or funds to obtain it are not available.

One figure that measures the ability of an area to accommodate pedestrians is their level of service (LOS). The level of service concept comes from automobile planning as early as 1965 and illustrated in the Highway Capacity Manual (Landis 2001). Fruin's (1971) application of the concept to pedestrians is focused on capacities, leaving out many of the elements that later researchers include, such as safety, security, continuity, system coherence and attractiveness (Sarkar 1993). Muraleetharan (2004) proposed an overall LOS by including capacity, convenience and conflictive measurements. These include measurements of width and separation, measurements of obstructions, measurements of flow rate, measurements of the number of passing bicycles and opposing events, measurements of space at corner, measurements of crossing facilities, measurements of turning vehicles and measurements of delay at road crossings. Muraleetharan's (2004) overall LOS demands a very time and resource intensive study of each individual sidewalk, which would be suitable for areas which have high levels of pedestrian usage. However, the value of this approach in low-density areas would probably be low due to increased cost per pedestrian.

Space syntax, developed by Hillier, Hanson and others, analyzes the relationship between humans and space using graphs (Bafna 2003). Similar to graph theory, individual spaces and their connections to each other are abstracted to a set of links and nodes. The convex space partitioning method involves dividing a continuous space, such as inside a building or within a landscape, into discrete units which are simplified to nodes, with links representing access between nodes (Bafna 2003). The linear or axial map produced by defining the longest sightlines could identify routes with the fewest possible turns. Given that accessibility is dependent upon distance and perceived distance is based upon the number of turns, this map has potentially useful information for accessibility studies (Gehl 1987; Berglund 2001; Bafna 2003).

Network Analyst and Representation of Least Cost Path and Service Areas

The software used for this study is the Network Analyst extension for ArcGIS 9.1 developed by Environmental Systems Research Institute (ESRI 2006). This software can manage both directed (i.e. water lines, gas lines, etc) and undirected (i.e. pedestrian travel, transportation, migration patterns, etc) flow systems. Network Analyst allows for the creation and analysis of a system of links (also called edges), nodes (also called junctions) and turns. This combination of points and lines allows the modeling of the movement of goods or organisms through its extent. The cost of travel or impedance, represented by distance or travel time, plays a major role in network modeling. One feature of the network that is important in symbolizing impedance is the turn.

Turns represent which links are accessible from their neighboring links, showing where movements such as u-turns and right or left turns can or cannot take place. An impedance value can be assigned to make the turn either an absolute barrier (i.e. no right turns) or a temporary barrier (stoplight). The turn's impedance value can be adjusted to correspond to the cost of travel. For instance, a road crossing with a pedestrian activated signal might have a lower impedance value than a stoplight with those signals. Turns can also be used to prohibit the use of specific network links.

The output from the Network Analyst software that is of interest in this study is the service area and the least cost path. In a service area analysis, a limit is set on the amount of travel that can take place. For instance, a 10 minute service area for a network location defines the area that can be reached in 10 minutes from that point (ESRI 2006). The least cost path involves defining a route for which the travel cost (time or distance) is the lowest. It can also be seen as the service area concept in a linear form.

Service areas can be used to evaluate the spatial extent of users locations relative to specific facilities. For instance, utility companies might use service areas to group customers into units for maintenance and billing. The focus can also be shifted from the origin to the network and its performance, which is what happened in this study. The creation of service areas and least cost paths proposed above should be used to show areas of poor and satisfactory performance. The least cost path concept can also be used to more accurately find gaps in accessibility.

Due to various barriers and lack of facilities a pedestrian service area with the maximum possible area is more often the exception in the built environment today. Defined by a circle, the ideal service area indicates an absence of barriers impeding travel within the potential service area boundary. Landscape ecologists have used the Patch Shape Index (mentioned earlier) to measure the circularity of a patch or area of interest. Here, PSI will be used to describe accessibility.

Service areas and least cost paths for pedestrians could be broken into many categories: ambulatory, visually impaired, mobility impaired, etc. The service area for an ambulatory pedestrian would be larger than for the other groups on a couple of conditions. The least cost path would similarly be shorter for ambulatory pedestrians than mobility-impaired pedestrians. The extent to which pedestrian facilities accommodate disabled pedestrians plays a role in the reduction of their service area size. In general, disabled pedestrians travel more slowly which also reduces their service area if it is based upon travel time and not distance (Otak 1997). Church and Marston (2003) compare the disparity between ambulatory and disabled persons' service areas using the concept of relative accessibility. Relative accessibility is an important tool in highlighting the inequalities in mobility caused by the built environment between pedestrians with varying mobility levels.

GIS Applications of Pedestrian Modeling

There are at least two examples of the use of GIS in pedestrian routing. Both of these applications are aimed at enabling mobility-impaired pedestrians to navigate their environment with a foreknowledge of potential barriers. Modeling Access with GIS in Urban Systems (MAGUS) is a versatile tool due to the ability to use gradated mobility levels (Beale, Matthews et al. 2003). One of three wheelchair types (manual self-propelled, manual assisted and powered) is chosen as the basis for determining the route. If one of the two manual types is chosen, the software prompts the user for a fitness level. Two output options are available: a single route or a service area. The versatility of MAGUS is somewhat curtailed by the fact that it is available only to those who have access to ESRI's proprietary ArcView GIS software.

The second example of a pedestrian routing software does not have this limitation as the data is served over the internet with scalable vector graphics. The data, queried by Java2 and made available to the internet, is stored and maintained within ESRI's geodatabase format. Similar to MAGUS, U-Access has different levels of mobility (three) that can be selected to create ability dependent routes. U-Access takes advantage of new technologies to make pedestrian related data available to a greater number of people than MAGUS.

Both of these pedestrian modeling tools are intended to guide pedestrians around obstacles in their environment. The aim of this thesis is not to create individualized routes, but to aid in the locating and prioritizing barriers that should be removed to give access to the greatest number of pedestrians possible. We have not seen GIS used to study pedestrian access using the combination of described methods before.

Parks and Open Space

Open space is an important asset to a community. Whether public or private, these spaces are characterized by areas of interaction as well as meditation. They can come in many different forms such as parks, greenbelts, streets or nature preserves (Thompson 2002). Streets are available to nearly everyone, although not necessarily accessible. Nature preserves, and perhaps greenbelts, could be considered regional facilities serving many and requiring travel distances that are not convenient for pedestrians. In this study, the traditional city park, characterized by amenities such as a green lawn, many trees, picnic facilities and playgrounds, was the destination analyzed for accessibility because of their local neighborhood locations.

Thompson (2002) claims that those who need to use public parks the most are those who usually don't have access to vehicles—children, unemployed people, disabled people and older people. Perhaps this is the reason that Calthorpe (1993) suggests having a 1-2 acre park accessible to a two-block radius. In any case, pedestrian access to parks determines their success in how well they serve the community and, more specifically, those who have a decreased mobility level.

All users can benefit from park services that range from active to passive activities. Benefits can be divided into four categories: public health, economic, environmental and social (Sherer 2006). Public health benefits from parks are derived by providing places for physical activity and contact with nature. Parks can financially benefit communities by increasing tourism, increase property values and raise quality of life levels. Pollution reduction, cooling through vegetation, and storm water runoff mitigation make up some of the ecologic advantages of parks (Sutton 1971; Samuels SE 2004). Social benefits from parks consist of crime reduction, recreation opportunities, and increased social capital (Putnam 2000; Farley 2005).

The value of parks is often overlooked as shown by budget cuts of departments that maintain parks (Sherer 2006). Funding spent on parks may not provide immediate benefits similar to transportation or utilities; however they have the potential to help communities grow in a healthy manner. Parks within walking distance of residents can reduce automotive dependence and increase physical activity. The Comprehensive Plan for the City of Spokane, Washington singles out pedestrians and bicyclists as those who should be provided access to parks.

Summary

Maslow (1943) suggested that humans have a hierarchy of needs, including physiological, safety, love, esteem and self-actualization. He suggests that one level of needs must be filled in order to satisfy the need above it. A similar concept could be applied to pedestrians. An example of a pedestrian hierarchy might be: a place to walk, an appropriate travel surface, convenient routes, and attractive surroundings. As levels in this hierarchy are completed, different types of pedestrians are attracted to it. For individuals who don't have other transportation options besides pedestrianism, these hierarchy levels aren't as important as other individuals. Ironically, the frequent pedestrians are the ones who would benefit the most from higher levels on the pedestrian facility hierarchy. The focus of this study is on the basic pedestrian need of accessibility and will not extend to attributes such as path surroundings.

Many factors contribute to a neighborhood's walkability, some of them are difficult to measure due to their subjectivity. The components of walkability included in this study are path continuity and pedestrian facility quality because they are the most objective among those mentioned earlier. Path continuity refers to the how well connected the pedestrian network is.

Pedestrian facility quality should be measured through factors including surface condition, path width, height discontinuities and curb ramp conditions.

The people-based measure of accessibility has many challenges and complexities, such as obtaining individual time schedules. Highly individualized results from this type of measure make its value to large numbers of people marginal. The purpose of this study is evaluating the accessibility of parks or fixed locations, making the place-based measure method the appropriate measure of accessibility here.

Within the boundary of the place-based method, the topological measure should be used on the pedestrian pathway network due to its flexibility with traveler's abilities. The attraction-based measure doesn't appear to be relevant to this study due to the limited number of explicit destinations available as covered by the chosen dataset's spatial extent.

Travel time, not travel distance, should be used in the determination of service areas due to the highly variable level of mobility among physically challenged pedestrians. For instance, an individual operating a motorized wheelchair might have greater mobility than an individual in a self-propelled wheelchair or an individual with an assistive walking device for ascending steep slopes. The use of travel time enables gradated impedances that aren't available with distance-based impedances. Features considered obstacles for pedestrians could be categorized as either relative or absolute barriers, and then given an impedance value. For example, a path having a cross slope pitch of 1:45 (rise:run) doesn't meet the ADA standard, yet should not be considered as impassable. Travel impedance might be assigned to that section of path that makes it slower to travel on than an ADA compliant section.

Attention should be given to the general type of street connectivity by selecting parks surrounded by both grid-like street configurations as well as curvilinear street and cul-de-sac neighborhoods. This will help to illustrate pedestrian connectivity surrounding the different parks. Suggestions for improvements to the pedestrian infrastructure can then be made for enhancing accessibility to the parks.

Space syntax has the potential to be integrated in accessibility measures, but the amount and detail of data as well as a lack of software capable of performing spatial syntax operations make it unattractive in this analysis.

CHAPTER 3 – STUDY AREA

Sites

To provide some depth to this study, three parks were evaluated for their accessibility to nearby residents. These include Audubon Park, Friendship Park and Comstock Park, all of which are located within the City of Spokane, Washington. The variety of surrounding street networks presented by these parks made them good choices in this study. Land development and the resulting transportation networks play a major role in the accessibility of any destination. Key attributes of each park are summarized in Table 2.

Table 2: Attributes of Spokane Parks Involved in Study; Traffic Count Source: (CMC 2004); Park Size Source: (Spokane Parks and Recreation Department 1997)

Park	Surrounding Street Pattern	Size (acres)	Nearest Arterial Road Vehicle Count/Speed Limit	Perimeter Pathway
Audubon	Rectilinear Grid	26.57	14,000/30	Limited
Comstock	Rectilinear Grid and Fragmented Grid/Warped Parallel	24.75	9,100/30	Partial
Friendship	Fragmented Grid/Warped Parallel	12.00	4,900/30	Complete

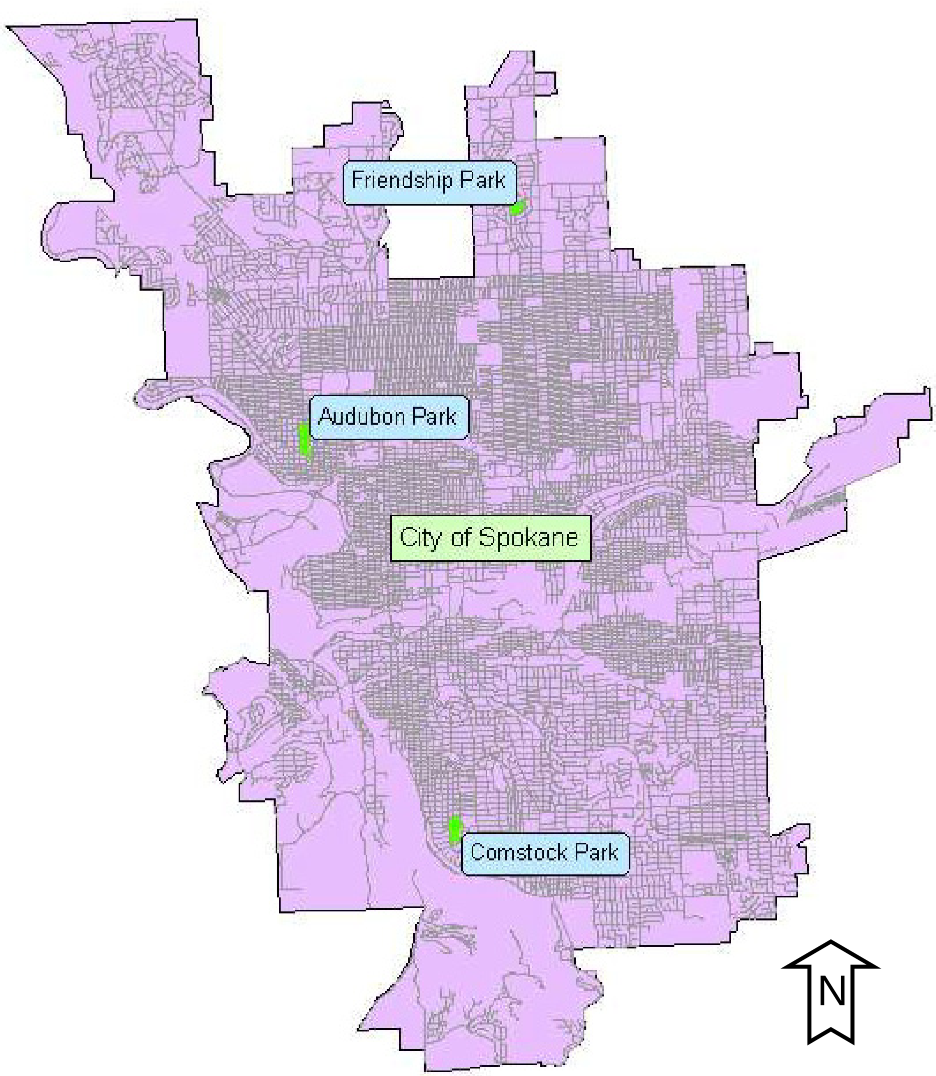

Figure 5: Locator Map for Parks to be Analyzed. Source: Author

Audubon Park

Audubon Park is located in the northwest portion of the city within a grid-like street pattern. The only streets that aren't aligned in a north/south orientation are Northwest Boulevard and

Driscoll Boulevard, which run in a northwest/southeast direction. Handy (2003) and others would suggest that the orthogonal type of nearby street network would offer greater accessibility. The two diagonal streets placed in the grid should add to the accessibility of Audubon Park.

Attractive facilities within the 26.57-acre park include playground equipment, bocce ball court, restrooms, many Ponderosa pine trees, a manicured lawn, shade, benches, tables and a stone hearth (Spokane Parks and Recreation Department 1997). Finch Elementary School is located adjacent to the park with no street separating the park property from the school property. The lack of a significant boundary between the two makes the park spatially accessible. The lack of a formal (ADA accessible) perimeter path around the park contributing to access between the two areas forces mobility impaired individuals to use the street, often congested with parked cars, or contend with the friction of travel on the grass.

This park has much to offer those who are primarily pedestrians (children, older individuals and the economically disadvantaged). The area surrounding the park is primarily residential and doesn't have any major barriers to impede access, such as rivers, steep terrain or highways. The importance of constructing a formal perimeter might increase if park access from the surrounding neighborhood was found to be high.

Friendship Park

Friendship Park (12-acres) is located within a neighborhood of curvilinear streets and cul-de sacs in northern Spokane (Spokane Parks and Recreation Department 1997). The nearby residences and their accompanying yards are more spacious than those found near Audubon Park. These facts help show the age of the neighborhood. Similar to Audubon Park, there are no major natural features that would prevent access to the park from any direction. The bounding street that receives the most traffic is Standard St., a road with two travel lanes, two parking lanes and a speed limit of 30 miles per hour. The average weekday vehicle count on this road was 4,900 in 2003-2004. This is in contrast to the 14,000 vehicles that pass by Audubon Park on Northwest Boulevard, which has four travel lanes and a speed limit of 30 miles per hour (CMC 2004).

The asphalt path that contains a large portion of the park is a favorable place for visitors to keep track of their walking distance. The curb ramps that are located at street intersections provide excellent access to the perimeter path, making the park well designed for pedestrians of a variety of skill levels. Other amenities to the park include playing fields, tennis and basketball courts, playground equipment, restrooms, benches and tables.

Comstock Park

The third park (Comstock Park) was chosen mainly for two vastly different nearby street patterns, described by Southworth and Ben-Joseph (1996) as the "interconnected rectilinear grid" and the "fragmented grid and warped parallel streets" (p. 2) The boundary between these two types of street patterns is also the busiest road adjacent to the park: Twenty-Ninth Street. It is composed of two travel lanes, one center turn lane and two parking lanes. Twenty-Ninth Street may decrease the effect of the supposed high level of accessibility of the grid-like street pattern on the accessibility measurement for the park.

The list of amenities for Comstock Park is very similar to that of Audubon Park except the inclusion of a swimming pool. Community swimming pools seem to be very attractive to nearby residents in the summer, especially those who don't have access to private swimming pools. Comstock Park (24.75 acres) is slightly smaller than Audubon Park (26.57 acres) and has a perimeter pedestrian path around the majority of the park (Spokane Parks and Recreation Department 1997). This path should make Comstock Park more accessible than Audubon Park.

The combined study of these three parks provides an introductory view into the degree of accessibility of parks within Spokane. The Spokane Parks and Recreation Department manages a total of 95 pieces of property, so three of them is quite a small representative sample. All of these properties could be analyzed for their accessibility measure once the LIFTS dataset is complete.

Comprehensive Plan for the City of Spokane: Parks and Pedestrians

The Comprehensive Plan for the City of Spokane, Washington provides some goals regarding pedestrians and their access to parks. Actual park area calculated per resident will be contrasted with researchers' suggestions on the amount of parkland per resident to give a rough estimate on how well the city is achieving these goals and suggestions.

The area of parks and open space should be large enough to serve residents. Calthorpe (1993) has suggested that an average of 3.5 acres of park area be provided for every 1,000 residents. Kelly and Becker (2000) base their suggestion of open space not on the number of residents, but on a percentage of developed land (5-8 percent of the developed land should be open space). The goal for the long term level of service defined in Spokane's Comprehensive Plan for neighborhood parks is 1.17 acres for every 1000 persons. Additionally, community parks should have 1.49 acres for every 1000 persons and major parks should have 2.59 acres for every 1,000 persons. Spokane has 2960 acres invested in 92 park and open space properties (excluding trails), so with a population of 198,700 (in 2004), there are 15 acres of park space for every 1,000 residents (Spokane Parks and Recreation Department 1997). This may exceed the above goal and recommendations; however much of this park area isn't reasonably accessible to pedestrians. The methods described here can be used to find out the degree of accessibility to Spokane parks from nearby residents.

Many sections in Spokane's Comprehensive Plan (Spokane Planning Services Department 2005) mention the desire to have pedestrian facilities provide an alternative transportation mode. Chapter 3, Land Use, indicates that buildings should be oriented to the street to serve the pedestrian better; block lengths should be 250 – 350 feet, and school sites that are accessible to neighborhood pedestrians. Chapter 3 also states that streets "should be generally laid out in a grid pattern that allows easy access within the neighborhood" (p. 10). Chapter 12, Parks, mentions providing "a convenient and pleasant open space-related network for pedestrian and bicyclist circulation throughout the City of Spokane" (p. 11).

The Transportation section of the Comprehensive Plan for the City of Spokane (2005) sets the goal of developing "safe pedestrian access to city parks from surrounding neighborhoods . . . The city shall analyze the existing safety of pedestrian access within a quarter mile walking distance of each park. Based on that analysis city departments shall implement projects that improve the pedestrian circulation safety" (p. 30). This chapter also discusses the need for well maintained and designed pedestrian facilities.

Another City department that has an interest in pedestrian accessibility is the Parks and Recreation Department. Their 20/20 Strategic Plan (2006) has this mission statement, "Provide convenient access to public lands for the purpose of enjoyable, affordable, and safe recreation" (p.1). The mode of transportation providing access is not mentioned; however pedestrian access can be labeled as convenient due to its low cost and flexibility.

The Comprehensive Plan doesn't specify how to improve pedestrian safety near parks. Improvements could focus on infrastructure, public education of both driver and pedestrian, law enforcement, or encouraging walking programs such as walking school buses (Kearns, Collins et al. 2003). This thesis focused on infrastructure analysis, which could be used to plan for facility improvements. Although safety is important, it is a potential by-product of improved accessibility and wasn't directly dealt with here.

CHAPTER 4 – METHODOLOGY

Introduction

The objective of this thesis is to measure the accessibility of parks in the City of Spokane for pedestrians with mobility impairments as well as ambulatory pedestrians. The saying "when performance is measured, performance improves" is very applicable here. Through the measurement of pedestrians' access to parks, policies can be put in place which provide better pedestrian facilities surrounding parks and other important destinations. This will assist those individuals that rely heavily on pedestrianism, as well as recreational pedestrians, to have a safer, more comfortable experience.

This section describes the methods used in assigning four different accessibility measurements to three different parks within the City of Spokane. Two of these metrics use a concept called relative or comparative accessibility, which compares the ideal accessibility with accessibility for a target group (mobility-impaired pedestrians in this study). The mobility-impaired accessibility measurement is also compared with the accessibility measurement of ambulatory pedestrians. The third metric simply analyzes the shape of the accessible area, while the fourth compares the statistics of routes leading out from the park.

The characteristics of a network with ideal accessibility include travel corridors with sufficient width, hard flat travel surfaces, no abrupt height changes, and convenient road crossing facilities. In this network, a pedestrian could travel 3 mph along any given link, with the exception of waiting for traffic at road crossings. Potential travel corridors on which pedestrians are prohibited constitute the major difference between ideal and ambulatory pedestrian accessibility measurements. Another difference is the hindering effect of traveling on surfaces other than concrete or asphalt, which reduces accessibility.

Mobility-impaired pedestrians commonly have an increased number of features that inhibit access to their destinations. Many characteristics of the pedestrian environment that go unnoticed by ambulatory individuals inhibit or even prohibit mobility-impaired individuals. A comparison of accessibility measurements for both of them reveals inequalities in the world of pedestrianism.

Accessibility measurements for pedestrians are valuable for funding decisions, design and construction priorities and targets for retrofits. One reason these metrics have not been made often is due to the lack of pedestrian-level data. This type of data has been collected, as described below, and was used to accurately portray pedestrian conditions relating to park access.

Input Data

The Spokane Transit Authority (STA) obtained federal funding through the Job Access and Reverse Commute (JARC) grant in 2005. This funding has been used to obtain spatial data regarding the pedestrian environment in the City of Spokane through the LIFTS (Lifeplan Improvement through Feasible Transportation Services) project. This small-scale dataset was used within this project to provide detailed information about pedestrian facilities (such as curb ramps, marked road crossings and surface height changes along sidewalks) in the vicinity of the chosen parks. This study follows the example set by the research of Omer (2006) who used datasets with a fine resolution to evaluate accessibility. That use of both socio-demographic data (not used here) and high resolution infrastructure resulted in a very detailed analysis of accessibility.

The attributes within the LIFTS dataset are set up to facilitate the creation of a network showing pedestrian facilities that are ADA or non-ADA compliant. These attributes were used to calculate service areas around three local Spokane parks, described previously, for both mobility impaired and ambulatory pedestrians.

Among the many datasets that were used in this study, these three compose the data input foundation: the pedestrian path dataset, the park polygon dataset and the point dataset containing barriers and curb ramps. The park polygon dataset was created by the City of Spokane in 2001 and was used mainly as a reference in defining study boundaries and origins. The creation of the other two datasets are described below.

Pedestrian Right-of-Way Dataset Creation

The pedestrian path dataset was created from the existing road centerline dataset (see Figure 6) and represents both the presence and absence of pedestrian facilities on both sides of the street. The value of using the road centerline data from the county is that attributes such as road name, road type and address ranges were transferred to the pathway network dataset. These centerlines were offset a distance eighteen feet in either direction in order to provide the approximate location of the adjacent sidewalks or formal pedestrian paths. Eighteen feet was chosen because it is half the width (thirty-six feet) of a typical street in Spokane.

Various methods were employed within ArcGIS and ArcINFO (products of Environmental Systems Research Institute (ESRI)) to create correct topologic relationships within the resultant pedestrian path dataset. In other words, the lines representing pedestrian rights-of-way were made to connect to each other only at their endpoints. Operations such as clean, trim and snap were used to make this dataset be useable within ESRI's Network Analyst.

The Offstreet (OS) dataset, developed for the City of Spokane, represents built surfaces such as driveways, sidewalks, patios, pedestrian bridges and others. It seems to have been developed from the grayscale orthophoto of Spokane created in approximately 1993. The features labeled as sidewalks were extracted from the dataset and used to align the pedestrian rights-of-way created from the road centerlines. This was done automatically using ArcGIS, and produced mixed results as displayed in Figure 7. The image on the left shows a positive example of the automated line moving process as the pedestrian rights-of-way were moved from their original location shown in orange to their new location displayed in red. The orthophoto in the background verifies that the majority of the lines are correctly aligned. On wide streets with complicated intersections, results were not as positive, as seen in the image on the right. Although this process did not move all the right-of way lines to the correct location, it was helpful to have a good portion of them aligned accurately.

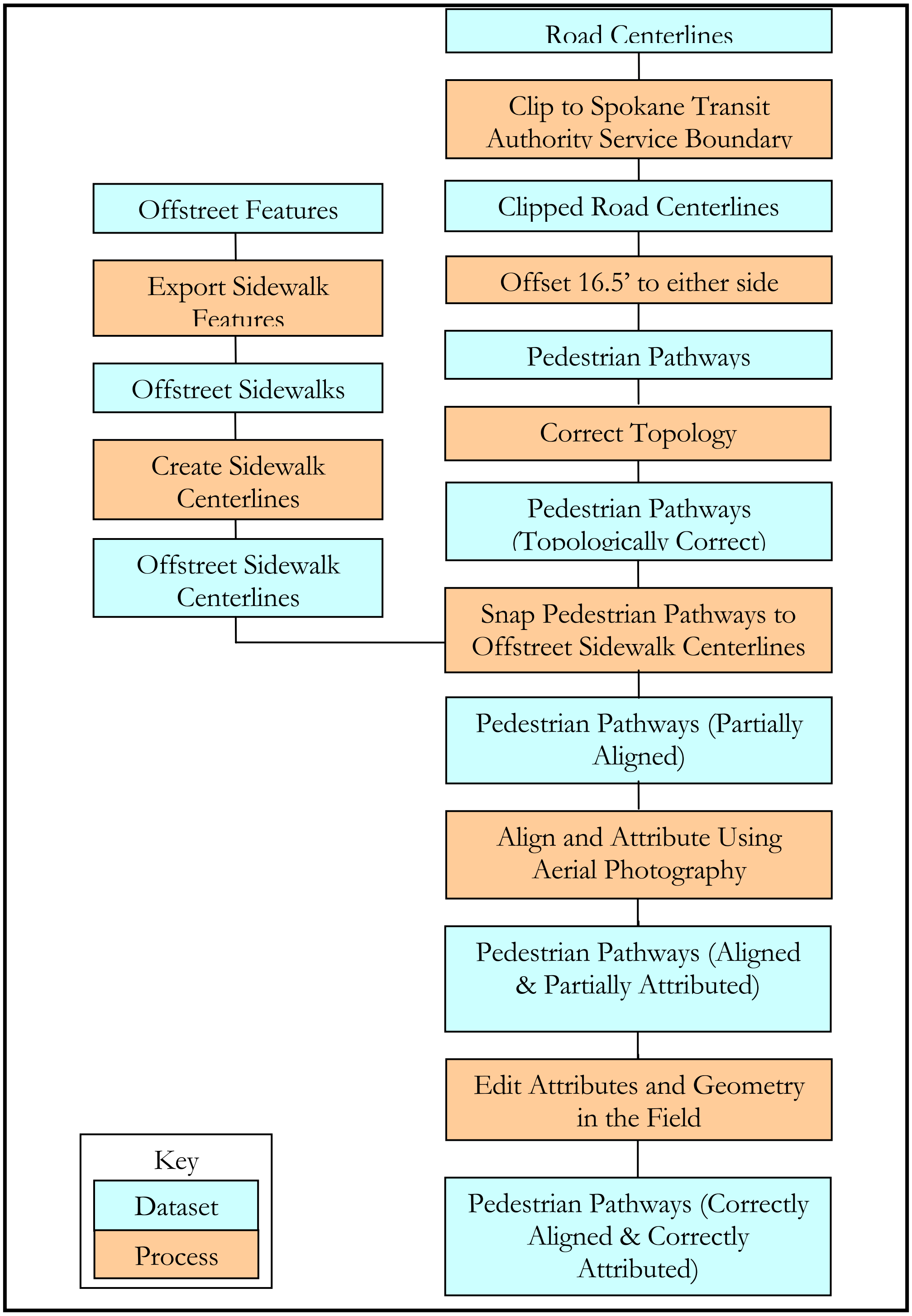

Figure 6: Creation of the Pedestrian Path Dataset. Source: Author

The right-of-way lines were edited in order to align them along the center of formal pedestrian paths as defined by the aforementioned orthophoto of Spokane. Further edits were performed in the field where changes to pedestrian facilities had been made after the orthophoto was produced. The orthophoto, and later color aerial photos, were used to record the locations of formal pedestrian paths, road crossings and driveway or alley crossings. Areas that lack

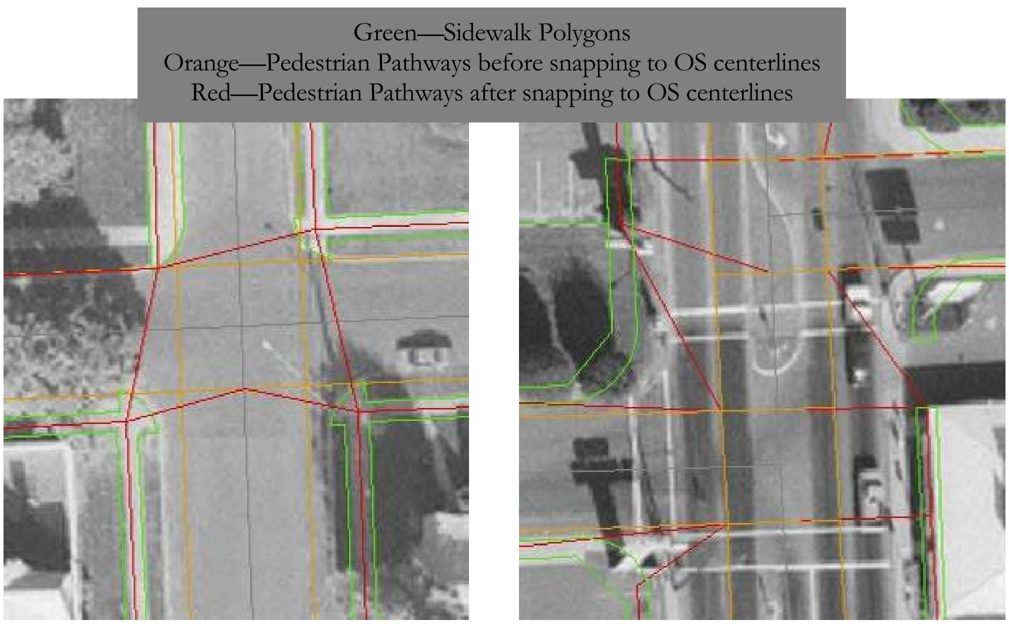

Figure 7: Mixed Results of Snapping Pedestrian Pathways to OS Centerlines; Desired Result on Left, Undesired Effects on Right. Source: Author

formal pedestrian paths were noted, but little attempt was made to record the surface type of those areas. For example, a pedestrian right-of-way that is obstructed by various landscaping elements in a yard might have a surface type of grass. This is in response to the purpose of the

LIFTS project, which is mapping accessibility for the physically disabled who need a flat, hard surface for mobility needs.

Point Barrier/Curb Ramp Dataset Creation

The second dataset that was used in this study is the point barrier/curb ramp dataset. This dataset was created by recording the locations of features that could serve as barriers or facilitators to mobility-impaired pedestrians. Examples of included features are mailboxes, utility poles, street signs, planters and other objects. If any object has been placed in such a way as to reduce the pedestrian travel corridor to less than 36" or less than 32" for a running length greater than 24", it is considered a barrier.

Other features which were recorded include those which changed the surface height of the pathway abruptly. This situation could occur where tree roots have pushed a section of the sidewalk up or where soil has settled and caused elevation discontinuities. In the downtown area, storm sewer grates, steam vents and freight elevators at ground level can cause obstacles to pedestrians using mobility aids.

This point dataset also contains curb ramps. Characteristics of the curb ramps such as running slope, cross slope, ramp type, presence/absence of landing at the top of the ramp and presence of abrupt height changes at the top or bottom of the ramp were noted. These characteristics have been divided into two categories: ADA and non-ADA compliant (Access-Board 2005).

For convenience within Network Analyst, the presence of both ADA and non-ADA compliant curb ramps were transferred to the road crossing features within the pedestrian right-of-way dataset. The presence of any barrier as described above was put into the linear features of the network in order to model a relative, not absolute, barrier. This was done to overcome the limitation of the Network Analyst software to handle barriers with relative impedances.

Impedance

The term impedance is used here to describe the cost of movement. In a free flowing network the only impedance involved is described by the simple friction of distance concept; length multiplied by travel rate (see Table 3). Network features which allow free flow were assigned a value of 1, which multiplied by the travel rate, does not affect travel time. To be consistent, all features within the network were assigned an impedance value.

The cost of travel is altered by two types of barriers: relative and absolute. A relative barrier causes a decrease in the rate of travel, yet still allows movement. For instance, a narrow sidewalk might not halt movement along its length but it does slow it down. Impedance for relative barriers are calculated by multiplying rate by a feature specific impedance factor, then multiplying that by the feaure's length (Table 3). The impedance factors reflecting relative barriers are ordinal, ranging from 2 to 5 with 2 providing the least resistance and 5 the most resistance. This method follows the suitability tradition used often in GIS analysis.

The lack of a sidewalk or curb ramp serves as an absolute barrier to mobility-impaired pedestrians because they disallow passage. Absolute barriers are calculated by multiplying the network link's length by the quantity of the maximum impedance factor multiplied by travel rate (Table 3). The maximum impedance factor used in this study is 99, which discourages a feature's inclusion in Network Analyst's calculation of shortest paths.

Information on impedance factors or values for each type of network feature can be found in the next section and in Appendix A.

Table 3: Impedance Calculation Summary. Source: Author

Free Flowing (No Impedance)	I = Length x (Rate x 1)
Relative Barrier	I = Length x (Rate x Impedance Factor)
Absolute Barrier	I = Length x (Rate x Max. Impedance Factor)

This study used time as the travel cost because it has the potential to reflect more accurately travel costs. The rate of travel can be estimated for different surfaces and other circumstances, multiplied by the actual route length resulting in a somewhat precise value of travel cost expressed as travel time. Impedance values for many surface types were taken from the MAGUS project (Modeling Access with GIS in Urban Systems) in Northamptonshire, England (Beale 2001). Impedance values for other feature attributes were inferred from the MAGUS project.

These impedance values were based on characteristics observed during field editing of the LIFTS project data, discussed above. The only feature that was considered an absolute barrier for both ambulatory and mobility-impaired pedestrians is any potential pedestrian right-of-way on which pedestrians are prohibited. Road crossings are perhaps the most common areas of prohibited pedestrian travel, yet there are certainly others.

Relative and Absolute Barriers

The list of absolute barriers for the mobility-impaired includes abrupt changes in the height of the path surface and inadequate travel corridor widths. There are two different height changes defined within the attributes of the LIFTS project datasets. The absence of a curb ramp at an intersection denotes a height change equal to the height of the curb, which can range from 1 to 10 inches. This situation is represented in the pedestrian right-of-way dataset, also referred to as the pedestrian path dataset. The other group of height changes includes discontinuous sidewalk sections and lips at the bottom of curb ramps or the sides of alleys and driveways. A path with multiple ½ inch or greater height changes is detailed in the pedestrian path dataset. Isolated incidences of ½ inch height changes are shown in the barrier/opportunity dataset as points, for positional accuracy.

Sections of the travel corridor which are too narrow to pass through serve as absolute barriers to pedestrians using assistive devices such as wheelchairs and walkers. Pedestrian routes can be narrowed by poor placement of utility poles, signs, fire hydrants and other objects.

These objects were accounted for in the pedestrian data model by assigning adjacent lines impedance values which correspond to the way barriers inhibit movement. For instance, a height discontinuity in a sidewalk was recorded in the same way as multiple height discontinuities, with an attribute value of "Poor Path Surface Condition". Thus a pedestrian path which narrows at a single point due to a poorly placed sign was analyzed the same as a path which is narrowed for its entire length by shrubs.

Relative barriers and their impedance values for both ambulatory and mobility-impaired pedestrians are difficult to define due to amount of subjectivity involved. For instance, how much does a pedestrian corridor width of less than 32 inches slow an ambulatory individual's walking pace? How much does a curb ramp that is not ADA compliant affect mobility of a mobility-impaired pedestrian? The ordinal ranking of relative barriers provides realistic impedance values because they don't attempt to answer the above questions. Rather they supply a method for defining routes offering the least or most resistance.

Impedances for the ambulatory pedestrian's relative network dataset were assigned for route surface types (grass, dirt and gravel), number of traffic lanes to cross (5 or greater), the absence of curb ramps, the absence of surface road crossing markings, and traffic control type at road crossings (stoplight, stoplight with pedestrian activated signal and stop sign).

For mobility-impaired individuals the relative barriers that were assigned impedances are identical to or greater than those associated with the ambulatory pedestrian. Impedances not affecting ambulatory pedestrians include the presence/absence of marked crosswalks, curb ramps which are not ADA compliant, the presence/absence of alternate paving, and excessive cross slope.

A separate set of impedances was assigned to the network for pedestrian facilities that could be made ADA accessible through retrofitting. Examples of features that could be easily retrofit include curb ramps that are excessively steep or have a height discontinuity at the top or bottom, sidewalks with height discontinuities or driveway crossings that create steep cross slopes. This dataset is referred to as the retrofit mobility-impaired network.

Impedances were assigned to features based in large part on the feature type. For instance, road crossings have five different attributes that combine to make up their total impedance. These attributes include the intersection traffic control type, road crossing markings, pedestrian island characteristics, the presence/absence of curb ramps and the number of vehicular traffic lanes to cross. Appendix A contains the impedance values for each feature type.

Turntables

One dataset which were used for the sole purpose of showing impedance is the turntable dataset. It comes mainly from the curb ramp features within the point barrier/curb ramp dataset and contains lines connecting two pedestrian right-of-way lines located along adjoining block faces. These turntable lines exist at locations where there are curb ramps that don't have landings (48 inches of flat space) at the top of the ramp. If a pedestrian traveling along the block face labeled "1" (Figure 8) arrives at an intersection and must cross the sloped portion of the ramp to turn the corner and continue to block face "2", they would encounter a cross slope which is usually steeper than the 1:48 pitch ADA recommends (Access-Board 2005). In the same scenario, the pedestrian should be able to proceed down the ramp and across the road without incident.

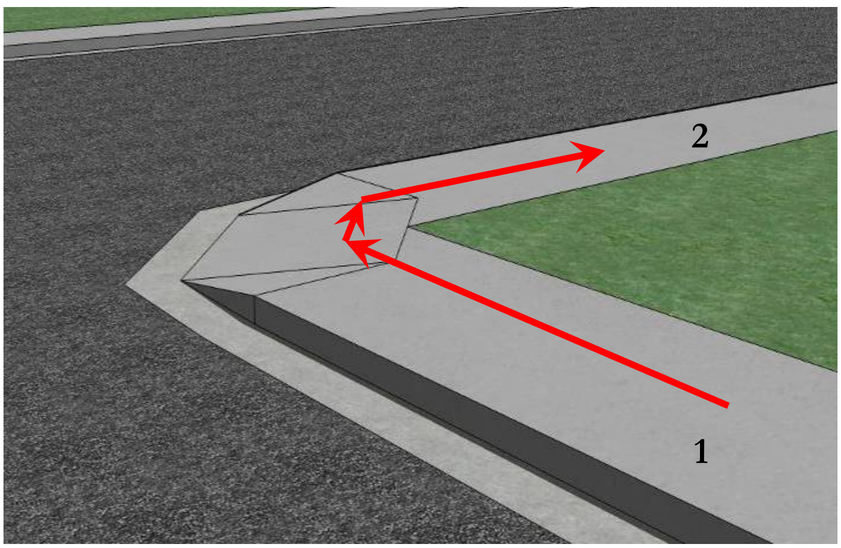

Figure 8: Cross Slope of Red Route Exceeds ADA Standard. Source: Author

However, turning to go down the attached block face could be difficult, especially if the ramp is icy or wet. Thus an assigned impedance value was used only when a route uses pedestrian right-of-ways on two different block faces consecutively, as shown by the red route in Figure 8.

Network Creation

Three versions of the network were created after each network feature was assigned 3 separate impedance values. These networks were called: baseline, ambulatory and mobility-impaired (see Figure 9).

Baseline Network

The baseline network (highlighted in yellow in Figure 9) was created from all features in the pedestrian right-of-way dataset, despite their characteristics. This network shows the potential extent of pedestrian accessibility. Any pedestrian could travel along any pedestrian right-of-way and have equal access as any other pedestrian, regardless of mobility level. The baseline network represents true equity among pedestrians, therefore no impedance values were used in its creation. In other words, all walking surfaces are modeled as firm, smooth surfaces which accommodate a walking rate of 3 miles per hour. For this network to be realized, the construction of absent facilities and the modification of non-ADA compliant facilities would need to occur.

Ambulatory Network

The ambulatory network describes how easily a person having a high degree of mobility, herein referred to as an ambulatory pedestrian, can move about along pedestrian rights-of-way.

This network (shown in green in Figure 9) was created with the full pedestrian path and barrier/opportunity dataset. Every feature was assigned an impedance value based on how an ambulatory individual was estimated to be affected by the characteristics of that feature. Pedestrian rights-of-way on which pedestrians are prohibited were assigned an extremely high impedance value, denoting a lack of access, or an absolute barrier, on that portion of the network. (After all features were assigned impedance values, the ambulatory pedestrian service area was created as described below).

Mobility-Impaired Network

The mobility-impaired network shows how a pedestrian with disabilities might encounter their environment by adding features that are relative or absolute barriers as defined by ADA standards. Examples of absolute barriers in this network include travel corridors <32" wide, the lack of curb ramps and surfaces with excessive cross slopes (>1:48). Instances of relative barriers are road crossings with; no markings, stoplights lacking pedestrian activated walk signals, or no pedestrian island. The creation of this network (highlighted in blue in Figure 9) involves three input datasets: the pedestrian path dataset, barrier/opportunity dataset and the turntable dataset.

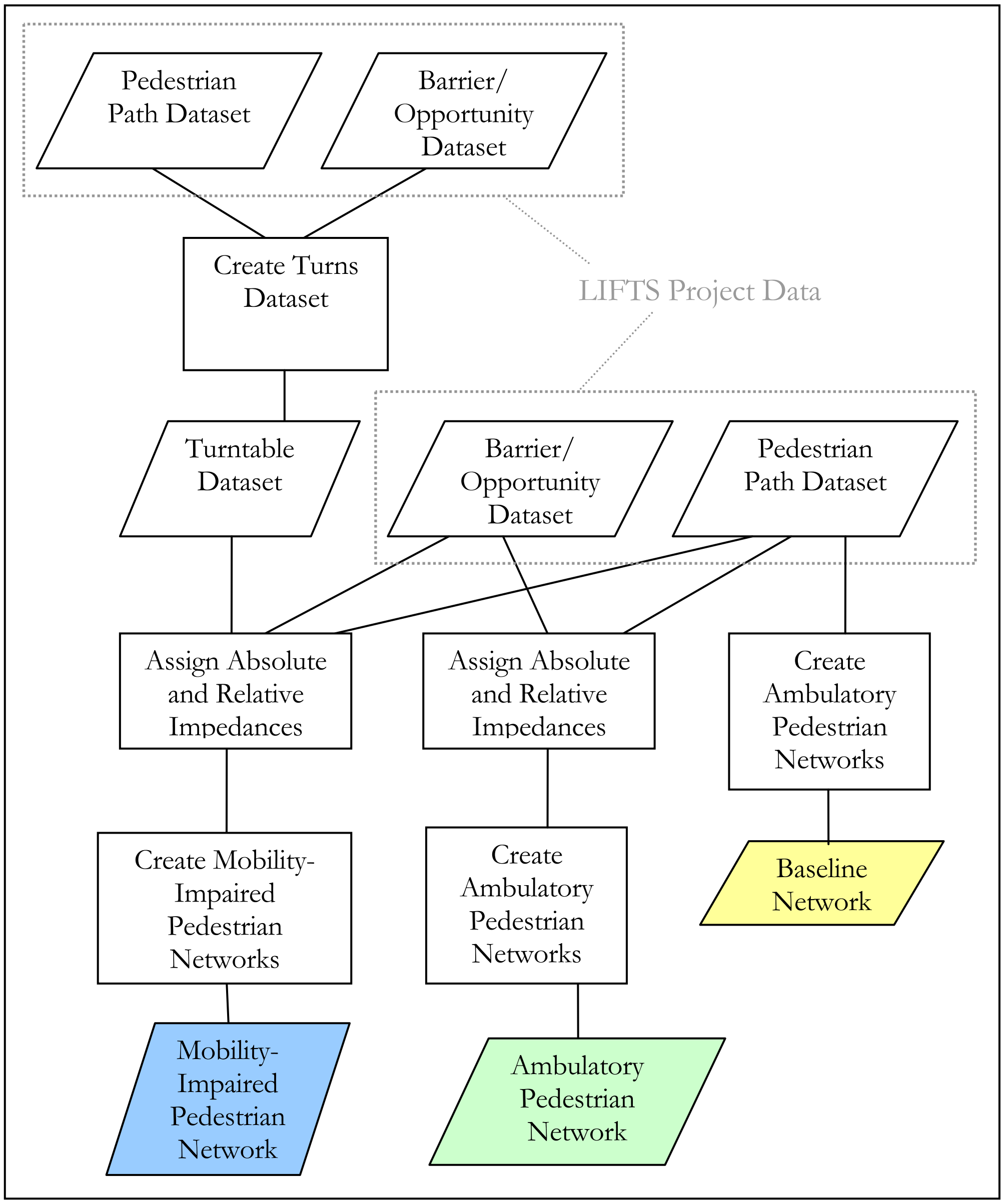

Figure 9: Pedestrian Networks Creation. Source: Author

Service Area Creation

Service areas are zones that have some relationship, accessibility in this study, to the service area origin. They can define places that, from the origin, are accessible within a travel time limit along a predetermined network. The travel time used in this study was 5 minutes, the time required to travel 400 meters at 3 miles per hour. Four hundred meters is the distance defined by Gehl (1987) as the average acceptable walking distance. The location of the service area origins is the first step in the creation of the service areas. The assignment of only one service area origin for each park does not accurately describe the park's accessibility because it only shows accessibility to that point within the park. Origins at the park's perimeter more accurately reflect how accessible the park as a whole is. Therefore, these origin points were assigned at road intersection crosswalks (marked and unmarked) and marked mid-block crosswalks along the park perimeter.

The chosen service area origins served both for the ambulatory and mobility-impaired groups. However, the lack of curb ramps along a park's perimeter greatly reduces the park's accessibility for mobility-impaired pedestrians. While non-ADA accessible curb ramps also reduce access, examination of the retrofit mobility-impaired network provides insight into the value of upgrading pedestrian facilities.

The service area origins are used in combination with the three park network datasets. The yellow portion of Figure 10 represents the cumulative baseline service area in which the only impedance is that of the travel time. The green and blue portions in Figure 10 represent the mobility-impaired and ambulatory service areas (respectively).

Service areas were created from each origin, then summed together spatially for each park in order to create a cumulative or park-wide service area for each mobility level. The result was nine service areas: three network versions multiplied by three different parks. The area of the park was subtracted from this cumulative service area in order to create accurate zones of access

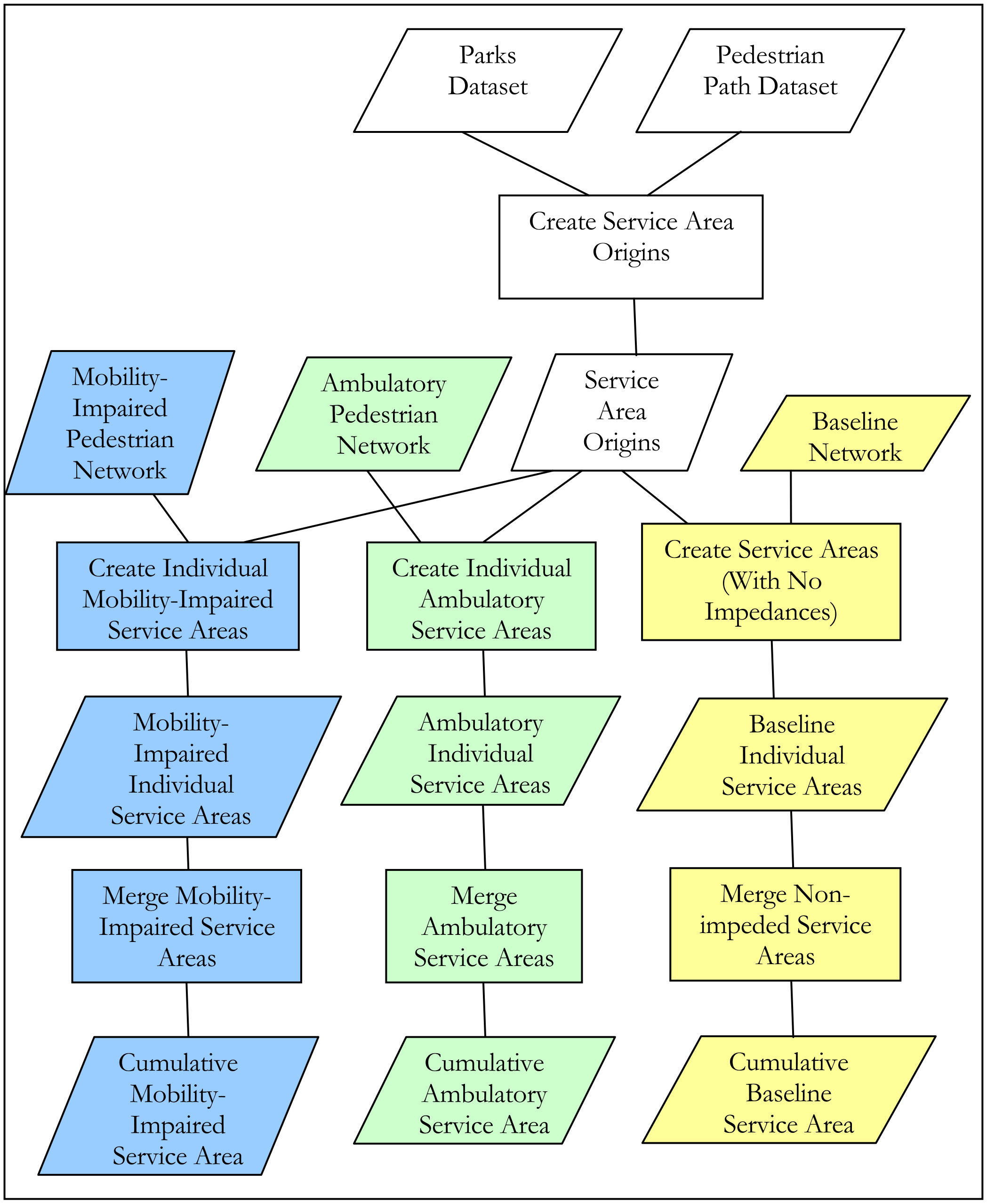

Figure 10: Creation of Baseline Service Area and Ambulatory Pedestrian Service Area.
Source: Author

Service Area Analysis

Once these service areas were created, their characteristics were used to describe the degree of accessibility for each park. Parameters from the service areas, area and perimeter, were used in three different equations: relative accessibility based on idealized pedestrian facilities (RAi), relative accessibility based on actual pedestrian facilities (RA), and the patch shape index or access equality metric (PSI). The importance of each metric is shown in Table 4.

Table 4: Summary of Applicable Accessibility Measures. Source: Author

Metric	**Input Data**	**Importance**
Relative Accessiblity (based on ideal network) (**RAi**)	Mobility Impaired and Baseline Service Areas	Measures how well both groups of pedestrians are served by pedestrian facilities surrounding parks.
	Ambulatory and Baseline Service Areas	
Relative Accessibility (based on actual network) (**RA**)	Mobility Impaired Service Area and Ambulatory Service Area	Measures the equality of accessibility to parks among pedestrians with two different degrees of mobility.
Normalized Patch Shape Index (**NPSI**)	Baseline Service Area	Measures the equity of accessibility from the point of origin outward in all directions.
	Ambulatory Service Area	
	Mobility Impaired Service Area	

$$RAi_g = \frac{A_i}{A_n}$$

Equation 4: Ratio Describing Relative Accessibility Based on Baseline Data

RAi was calculated for both mobility-impaired and ambulatory pedestrians, resulting in six values (two mobility levels multiplied by three parks). This metric communicates two items: the proximity to ADA compliancy of the current pedestrian facilities; and percentage of appropriate pedestrian facilities within close proximity to each park. High RAi (see Equation 4) values indicate that mobility-impaired accessibility is nearly equal to ideal accessibility.

The variables for Equation 4 are as follows: g is a combination of mobility level and park of which there are 6 combinations; A_i is the area of the service area based on the network containing impedances and A_n is the area of the baseline service area.

The RA (shown in Equation 5) is very similar to the RAi, comparing the actual circumstances of the two mobility levels. These ratios (one for each park) show the disparity (or lack of it) between how well mobility-impaired individuals can move about in contrast to ambulatory pedestrians. Thus, a low RA value represents a large degree of infrastructure that does not adequately serve mobility-impaired pedestrians.

$$RA_g = \frac{A_m}{A_a}$$

Equation 5: Ratio Describing Relative Accessibility Based on Simulated Ambulatory Pedestrian Data. Source: Church and Marston 2003.

The variables for Equation 5 represent: g is a combination of mobility level and park of which there are 6 combinations; A_m is the area of the mobility-impaired service area and A_a is the ambulatory service area.

The NPSI (Equation 6) value is more complicated than the previous ratios. Its merit is its ability to measure how equitable each service area is to residents surrounding the parks. The similarity of a service area's shape to the ideal service area's shape shows how equitable adequate pedestrian facilities are to residents surrounding the origin, or park. High NPSI values show a high degree of spatial equality in park accessibility for nearby residents.

$$NPSI_g = \frac{\dfrac{P_i}{2\sqrt{A_i \pi}}}{\dfrac{P_o}{2\sqrt{A_o \pi}}}$$

Equation 6: Calculation of the Normalized Patch Shape Index. Source: Forman 1986, modified by author

The variables for Equation 6 are as follows: g is a combination of mobility level and park of which there are 6 combinations; P_i is the perimeter of the service area based on the network containing impedances and A_i is its area. P_o is the perimeter of the quarter-mile buffer surrounding the corresponding park and A_o is its area.

The metrics based on the service areas were calculated and compared with the statistics obtained from the PRD routes as described below.

Linear Access Measurements

PRD

The previous accessibility measurements were based on polygons, while the following measurement is based on individual routes. The Pedestrian Route Directness metric is a simple spatial calculation made by the division of a route's actual length by the most direct distance between its origin and destination. Its basis on individual routes makes a summation of the results necessary in order to compare it with the service areas. The calculations of the Pedestrian Route Directness metric around each park can be compared to the accessibility values obtained by service area statistics. This comparison might reveal a relationship between the two and help to establish a more robust measure of accessibility (see Table 5). The two methods can also be compared to find their respective strengths and weaknesses.

Table 5: Summary of a Linear-Based Accessibility Measure. Source: Author

<table>
<tr><th>Metric</th><th>Input</th><th>Importance</th></tr>
<tr><td rowspan="2">Pedestrian Route Directness (PRD)</td><td>Ambulatory Pedestrian Routes</td><td rowspan="2">Provides a second method of evaluating accessibility.</td></tr>
<tr><td>Mobility-Impaired Routes</td></tr>
</table>

The origin for individual routes is the main ADA compliant entry into each park. The destinations are the points at which the outer boundary of the baseline service area intersects the pedestrian network (see Figure 11). Some of the destinations may be entirely inaccessible to mobility-impaired pedestrians due to the pedestrian right-of-way surfaces in those locations (i.e. dirt, gravel or grass). The number of inaccessible destinations were recorded and compared with the total number of destinations as a measure of accessibility.

The average PRD value was calculated for each park and compared to show which park is most accessible (see Equation 7). The input datasets to create these routes were the baseline service areas for each park, the service area origins (which show the main ADA accessible entry) and the pedestrian networks for both mobility levels (see Figure 12).

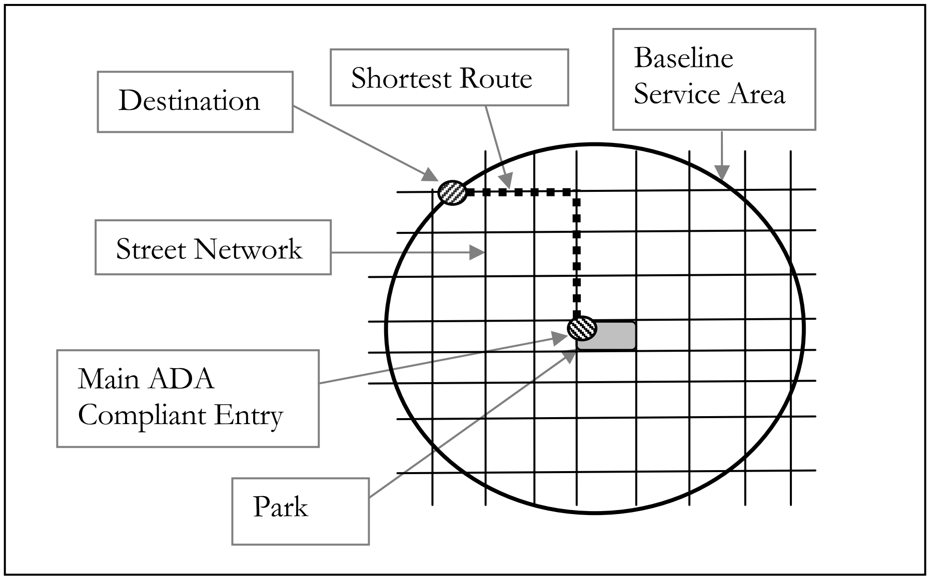

Figure 11: PRD Route Showing Destination Location. Source: Author

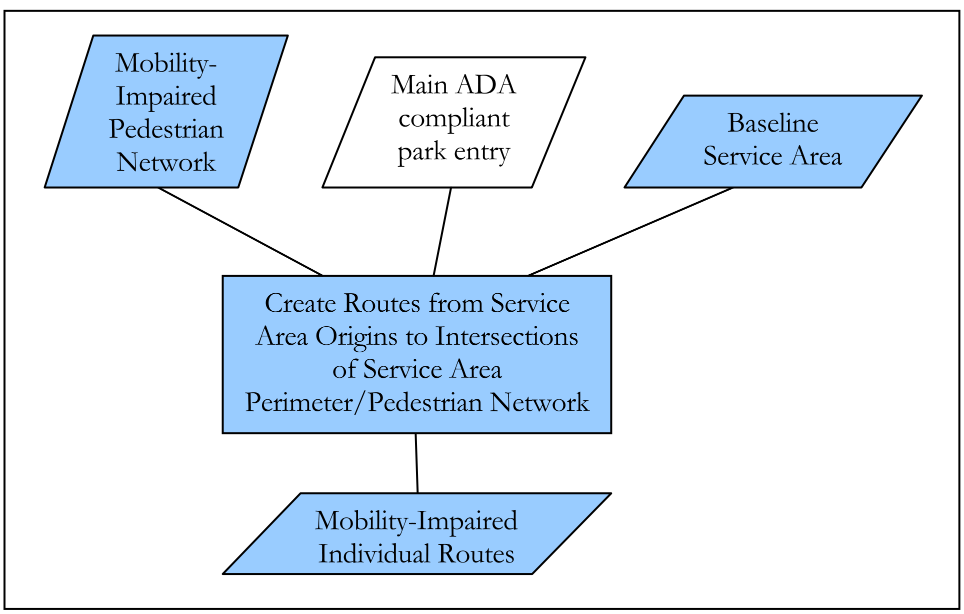

Figure 12: Creation of Mobility-Impaired and Ambulatory Pedestrian Routes for PRD Calculation. Source: Author

$$PRD_{mg} = \frac{\sum \frac{L_n}{L_e}}{k}$$

Equation 7: Calculation of Composite Pedestrian Route Directness. Source: Dill 2004 modified by author

The calculation of the cumulative PRD value is illustrated in Equation 7. The variables listed are as follows: m represents the mobility-imaired category; g represents the park; L_n is the route with the least impedance from origin to destination along the network; L_e is the Euclidean distance from the origin to the destination; k is the number of routes summed in numerator.

The routes created for the PRD measurement were analyzed to find mean, minimum and maximum values among each park. The mean PRD value of each park was compared with the related service area to analyze any correlations. The outcomes of these calculations were posted in the Analysis section.

CHAPTER 5 – ANALYSIS OF ACCESS TO SPOKANE PARKS

Descriptions of the accessibility calculations involving polygons or service areas are followed by those using linear computations. Comments on the methods used and opportunities for park accessibility conclude this chapter. The methods used to determine accessibility are evaluated in addition to the results found for each park.

Service Area Characteristics

The service areas of the different mobility groups have many similarities between the three parks. The size of each service area reflects their associated impedances; the largest has the least impedance (baseline) while the most impeded (mobility-impaired) has the smallest extent. The service areas are described in more detail after a brief discussion of the parks' access points, which are the basis for the service areas.

Getting to the Park

Statistics of park access points, located at every street which intersects the park's perimeter, show that access to parks is not at all spatially equitable. In Table 6, park access points are summarized in terms of which are accessible to the ambulatory and mobility-impaired pedestrian. Moving from left to right, the table pares down which access points are usable by mobility-impaired pedestrians. These figures show that these three parks are almost entirely inaccessible to pedestrians who need curb ramps, one on each side of the street.

Table 6: Description of Access Points to Three of Spokane City's Parks. Source: Author

Parks	Perimeter Curb Ramps				Ambulatory Pedestrian Access Points
	Total	ADA Compliant Perimeter Ramp	ADA Compliant Perimeter Ramp; Curb Ramp Across Street	ADA Compliant Perimeter Ramp; ADA Compliant Curb Ramp Across Street	
Audubon	3	2	1	1	30
Friendship	6 (1*)	4 (1*)	1	0	9
Comstock	6 (4*)	6 (4*)	1	0	18
*These curb ramps are located in parking lots or by off-street parking.					

There are 57 access points available to ambulatory pedestrians compared to only one for mobility impaired pedestrians. Unless arriving by motor vehicle, Comstock Park and Friendship Park are not accessible to mobility-impaired users. These two parks have ADA compliant curb ramps located in parking lots, which do not support the goal of the Spokane Parks and Recreation Department (2006) to have "convenient access" to parks (p.1). It is not reasonable that an individual living across the street from the park must drive to the park's parking lot just to access the park.

Accessibility of Each Park

Friendship Park

Access for the Mobility-Impaired Pedestrian

Stated above, Friendship Park lacks a truly accessible entry into the park from across its bounding street. Two of the perimeter curb ramps have 'mates' on the other side of the street, yet in both cases one in each of the spatial pairings is not ADA compliant. Hence, the service area for mobility-impaired pedestrians is the same shape as the park, essentially no change in the size of the service area (see Figure 13). A lack of access by mobility-impaired pedestrians to this park is certainly contrary to the standards set by the Americans with Disabilities Act, as well as the Spokane Parks and Recreation Department's 20/20 Strategic Plan (2006). Many changes to the neighborhood and its pedestrian facilities are necessary to make Friendship Park accessible.

Access for the Ambulatory Pedestrian

The ambulatory pedestrian service area shows the disadvantage of the surrounding type of street pattern: a low degree of connectivity. Many cul-de-sacs make this service area cover only 33% of the area within a 1320 foot radius of the park. Even one cul-de-sac 280 feet to the north of the park does not have access to the park within a 5 minute walk.

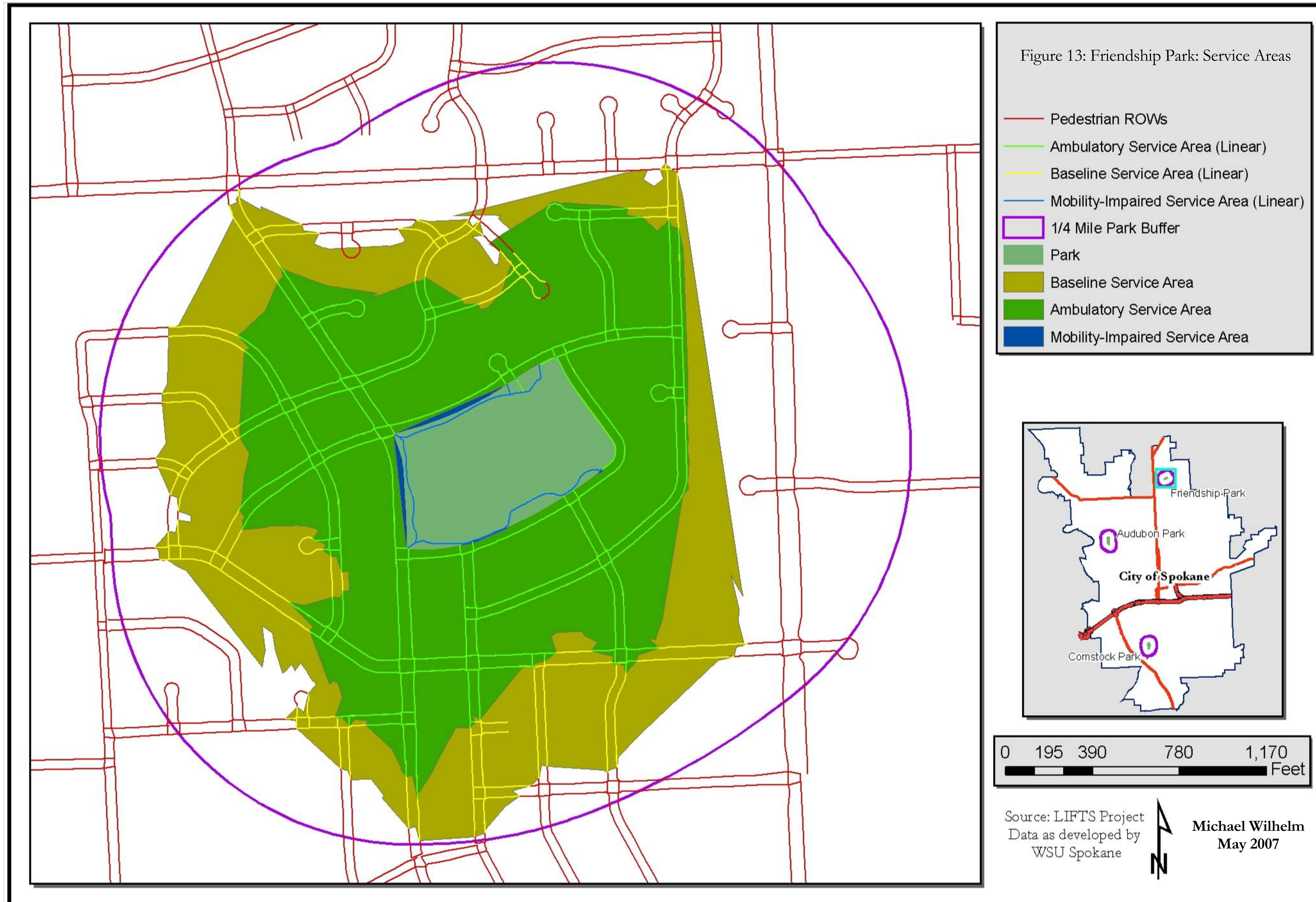
Figure 13: Friendship Park: Service Areas
Pedestrian ROWs
Ambulatory Service Area (Linear)
Baseline Service Area (Linear)
Mobility-Impaired Service Area (Linear)
1/4 Mile Park Buffer
Park
Baseline Service Area
Ambulatory Service Area
Mobility-Impaired Service Area
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 195 390 780 1,170
Feet
Source: LIFTS Project Data as developed by WSU Spokane
N
Michael Wilhelm
May 2007

Ideal Access

The calculation of the ambulatory and baseline service areas show that even if every pedestrian right-of-way was accessible, a large portion of the neighborhood is still not within a five minute walk to the park, again due to the curvilinear street layout.

<u>Comstock Park</u>

The neighborhood surrounding Comstock Park illustrates the effect of street connectivity on accessibility. To the north, the street pattern is a semi-regular grid, conducive to optimal accessibility. To the east and especially to the west, the street configuration appears to be designed specifically for access to the park, radiating outward from the park (see Figure 14). The cul-de-sac and warped street arrangement to the south is similar to that of the Friendship Park neighborhood.

Access for the Mobility-Impaired Pedestrian

The mobility-impaired service area for Comstock Park shows a lack of ADA accessibility to the park, except from parking lots as stated previously. The only other potentially accessible entry is on the southeast side, yet it lacks a sidewalk to its north. Once again, major changes would be necessary to provide park access for pedestrians who require an ADA compliant built environment.

Access for the Ambulatory Pedestrian

Access appears to be favorable for walking to the park from the majority of the neighborhood. Sidewalks to the north and west in addition to few intersections to the west allow for good accessibility for walkers. Access from south of the park is curtailed by the lack of street connectivity, making a cul-de-sac only 300 feet from the park perimeter inaccessible within 5 minutes of walking.

Ideal Access

The baseline service area demonstrates the potential of being able to reach points which are nearly 1320 feet away from the park (Euclidean, not network-based distance) by a 5 minute walk. 1320 feet is the distance walked at a constant rate of 3 mph. Figure 14 shows nine roads which have the potential to provide a maximum 5 minute access to the park for residents within one quarter of a mile. The maximum spatial extent for convenient accessibility could be reached by making pedestrian rights-of-way along these streets ADA compliant.

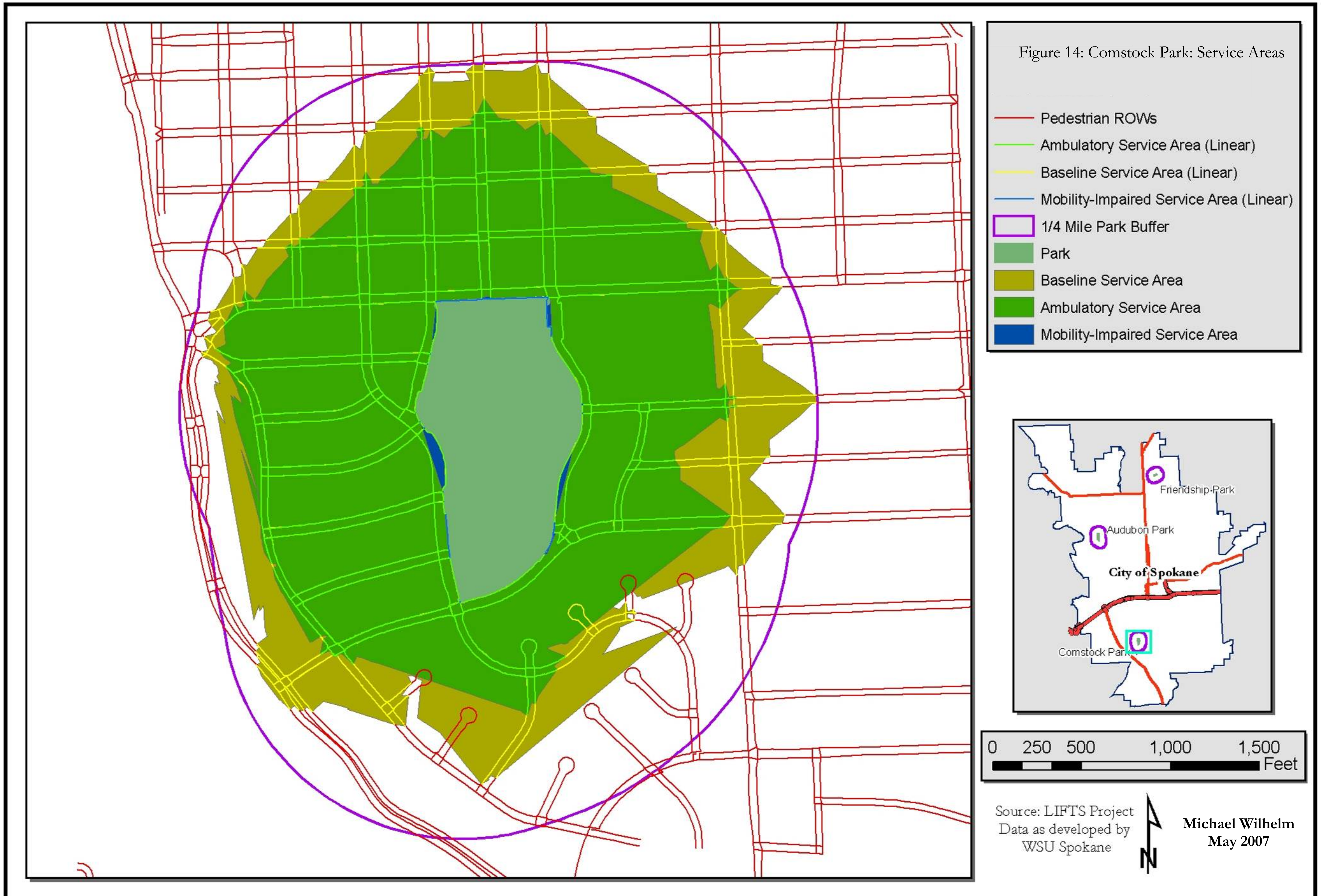

Figure 14: Comstock Park: Service Areas
Pedestrian ROWs
Ambulatory Service Area (Linear)
Baseline Service Area (Linear)
Mobility-Impaired Service Area (Linear)
1/4 Mile Park Buffer
Park
Baseline Service Area
Ambulatory Service Area
Mobility-Impaired Service Area
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 250 500 1,000 1,500 Feet
Source: LIFTS Project
Data as developed by
WSU Spokane
N
Michael Wilhelm
May 2007

Audubon Park

Access for the Mobility-Impaired Pedestrian

The service area for mobility-impaired pedestrians includes only 201 linear feet of sidewalk to the north of Audubon Park. This trivial service area uses the ADA accessible road crossing used by individuals en route to Finch Elementary School. The lack of a street dividing the school and park properties allows an accessible entry point for one facility to serve the other. Perhaps the influence of the two combined to require an accessible road crossing.

Access for the Ambulatory Pedestrian

The shape of the ambulatory pedestrian service area is similar to that of the baseline service area (see Figure 15). This indicates that the ambulatory pedestrian network impedances have slowed the ambulatory pedestrian nearly equally and minimally on all sides of the park. Although curb ramps are difficult to find in this neighborhood, sidewalks are abundant. Numerous sidewalks and a grid-like street pattern contribute to an ambulatory service area that occupies 65% of the baseline service area.

Ideal Access

The baseline service area occupies 81 percent of the quarter mile buffer area (see Figure 15. Residents living one-quarter mile to the east and west of the park have potential access to the park within a 5-minute walk. Access is more limited in directions that are diagonal to the street grid pattern (i.e. northeast and southwest). Northwest Boulevard and Driscoll Boulevard are aligned diagonally to the street grid and slightly extend access to the southeast and the north/northwest, respectively.

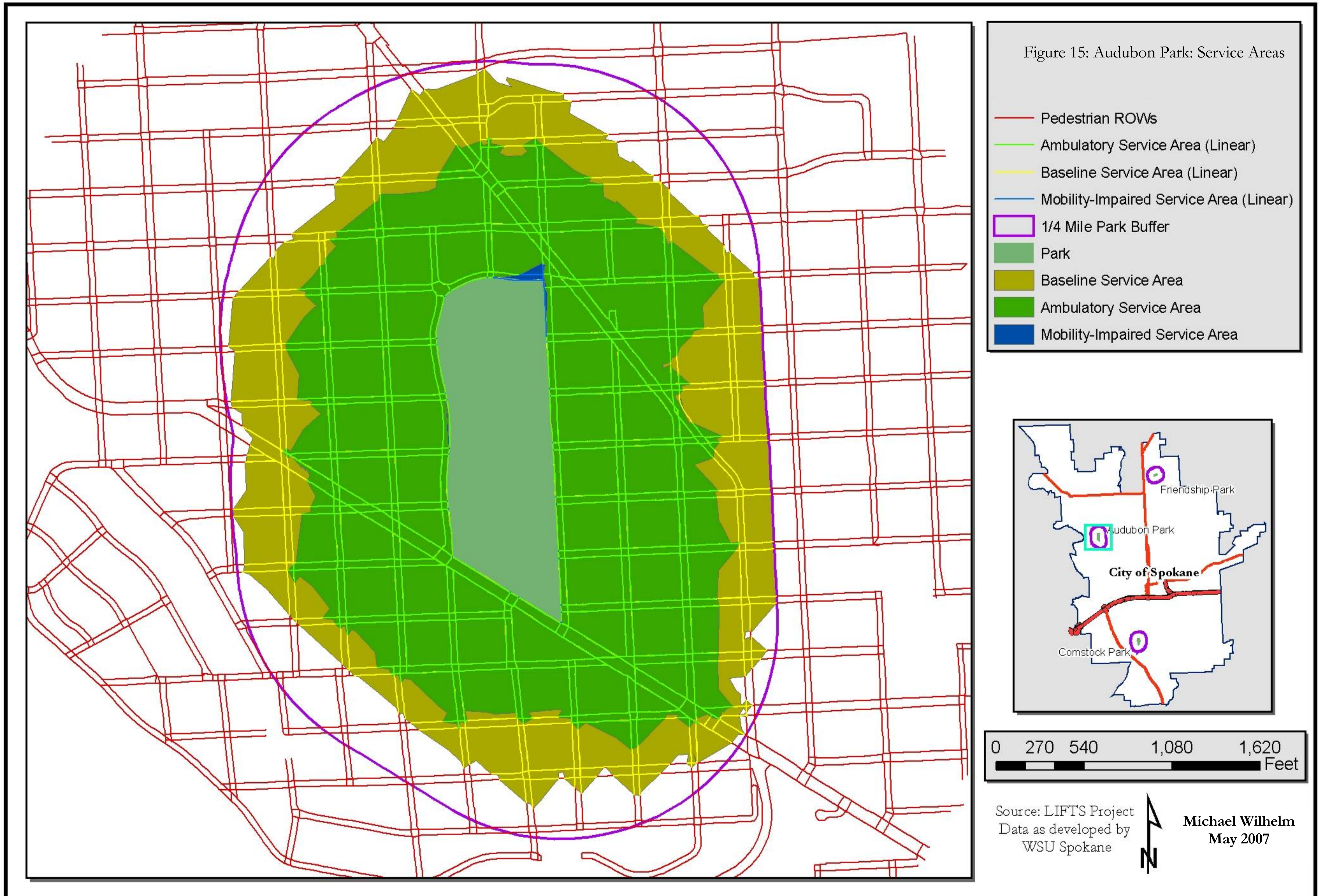
Figure 15: Audubon Park: Service Areas
Pedestrian ROWs
Ambulatory Service Area (Linear)
Baseline Service Area (Linear)
Mobility-Impaired Service Area (Linear)
1/4 Mile Park Buffer
Park
Baseline Service Area
Ambulatory Service Area
Mobility-Impaired Service Area
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 270 540 1,080 1,620
Feet
Source: LIFTS Project
Data as developed by
WSU Spokane
N
Michael Wilhelm
May 2007

Comparison of Service Area Metrics

The results of the relative accessibility (RA and RAi) and Normalized Patch Shape Index (NPSI) calculations for each park are compared below. The comparison of each park's values allows them to be ranked in terms of most and least accessible. They also provide a better understanding of the strengths and weaknesses of each park's accessibility and potential. The two relative accessibility calculations are described first, followed by the Normalized Patch Shape Index metric.

The results from the mobility-impaired pedestrian service areas are to be expected. Friendship Park and Comstock Park both have RA and RAi values of 0, reflecting their absolute inaccessibility for individuals requiring ADA accessible facilities. Table 7 shows Audubon Park having RA and RAi values of 0.002 and 0.003. In other words, only 0.3% of the area occupied by the ambulatory service area, and 0.2% of the baseline service area, is accessible to mobility-impaired pedestrians. Between the three parks, mobility-impaired pedestrians can access less than 0.1% of the area reachable by the ambulatory bipeds.

The RAi values for the ambulatory service areas are much larger than for the mobility-impaired service areas due to the minimal number of barriers to ambulatory pedestrians. The service area for Comstock Park has the highest RAi value (0.711). Friendship Park's associated RAi value is 0.584 and Audubon Park's is 0.650.

One reason for Audubon Park's low RAi value is the higher density of intersections, which have a higher associated cost of travel than do sidewalks (see Figure 15). It appears that the majority of routes within the ambulatory service area end at or before the fourth road crossing from the park. In other words, the assigned impedances model a pedestrian having time to walk just four blocks (approximately 300 ft each) due to the stopping time allowed for intersections. Although traditional pre-war grid street layouts provide a high degree of connectivity and travel choice to pedestrians, they also reduce accessibility by increasing travel time unless the pedestrian doesn't have to pause at all at intersections.

This is somewhat contradictory to notions that high levels of grid-based connectivity are desirable for pedestrians (Randall and Baetz 2001; Handy, Paterson et al. 2003; Dill 2004).

The NPSI values for the MI service areas near Friendship and Comstock Parks can be misleading because the service areas and NPSI values are identical to the park. Thus, these values can be ignored if their purpose is to describe spatial equity of access because the service areas show that access from outside the park is not provided.

The NPSI value for Audubon Park's MI service area has value because the service area extends beyond park boundaries. The NPSI value for the ambulatory service area is higher or less ideal because it has a more jagged edge than that of the MI service area (view Figure 15). Despite having a more ideal NPSI value, the MI service area can be observed in Figure 15 to provide less spatially equitable accessibility around the entire park. The apparent conflict can be explained by the fact that the MI service area doesn't surround the park,

Table 7: Accessibility Analysis Results Based on Polygon Service Areas. Source: Author

	Friendship Park	**Comstock Park**	**Audubon Park**
Park Area	513709 sq ft	1134608 sq ft	1250436 sq ft
Baseline Service Area	5183728 sq ft	7837455 sq ft	9910011 sq ft
Ambulatory Service Area	3029068 sq ft	5572816 sq ft	6440024 sq ft
Mobility-Impaired Service Area	513709 sq ft	1134608 sq ft	1266720 sq ft
RAi: Ambulatory	0.584	0.711	0.650
RAi: Mobility-Impaired	0	0	0.002
RA: Mobility-Impaired	0	0	0.003
PSI: 1/4 Mile Park Buffer	1.008	1.017	1.032
NPSI: Ambulatory	1.482	1.402	1.412
NPSI: Mobility-Impaired	1.133	1.305	1.285

while the ambulatory service area does. Valid comparisons of NPSI values require that the involved service areas either surround the park or not.

Ambulatory pedestrians have more spatially equitable access to all three parks. Service areas for this mobility group have NPSI values ranging from 1.402 to 1.482, as shown in Table 7. Comstock Park has the most spatially equitable access of the three parks for ambulatory pedestrians, revealed by an NPSI value of 1.402. The corresponding value for Audubon Park is slightly larger. Around the perimeter of the park, the distance from park to service area boundary is close to equal for both of these parks. This distance for Friendship Park's service area has large differences in all four cardinal directions (see Figure 13), reflected in the higher NPSI value.

The service area for the ambulatory group entirely surrounds its corresponding parks, making its NPSI value describe access to the park, unlike the value for the Audubon Park MI service area. Because the validity of the NPSI value depends upon this occurrence, either centroid location difference thresholds need to be set or observations of graphics depicting service area and facility should occur.

The two metrics mentioned above have some limitations, yet can play an important role in portraying a more complete assessment of a facility's accessibility. Another piece which can be included in this evaluation is the linear metric described by Hess (1997) as Pedestrian Route Directness (PRD).

Linear Measurement Results

The linear measurement of accessibility (PRD) is partially based on the polygon generated baseline service areas. Points at which the baseline service area intersects the pedestrian network were defined as destinations, either accessible or non-accessible depending on the ground material at that location. Points on road crossings have been excluded because they are areas for travel, and thus not valid destinations. If a destination positioned on a driveway or alley crossing had a sidewalk located adjacent to the driveway or alley crossing, it was considered accessible and included in the PRD measurement. Any destination therefore must be located on a flat, hard surface and out of the way of major travel (i.e. from roads).

The origin was chosen by defining which park entry points are ADA accessible, then locating a point at the intersection of the road crossing feature and the park's perimeter path feature. This location and the pedestrian facilities close to it played a significant role in determining what areas of the neighborhood were accessible to the park.

It is important to note that the terms 'origin' and 'destination' are used arbitrarily and could be inverted. The pedestrian network used here is not a directed network, so traveling to the park from a residence takes the same amount of time as traveling from the park to that residence. Below are the results of the PRD calculations for each park origin followed by a comparison between them (see Table 8).

Friendship Park

The destinations for this neighborhood were well distributed in all directions from the park with the exception of the eastern portion of the neighborhood. There are no roads oriented east and west for 2150 feet which allow access from Nevada Street and its two attached cul-de-sacs toward the park (see Figure 16). Out of 45 total destinations only 16 of them are located on an accessible surface.

The routes from the park to the 16 destinations varied widely in their PRD values, ranging from 1.02 to 7.1. The route linking the park entry with Destination 45 on Figure 16 has the highest PRD value of all routes in this study. These two points could have a very direct route, yet due to a lack of sidewalks and curb ramps a 1300 foot trip turns into one of 9232 feet. The route from Destination 1 to Destination 21 in Figure 16 has the second lowest overall PRD value and provides sidewalks and curb ramps at intersections the entire distance. However, one curb ramp is non-ADA compliant which makes it inaccessible.

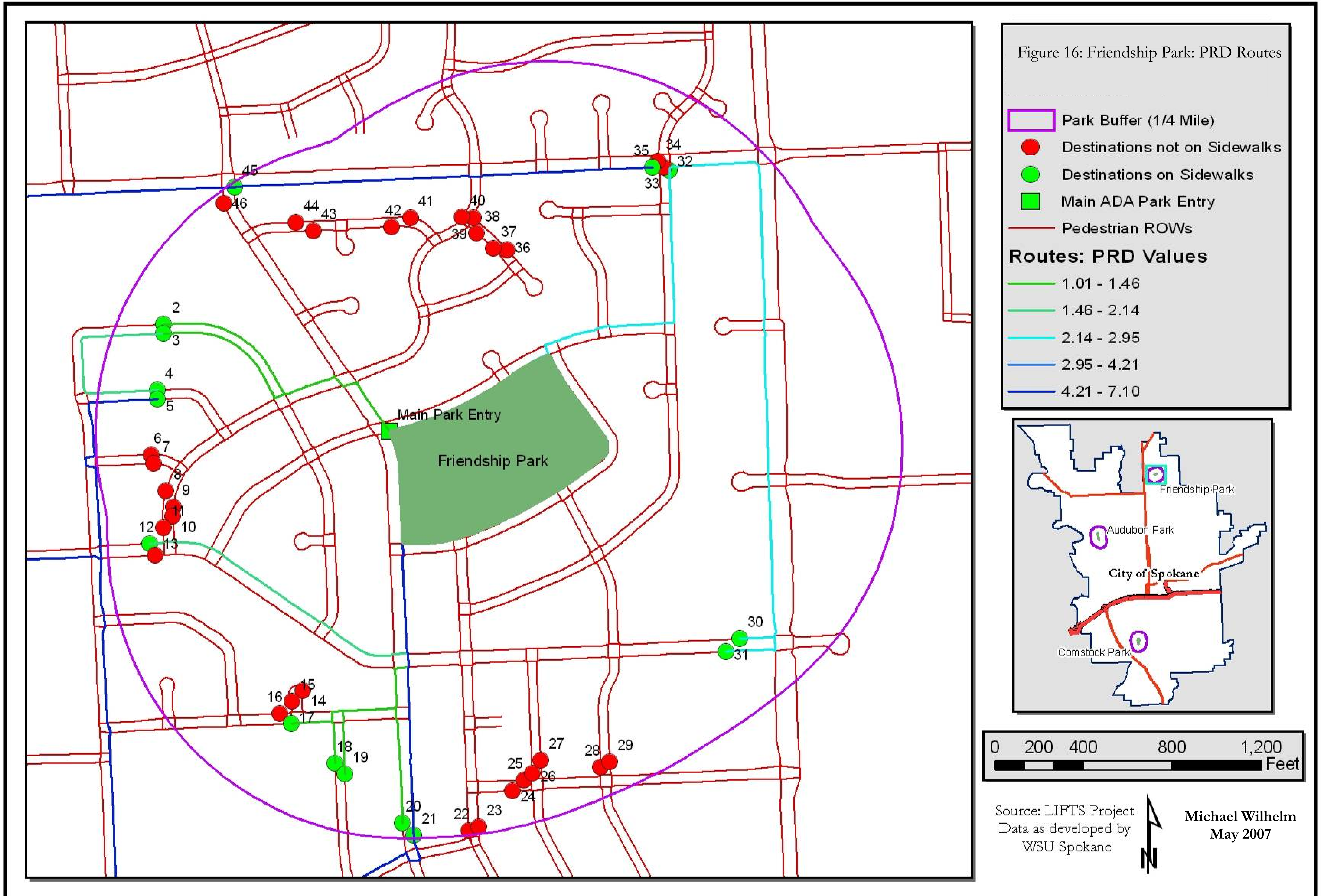

Figure 16: Friendship Park: PRD Routes
Park Buffer (1/4 Mile)
Destinations not on Sidewalks
Destinations on Sidewalks
Main ADA Park Entry
Pedestrian ROWs
Routes: PRD Values
1.01 - 1.46
1.46 - 2.14
2.14 - 2.95
2.95 - 4.21
4.21 - 7.10
Main Park Entry
Friendship Park
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 200 400 800 1,200 Feet
Source: LIFTS Project Data as developed by WSU Spokane
Michael Wilhelm
May 2007
N

The route distances range from 1322 to 11,119 feet. The average distance (3702 feet) equals approximately 14 minutes of travel time at 3 miles per hour, almost three times the recommended 5 minute, or 400 meters according to Gehl (1987) , travel time reach of a destination. This neighborhood has potential to have an accessible park, yet lacks the proper pedestrian facilities needed to achieve that status.

Comstock Park

The ratio of accessible destinations to total destinations in this neighborhood is 33:64. The majority of the inaccessible destinations, due to a lack of sidewalks, are located in the southwestern half of the neighborhood (see Figure 17). The location chosen for the main park entry is on a side of the park away from most of the accessible destinations. The only sidewalk near the entry extends to the east and is used for most of the PRD related routes.

The range of PRD values in this area is 1.02 to 5.26 with a mean of 3.33. Most of the routes travel outside the park's quarter mile buffer and vary in distance from the ideal 1320 feet to 11,973 feet (2.26 miles). This park needs an accessible entry on the north side in order to reduce the distance for an ADA accessible route in the northern half of this neighborhood.

Audubon Park

The accessible destinations from this park are well distributed in all directions. Due to the even spatial distribution of destinations, any point on the perimeter selected as the origin provides an equally short route to each destination.

The total number of destinations is 97; 56 of which are accessible based on criteria stated above, with another 22 falling on road crossings.

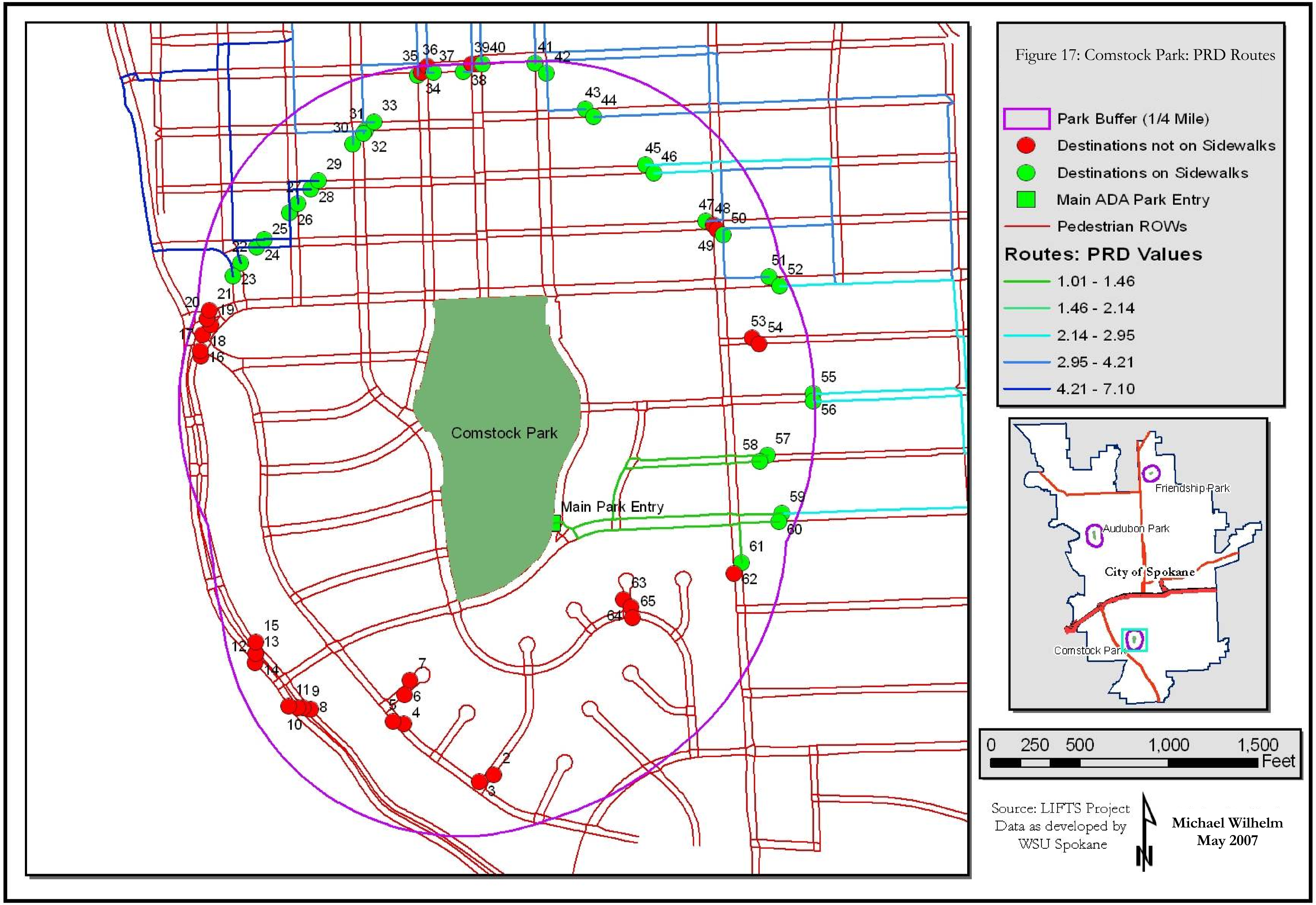

Figure 17: Comstock Park: PRD Routes
Park Buffer (1/4 Mile)
Destinations not on Sidewalks
Destinations on Sidewalks
Main ADA Park Entry
Pedestrian ROWs
Routes: PRD Values
1.01 - 1.46
1.46 - 2.14
2.14 - 2.95
2.95 - 4.21
4.21 - 7.10
Comstock Park
Main Park Entry
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 250 500 1,000 1,500 Feet
Source: LIFTS Project Data as developed by WSU Spokane
N
Michael Wilhelm
May 2007

Only a small portion (approximately 100 feet) of the PRD routes extended outside the park's quarter mile buffer, indicating good network connectivity and a high number of accessible surfaces (see Figure 18). PRD values for this locale are the lowest in this study as shown by a mean value of 1.49 and a maximum of 2.138 (see Table 8). However, this neighborhood lacks curb ramps at approximately 110 of its 120 intersections. Its potential for providing park access for mobility-impaired pedestrians is high.

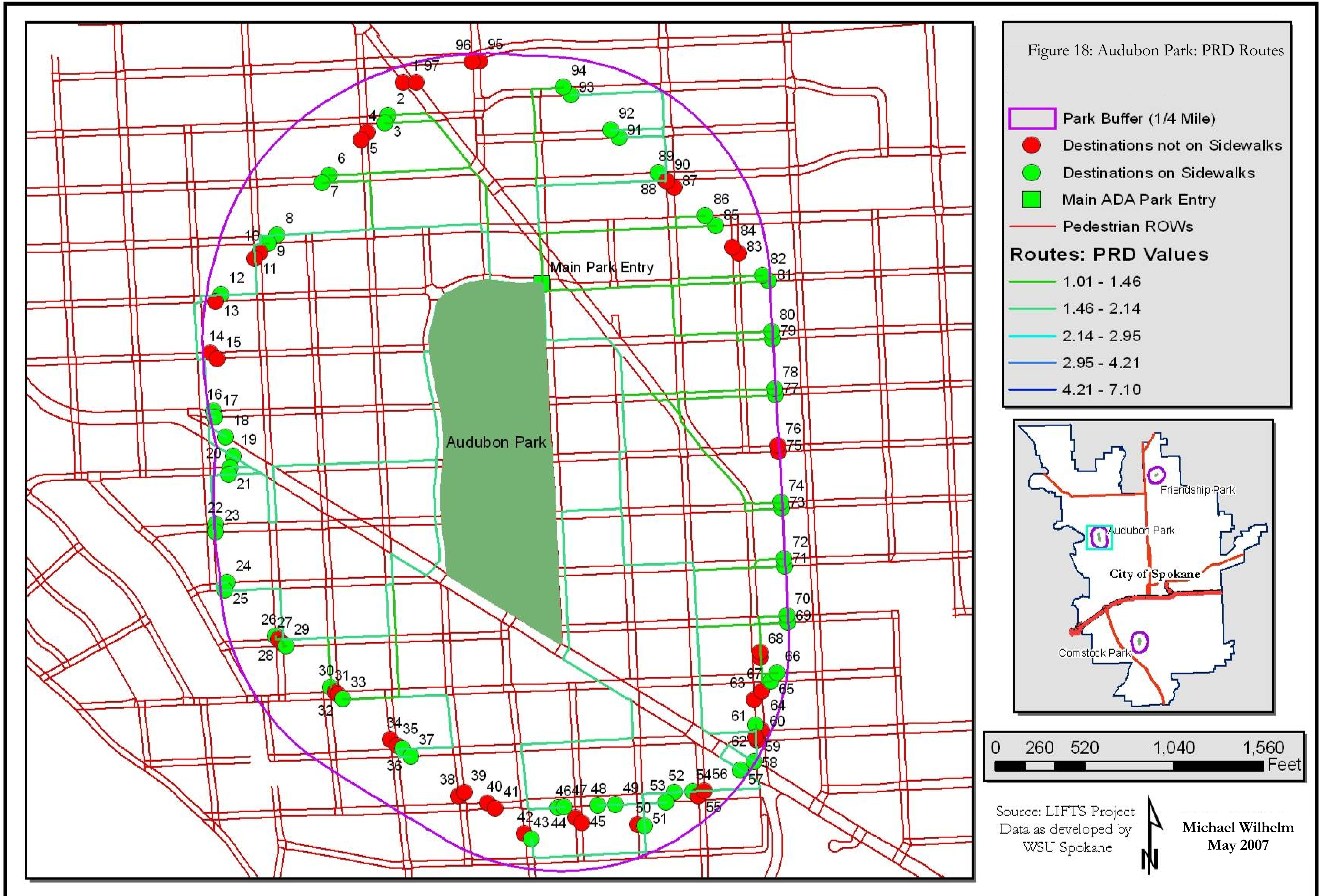

Figure 18: Audubon Park: PRD Routes
Park Buffer (1/4 Mile)
Destinations not on Sidewalks
Destinations on Sidewalks
Main ADA Park Entry
Pedestrian ROWs
Routes: PRD Values
1.01 - 1.46
1.46 - 2.14
2.14 - 2.95
2.95 - 4.21
4.21 - 7.10
Main Park Entry
Audubon Park
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 260 520 1,040 1,560
Feet
Source: LIFTS Project
Data as developed by
WSU Spokane
N
Michael Wilhelm
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Table 8: PRD Values and Routes Distances Displayed by Park. Source: Author

Park	Friendship	Comstock	Audubon
PRD Value: Mean	2.582	3.329	1.490
PRD Value: Minimum	1.027	1.018	1.032
PRD Value: Maximum	7.096	5.26	2.138
Route Distance (ft): Mean	3702	7435	3257
Route Distance (ft): Minimum	1322	1320	1320
Route Distance (ft): Maximum	11119	11973	6374

Each park's PRD value depends upon many variables such as total sidewalk percentage of the neighborhood, baseline service area extent, street configuration and location of park entry relative to location of available destinations. These factors were considered as the PRD values from each park were compared.

Comparison of the Parks' PRD Values

The number of accessible destinations used for this portion of the analysis is directly related to the percent of sidewalks in each of the neighborhoods. As mentioned previously, there is a greater percentage of sidewalks in the Audubon Park neighborhood than the other two neighborhoods. This is reflected by the fact that is has the highest percentage of destinations having an accessible surface (see Figure 19). Comstock Park has a slightly lower percentage, while Friendship Park shows a very low percentage due to a lower percentage of sidewalks in the neighborhood.

While average and maximum PRD values for each park vary greatly, the minimum values are similar (see Table 8). The isolated nature of Friendship Park from the eastern portion of its quarter-mile buffered area contributes to making this neighborhood's routes have the highest PRD value among the three parks. The Audubon Park routes have the lowest average PRD value despite having the highest minimum value. The routes to Comstock Park displayed a low degree of directness due to a lack of sidewalks. Also, the location of the park entry or route origin was further away from the majority of accessible destinations than the other parks.

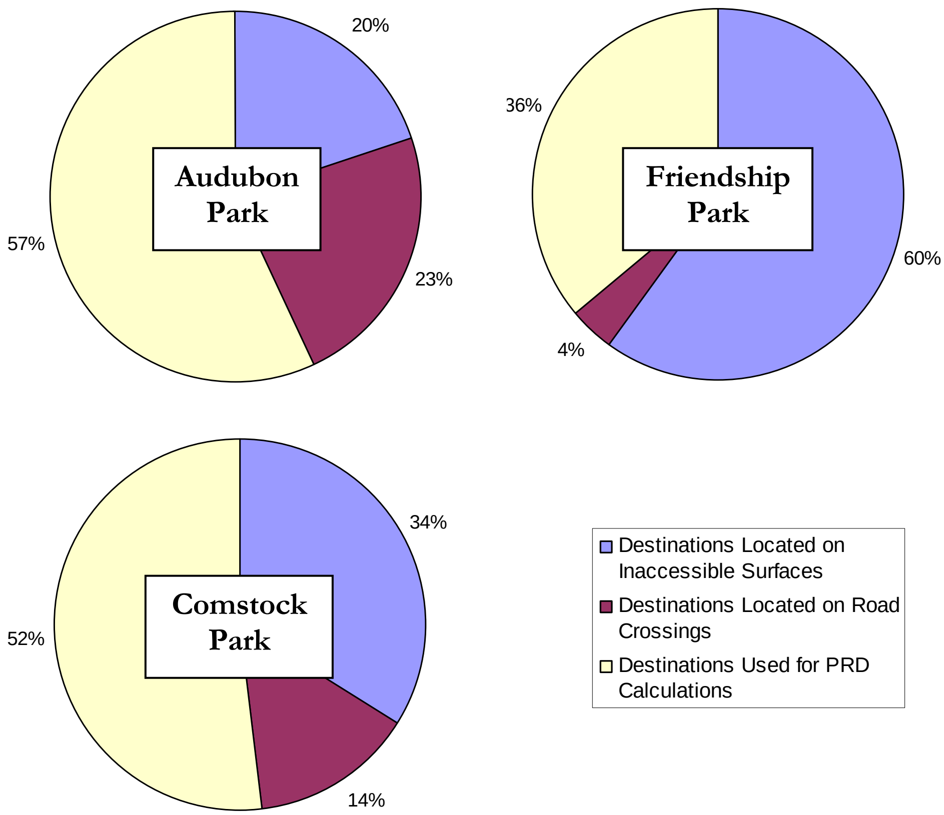

Figure 19: Destinations from Parks Categorized by Presence/Absence of Accessible Position. Source: Author

Randall and Baetz (2001) suggest that the range for acceptable PRD values for "pre-1940s neighborhoods, streetcar suburbs, grid street patterns" is between 1.40 and 1.48 (p. 4). The mean for Audubon Park's routes is slightly out of this range, yet is by far the closest of the three parks to being within the suggested reach. Forty-five percent of its routes have a PRD value above the acceptable range. The mean PRD values for routes in the Comstock and Friendship neighborhoods are higher than the recommended range by Randal and Baetz (Randall and Baetz 2001) of 1.63-1.88 for "conventional suburbs, postwar, curvilinear street patterns, cul-de-sacs" (p. 4). Eighty-five percent of routes to Comstock Park and forty-seven percent of routes to Friendship Park have higher than acceptable values.

The fact that the area surrounding Audubon Park has the lowest average PRD values signifies that it is the neighborhood which offers the most efficient and direct access to the park. This is important to know in deciding which areas should have pedestrian facility upgrades or new construction. However, this is not the only item that should be considered in the prioritization process. Other factors important in this process might be average resident age, percentage of mobility-impaired individuals, likelihood of residents to use the park and probability of pedestrianism as a travel method.

Discussion

Many of the analysis results are to be expected, such as smaller service areas for mobility-impaired pedestrians than for ambulatory pedestrians. Other results, such as the most accessible route from residence to park, are not as easily anticipated. The results show that each park has strengths and weaknesses in terms of being accessible to their respective neighborhoods.

Analysis of the results revealed some limitations to the methods employed and the data used. These issues are described below followed by each park's accessibility summary.

The creation of service areas went smoothly, except when the results were viewed. Service area polygons in neighborhoods having cul-de-sacs (i.e. near Comstock and Friendship Park) often portray erroneous results due to the neighborhoods' low degree of connectivity. For example, a cul-de-sac that is not accessible based on the service area creation parameters might protrude into the service area polygon, shown in Figure 20. The gold service area polygon shows that two cul-de-sacs, shown with red lines, are within the service area. However, the yellow lines, which symbolize those network lines that are defined as being within the service area, illustrate that the cul-de-sacs are not in the service area. This is caused by the software's method of drawing service area polygons in sections of accessibility that are closer to the origin than adjacent zones. Line generated service areas more accurately portray areas of accessibility, yet they cannot be used for NPSI or other calculations involving area.

The pedestrian network used in the PRD analysis did not extend over a half mile from each park's perimeter. Impedances for surface type, pedestrian facility quality, presence/absence of curb ramps and traffic control devices were assigned to network features within a quarter mile boundary of each park. The remaining network features were assigned impedances based solely on the presence/absence of sidewalks. A lack of resources needed to attribute more completely the pedestrian network outside the quarter mile buffer was the motive for the simplified feature attribute assignments. It is important to point out this deficiency because the PRD routes (based on the least impedance) might not be the most accessible. It is possible that a route needs to be modified due to barriers not recorded. After the network dataset is finished within the city boundaries this issue will disappear.

Figure 20: Deceptive Representation of Service Area by the Service Area Polygon.
Source: Author

Other limitations to the PRD method used include: the calculated "most efficient" route is rarely accessible, which can be slightly misleading. For ambulatory pedestrians, the calculated PRD route would serve well. However, to create accessible routes only, the impedances need to be adjusted. In addition, realistic routes would originate from more than just one park entry, granted the target user group can use more than one entry.

The lack of service areas for mobility-impaired pedestrians around two parks does not allow for comparisons between the other mobility levels. In the interest of curiosity, the impedances for all existing curb ramps and sidewalks were changed to symbolize that they are ADA accessible. In two of the three parks, these imaginary retrofits did not significantly improve the service area for mobility-impaired pedestrians, as displayed in Figure 22. The service area surrounding Friendship Park received the greatest expansion, from 0 to 1,116,616 sq ft (see Figure 21). The most obvious changes are to the south and west of the park, while the east and northeast portions changed very little. These results show the need for new construction as well as the modification of existing infrastructure.

The area surrounding Audubon Park has a higher percentage of sidewalks than do the other two park neighborhoods. This neighborhood also displays the most connectivity as shown by the baseline service area reaching the maximum quarter-mile buffer surrounding the park (see Figure 15). These two observations suggest that Audubon Park has the potential to have a high degree of accessibility if additional ADA compliant pedestrian facilities were constructed.

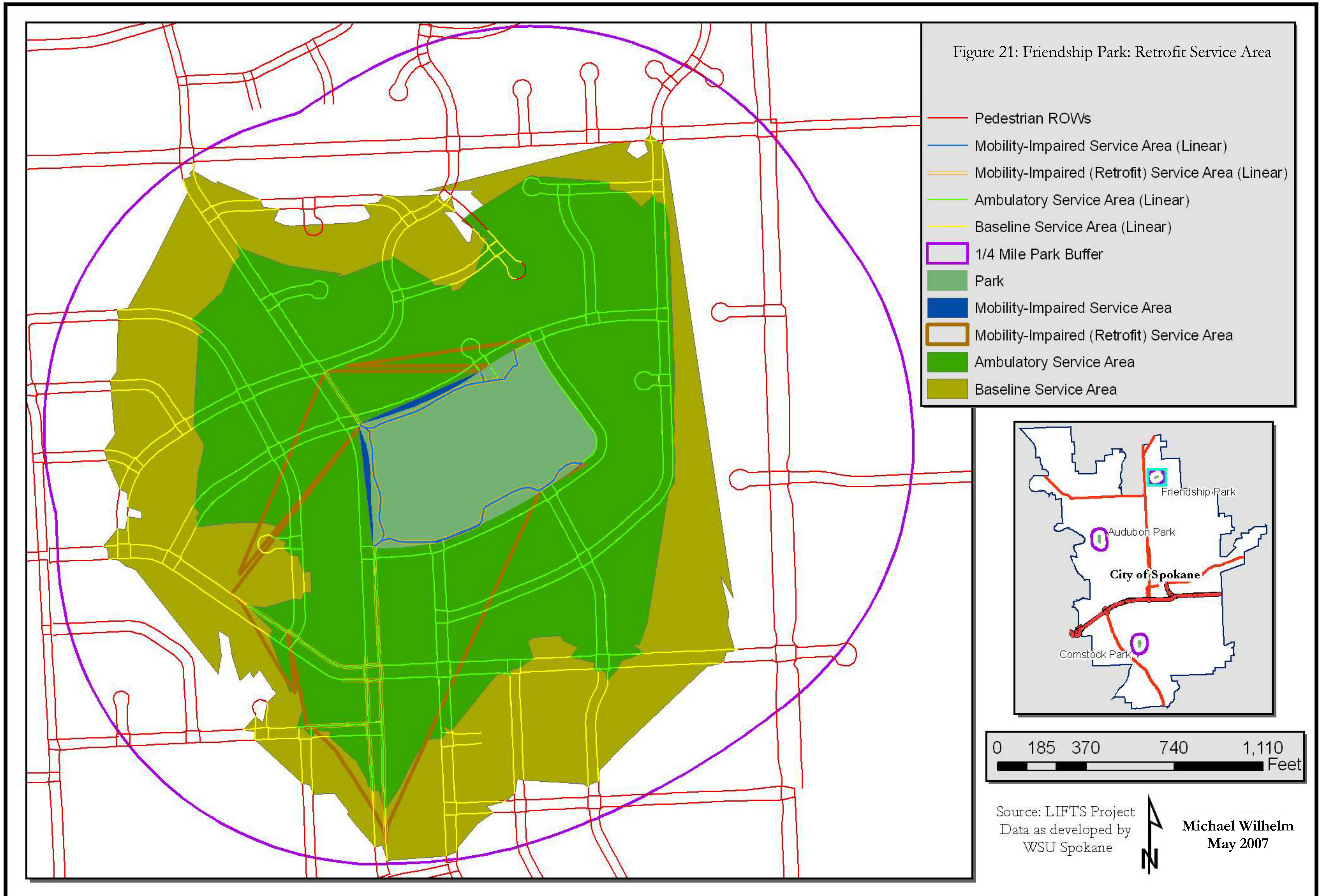
Figure 21: Friendship Park: Retrofit Service Area
Pedestrian ROWs
Mobility-Impaired Service Area (Linear)
Mobility-Impaired (Retrofit) Service Area (Linear)
Ambulatory Service Area (Linear)
Baseline Service Area (Linear)
1/4 Mile Park Buffer
Park
Mobility-Impaired Service Area
Mobility-Impaired (Retrofit) Service Area
Ambulatory Service Area
Baseline Service Area
Friendship Park
Audubon Park
City of Spokane
Comstock Park
0 185 370 740 1,110
Feet
Source: LIFTS Project
Data as developed by
WSU Spokane
N
Michael Wilhelm
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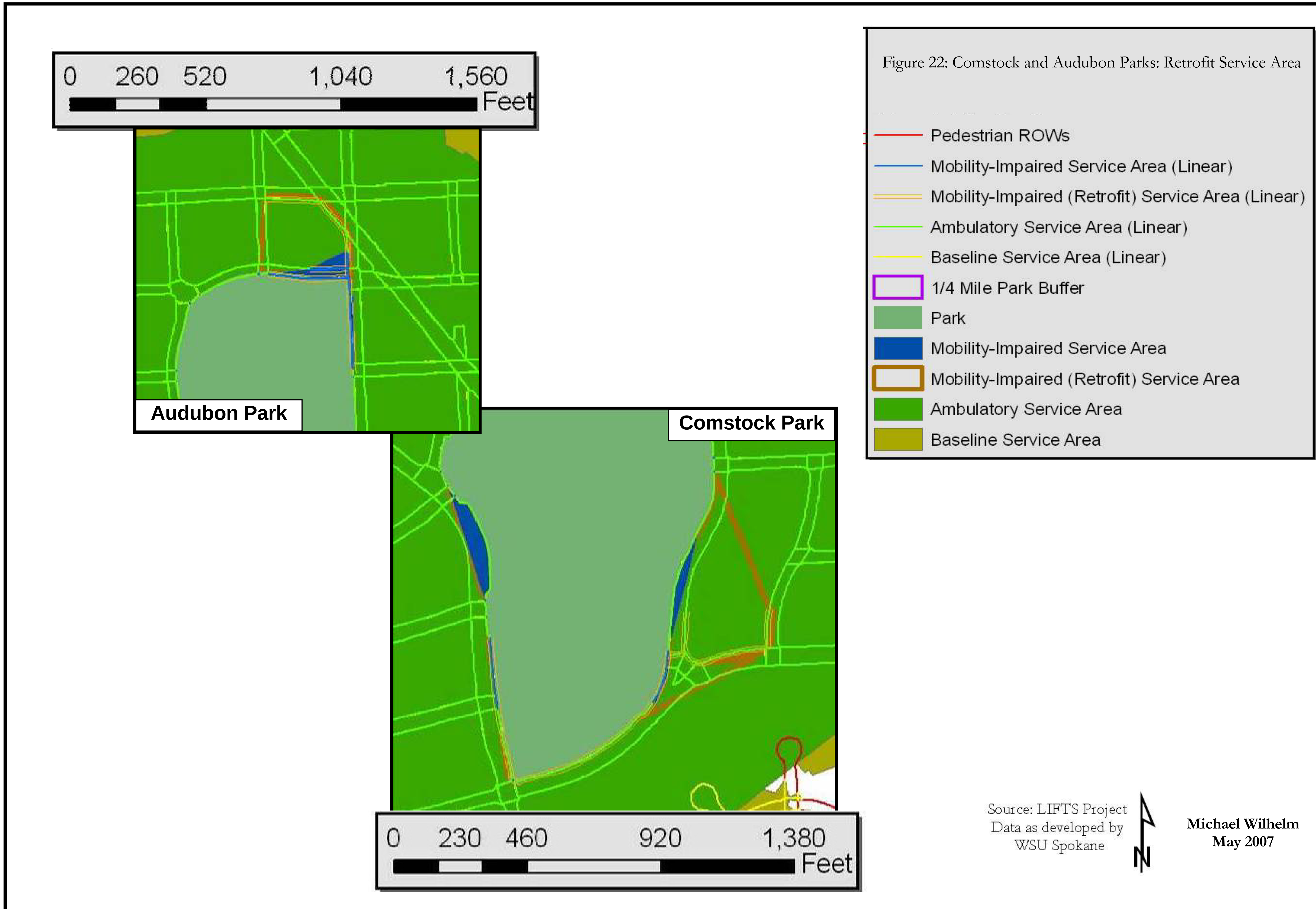
0 260 520 1,040 1,560
Feet
Audubon Park
Comstock Park
0 230 460 920 1,380
Feet
Figure 22: Comstock and Audubon Parks: Retrofit Service Area
Pedestrian ROWs
Mobility-Impaired Service Area (Linear)
Mobility-Impaired (Retrofit) Service Area (Linear)
Ambulatory Service Area (Linear)
Baseline Service Area (Linear)
1/4 Mile Park Buffer
Park
Mobility-Impaired Service Area
Mobility-Impaired (Retrofit) Service Area
Ambulatory Service Area
Baseline Service Area
Source: LIFTS Project
Data as developed by
WSU Spokane
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Michael Wilhelm
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Friendship Park shows the highest degree of accessibility with the modification of existing pedestrian facilities. The term modification here refers to making existing facilities ADA compliant. Friendship Park also has the highest amount of park perimeter curb ramps located at road intersections, a key for increasing accessibility.

The Comstock Park neighborhood has the highest relative accessibility for ambulatory pedestrians, indicating that ambulatory pedestrians have the least total impedances. This observation combined with the fact that is has the worst relative accessibility for mobility-impaired pedestrians demonstrate that making this neighborhood's pedestrian facilities ADA compliant would be the most costly.

The methods employed to measure the accessibility of the three parks showed value in creating a systematic method of evaluating accessibility. This method can be used to provide important information for policy and budget decisions prompted by the Americans with Disabilities Act. There is a great need to provide access to parks for everyone wanting to gain the benefits parks offer.

CHAPTER 6 – CONCLUSION

Summary

Pedestrianism will play an increasingly more important role in the future due to new environmental policies, changes in development patterns and an increase in the number of individuals unable to drive motor vehicles due to aging and infirmities. The walkability, or ease of walking, of any community depends on a variety of factors, one of which is accessibility. A robust combination of metrics for each of these factors would play an important role in assessing walkability. The methods of measuring accessibility described in this study are aimed at providing a piece to this comprehensive equation.

Relative accessibility is simple and provides a first step in displaying which neighborhoods are deficient in allowing access for any pedestrians with mobility limitations. The Normalized Patch Shape Index was useful in assessing each park's distribution of accessible are. The Pedestrian Route Directness metric provides a look at how convenient the access is to the parks. These three measurements together provide a comprehensive view of each park's accessibility.

The dataset used in this study has a high degree of spatial and attribute detail, which is required for identifying ADA accessible routes and service areas. Despite the high cost of creating and maintaining datasets like this one, many reasons exist for having them. They would be useful in pedestrian routing (similar to the Directions functionality on Google Maps or Mapquest), a pedestrian facility construction/maintenance inventory or analyses similar to this one.

Recommendations

This study produced two categories of recommendations, one for the City of Spokane and one for those interested in the research of accessibility measurement. The three parks studied have poor accessibility for mobility-impaired pedestrians, including individuals pushing baby strollers, wheelchair users and anyone else needing ADA compliant pedestrian facilities. If all parks in the city have the same poor level of service for this population, many changes must be made to achieve the goals set forth by the Spokane Parks and Recreation Department (2006). Existing sidewalks and curb ramps need to be made ADA compliant and new facilities need to be installed in these neighborhoods. Potentially limited funding requires spatial prioritization of construction, would should begin at the park, extend from the park in evenly spaced "pedestrian arterials" and finally fill in the gaps.

The method of measuring accessibility used in this research combines elements from other disciplines, making it more robust than discipline specific methods. It illustrates that connectivity, a common measurement used in evaluating walking conditions, is only one part of appraising the pedestrian network. A portion of Comstock Park's neighborhood which has long block faces, seen as having a low degree of connectivity, displays a high degree of accessibility to the park. Thus, the orientation of pedestrian facilities to common destinations can be as predictive in the choice of travel mode as values for block length, intersection density and link-node ratio, which are suggested by Dill (2004). The accessibility measurements observed in this study inherently analyze street orientation and other factors in determining areas most likely to be used by pedestrians.

For Further Study

This study focuses solely on the ability to access parks, just one component of walkability. Research from other walkability factors could be used to assign qualitative values to the input dataset. Examples include exposure to weather, slope, traffic intensity, aesthetic value and neighboring land uses. Routes could then be defined based on these level-of-service attributes, allowing pedestrians more control over what their walking experience could be. This resultant dataset could be a very detailed urban equivalent of a hiker's trail guide.

The inclusion of slope into the dataset requires a simple process because it can be taken from a common elevation dataset. Although many common elevation datasets are not detailed enough to define non-ADA compliant features, it certainly allows a broad first cut of features which are too steep.

The three broad categories of mobility utilized in this study are perhaps not ideal in analyzing accessibility for the wide variety of pedestrian abilities. Providing an interface allowing user-defined values for features within the dataset would permit a more realistic and customized look at accessibility. For instance, features that a visually-impaired pedestrian considers as barriers may not bother a wheelchair user. A greater number of impedances than were assigned here would be needed to allow features to have either some or no effect on travel.

A dataset similar to the one used here might be incorporated into studies of people-based measures of accessibility. Impedances included in the input dataset would allow a more realistic view of the places that are accessible based on time constraints. Previous studies have used a constant rate of travel, ignoring any absolute or relative impedances, as pointed out by Weber and Kwan (2002). Many issues still need to be researched, individually and in combination, to provide a true measurement of accessibility.

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APPENDIX A: ASSIGNED IMPEDANCE VALUES

Features representing NO FORMAL PATH, ALLEY CROSSING, DRIVEWAY CROSSING, or PATHWAY BRIDGE OR UNDERPASS were assigned the following impedance values. Values range from 1-5 and signify no impedance to most impedance respectively. The value of 99 symbolizes an absolute barrier or the most impedance.

<u>Linear Barriers</u>
Ambulatory
1 (**Accessible**), 2 (**Too Narrow**), 3 (**Poor Path Surface Condition**), 3 (**Too Steep**), 5 (**>1 of 3 exist: Too Narrow, Too Steep, Poor Path Surface**)
Mobility-Impaired
1 (**Accessible**), 99 (**Too Narrow**), 99 (**Poor Path Surface Condition**), 99 (**Too Steep**), 99 (**>1 of 3 exist: Too Narrow, Too Steep, Poor Path Surface**)

<u>Surface</u>
Ambulatory
1 (**Concrete**), 1 (**Asphalt**), 1 (**Alternative Paving**), 3 (**Dirt**), 4 (**Grass**), 5 (**Gravel**)
Mobility-Impaired
1 (**Concrete**), 1 (**Asphalt**), 2 (**Alternative Paving**), 99 (**Dirt**), 99 (**Grass**), 99 (**Gravel**)

Features having an attribute value representing FORMAL PATH for the Pedestrian Path Type attribute were assigned impedance values as follows (ordered by the underlined attribute and the bold attribute value):

<u>Linear Barriers</u>
Ambulatory
1 (**Accessible**), 2 (**Too Narrow**), 3 (**Poor Path Surface Condition**), 3 (**Too Steep**), 5 (**>1 of 3 exist: Too Narrow, Too Steep, Poor Path Surface**)
Mobility-Impaired
1 (**Accessible**), 99 (**Too Narrow**), 99 (**Poor Path Surface Condition**), 99 (**Too Steep**), 99 (**>1 of 3 exist: Too Narrow, Too Steep, Poor Path Surface**)

<u>Surface</u>
Ambulatory
1 (**Concrete**), 1 (**Asphalt**), 1 (**Alternative Paving**), 3 (**Dirt**), 4 (**Grass**), 5 (**Gravel**)
Mobility-Impaired
1 (**Concrete**), 1 (**Asphalt**), 2 (**Alternative Paving**), 99 (**Dirt**), 99 (**Grass**), 99 (**Gravel**)

Features having an attribute value representing ROAD CROSSING for the Pedestrian Path Type attribute were assigned impedance values as follows (ordered by the underlined attribute and the bold attribute value):

Traffic Control Type
Ambulatory
7 (**Stopsign**), 4 (**Stoplight**), 2 (**Stoplight with pedestrian activated signal**), 3 (**Flashing caution stoplight**), 3 (**Signed pedestrian crossing**), 99 (**Prohibited**), 4 (**Uncontrolled**)
Mobility-Impaired
8 (**Stopsign**), 4 (**Stoplight**), 2 (**Stoplight with pedestrian activated signal**), 3 (**Flashing caution stoplight**), 3 (**Signed pedestrian crossing**), 99 (**Prohibited**), 5 (**Uncontrolled**)

Pedestrian Island
Ambulatory
1 (**Not Applicable**), 1 (**Accessible**), 4 (**Not Accessible**)
Mobility-Impaired
1 (**Not Applicable**), 1 (**Accessible**), 99 (**Not Accessible**)

Road Xing Markings
Ambulatory
1 (**Striped non-ADA compliant**), 1 (**Striped ADA compliant**), 4 (**Crossing not striped**)
Mobility-Impaired
3 (**Striped non-ADA compliant**), 1 (**Striped ADA compliant**), 4 (**Crossing not striped**)

Linear Barriers
Ambulatory
1 (**Accessible**), 6 (**No Ramps**), 5 (**1 Non-ADA compliant ramp**), 3 (**2 Non-ADA complaint ramps**), 2 (**1 ADA compliant and 1 non-ADA compliant ramps**), 4 (**1 ADA compliant ramp**)
Mobility-Impaired
1 (**Accessible**), 99 (**No Ramps**), 99 (**1 Non-ADA compliant ramp**), 99 (**2 Non-ADA complaint ramps**), 99 (**1 ADA compliant and 1 non-ADA compliant ramps**), 99 (**1 ADA compliant ramp**)

Lane Number
Ambulatory
1 (**One lane**), 1 (**Two lanes**), 2 (**Three lanes**), 3 (**Three lanes**), 5 (**Four lanes**), 7 (**>= Six lanes**)
Mobility-Impaired
1 (**One lane**), 1 (**Two lanes**), 2 (**Three lanes**), 4 (**Three lanes**), 6 (**Four lanes**), 10 (**>= Six lanes**);

APPENDIX B: NETWORK DATASET CREATION

Pedestrian Network Creation

Within the properties of sw3, all fields were made visible in order to be exported to another dataset.

Selected features from sde2.MIKE.sw3 that have their center within 1320 ft from the ¼ mile buffer (1/2 mile total) from the 3 parks were exported to a new feature class.

A new Topology was created within the Ped_Access.mdb called Ped_Network_Top in order to correct and verify topology. The cluster tolerance was set to 0.01 feet. Two datasets participate in the topology: SA_Origins and sw3_HalfMile2. SA_Origins was ranked 2 and sw3_HalfMile2 was ranked 1. The rules for sw3_HalfMile2 are Must Not Intersect or Touch Interior, Must Not Have Dangles, Must Not Have Pseudos, Must Be Single Part.

The topology of sw3_HalfMile was corrected within the ¼ mile buffer surrounding each park.

The Ped_Network_ND network dataset was created with sw3_HalfMile2 and SA_Origins participating. End point connectivity was assigned to sw3_HalfMile2, while the Connectivity Policy for SA_Origins was set to Honor. The connectivity was not modified with elevation data. The default "Global Turns" modeled turns in the network. The only attribute in the network dataset is length (usage = cost, units = feet, data type = double). Driving direction settings are established in the network dataset.

Network Turns Feature Creation

The turns were created on corners that have curb ramps with no accessible landing at the top (Ramp Typology = 112, 122, 212, 222, 312, 322, 412, or 422). These turns were assigned an impedance value of 99 for mobility impaired pedestrians due to cross slopes in excess of the recommended 1:48.

Service Area Creation

A point feature class was created within Ped_Access.mdb called SA_Origins in order to store the service area origins. The Park attribute contains the park name for which the origins are associated. The OriginNo contains a stable, unique id number for each point.

The service area origins were created by using the Intersection tool in the Editor toolbar on all road crossings intersecting the park's perimeter (as defined by the 3Parks dataset). All points where road crossings and park perimeters intersect have a service area origin, except on corners where both road crossings come together to form one entry point (only one origin point was created there).

Impedance

Impedance factor values were assigned to each attribute value on a scale of most favorable (1) to least favorable (5). Using a formula, in parenthesis below, dependent on feature type the impedance values are combined to alter the travel rate. The impedance values are shown below with the attributes that contribute to the degree of their favorability. Values for mobility-impaired pedestrians are shown in italics.

No Formal Path: Linear Barriers, Surface
Formal Path: Linear Barriers, Surface, Path Surface Position
Alley Crossing: Linear Barriers, Surface
Driveway Crossing: Linear Barriers, Surface
Road Crossing: Traffic Control Type, Pedestrian Island, Road Xing Markings, Linear Barriers, Lane Number
Pathway Bridge or Underpass: Linear Barriers, Surface

<u>Value Assignment by Attribute</u>
Formal Path, No Formal Path, Alley Crossing, Driveway Crossing, Pathway Bridge or Underpass

Linear Barriers (L): 1 (Accessible), 2 (Too Narrow), 3 (Poor Path Surface Condition), 3 (Too Steep), 5 (>1 of 3 exist: Too Narrow, Too Steep, Poor Path Surface); *1 (Accessible), *99 (Too Narrow), *99 (Poor Path Surface Condition), *99 (Too Steep), *99 (>1 of 3 exist: Too Narrow, Too Steep, Poor Path Surface)*

Surface (S): 1 (Concrete), 1 (Asphalt), 1 (Alternative Paving), 3 (Dirt), 4 (Grass), 5 (Gravel); *1 (Concrete), 1 (Asphalt), 2 (Alternative Paving), *99 (Dirt), *99 (Grass), *99 (Gravel)*

Road Crossing

$$\text{Travel Rate} = \left(0.2 * \frac{1}{T}\right) + \left(0.2 * \frac{1}{P}\right) + \left(0.2 * \frac{1}{M}\right) + \left(0.2 * \frac{1}{L}\right) + \left(0.2 * \frac{1}{N}\right)$$

Traffic Control Type (T): 7 (Stopsign), 4 (Stoplight), 2 (Stoplight with pedestrian activated signal), 3 (Flashing caution stoplight), 3 (Signed pedestrian crossing), *99 (Prohibited), 4 (Uncontrolled); *8 (Stopsign), 4 (Stoplight), 2 (Stoplight with pedestrian activated signal), 3 (Flashing caution stoplight), 3 (Signed pedestrian crossing), *99 (Prohibited), 5 (Uncontrolled)*

Pedestrian Island (P): 1 (Not Applicable), 1 (Accessible), 4 (Not Accessible); *1 (Not Applicable), 1 (Accessible), *99 (Not Accessible)*

Road Xing Markings (M): 1 (Striped non-ADA compliant), 1 (Striped ADA compliant, 4 (Crossing not striped); *3 (Striped non-ADA compliant), 1 (Striped ADA compliant, 4 (Crossing not striped)*

Linear Barriers (L): 1 (Accessible), 6 (No Ramps), 5 (1 Non-ADA compliant ramp), 3 (2 Non-ADA complaint ramps), 2 (1 ADA compliant and 1 non-ADA compliant ramps), 4 (1 ADA compliant ramp); *1 (Accessible), *99 (No Ramps), *99 (1 Non-ADA compliant ramp), *99 (2 Non-ADA complaint ramps), *99 (1 ADA compliant and 1 non-ADA compliant ramps), *99 (1 ADA compliant ramp)*

Lane Number (N): 1 (One lane), 1 (Two lanes), 2 (Three lanes), 3 (Three lanes), 5 (Four lanes), 7 (>= Six lanes); *1 (One lane), 1 (Two lanes), 2 (Three lanes), 4 (Three lanes), 6 (Four lanes), 10 (>= Six lanes);*

$$I_{om} = \left(0.5 \times \frac{1}{[MI\_LinBar]}\right) + \left(0.5 \times \frac{1}{[MI\_Surface]}\right)$$

$$I_{rm} = \left(0.2 \times \frac{1}{[MI\_LinBar]}\right) + \left(0.2 \times \frac{1}{[MI\_IntCtrlType]}\right) + \left(0.2 \times \frac{1}{[MI\_PedIsl]}\right) + \left(0.2 \times \frac{1}{[MI\_XingMrkng]}\right) + \left(0.2 \times \frac{1}{[MI\_LaneNo]}\right)$$

*The impedance factor value of 99 was used to select out features which create an absolute barrier. See the VBScript code below.

<u>Value Assignment to Feature</u>

Twelve fields were added to sw3_HalfMile2 which store impedance values for the seven different attributes listed above, six for ambulatory and six for mobility impaired pedestrians. Features were selected according to their attribute values and the values for these new attributes were assigned.

All features which do not have a value that indicates a lack of access were considered to be accessible. For example, all formal paths had the value 1 assigned for the Intersection Control Type impedance attribute (A_IntCtrlType and MI_IntCtrlType) due to their lack of values for the Intersection Control Type attribute. Another example is that all features which do not have a Linear Barrier attribute value assigned were given a value of 1 ("Accessible") for the A_LinBar and MI_LinBar attributes due to the apparent lack of impedance relating to this attribute (narrowness, steepness and surface height continuity).

$$I_{oa} = \left(0.5 \times \frac{1}{[A\_LinBar]}\right) + \left(0.5 \times \frac{1}{[A\_Surface]}\right)$$

$$I_{ra} = \left(0.2 \times \frac{1}{[A\_LinBar]}\right) + \left(0.2 \times \frac{1}{[A\_IntCtrlType]}\right) + \left(0.2 \times \frac{1}{[A\_PedIsl]}\right) + \left(0.2 \times \frac{1}{[A\_XingMrkng]}\right) + \left(0.2 \times \frac{1}{[A\_LaneNo]}\right)$$

The variables are as follows: I represents impedance, r represents road crossing features, o represents features other than road crossing, a symbolizes ambulatory pedestrians, m symbolized mobility-impaired pedestrians, variables enclosed in brackets represent attribute values from the stated attribute field.

The following VBScript was used to populate the [MI_ImpedMins] attribute for the "no formal path", "formal path", "alley crossing", "driveway crossing", "pedestrian bridge or underpass" or "not recorded" features.

```
Dim a as Double
IF [MI_LinBar] = 99 or [MI_Surface] = 99 THEN
  a = 0.001
ELSE
  a = (0.5 * (1/ [MI_LinBar])) + (0.5 * (1/ [MI_Surface] ))
END IF
```

The following VBScript was used to populate the [A_ImpedMins] attribute for the "no formal path", "formal path", "alley crossing", "driveway crossing", "pedestrian bridge or underpass" or "not recorded" features.

```
Dim a as Double
IF [A_LinBar] = 99 or [A_Surface] = 99 THEN
  a = 0.001
ELSE
  a = (0.5 * (1/ [A_LinBar])) + (0.5 * (1/ [A_Surface] ))
END IF
```

The following VBScript was used to populate the [A_ImpedMins] attribute for the "road crossing" features.

```
Dim a as Double
IF [A_LinBar] = 99 or [A_IntCtrlType] = 99 or [A_PedIsl] = 99 or [A_XingMrkng] = 99 or
[A_LaneNo] = 99 THEN
  a = 0.001
ELSE
  a = (0.2 * (1/ [A_LinBar])) + (0.2 * (1/ [A_IntCtrlType] )) + (0.2 * (1/ [A_PedIsl] )) + (0.2
* (1/ [A_XingMrkng] )) + (0.2 * (1/ [A_LaneNo] ))
END IF
```

The following VBScript was used to populate the [MI_ImpedMins] attribute for the "road crossing" features.

```
Dim a as Double
IF [MI_LinBar] = 99 or [MI_IntCtrlType] = 99 or [MI_PedIsl] = 99 or [MI_XingMrkng] =
99 or [MI_LaneNo] = 99 THEN
  a = 0.001
ELSE
  a = (0.2 * (1/ [MI_LinBar])) + (0.2 * (1/ [MI_IntCtrlType] )) + (0.2 * (1/ [MI_PedIsl] )) +
(0.2 * (1/ [MI_XingMrkng] )) + (0.2 * (1/ [MI_LaneNo] ))
END IF
```

<u>Travel Rate Assignment</u>

After the Impedance values have been assigned, two new fields were created to store the rate of travel values; [A_Rate] and [MI_Rate]. The rate of travel used in these calculations is 264 feet per minute or 3 miles per hour. The unit feet per minute is used because the distance attribute that was used in the travel time calculation is in feet.

[A_Rate] = [A_ImpedMins] * 264
[MI_Rate] = [MI_ImpedMins] * 264

After the rate attributes have been assigned, the travel time attributes need to be assigned; [A_TravTime] and [MI_TravTime]. These values are in minutes, as indicated earlier. The calculations for these attributes are as shown below.

[A_TravTime] = [SHAPE_Length] / [A_Rate]
[MI_TravTime] = [SHAPE_Length] / [MI_Rate]

The baseline travel time was calculated and inserted into the [TravTime] field within the pedestrian network dataset. These values were created using the following equation:

[TravTime] = [SHAPE_Length] / 264

<u>Network Turn Dataset Integration</u>

The [MI_TravTime] attribute was added to the network turn dataset CurbRampXings. Essentially the function of this dataset is to highly discourage mobility-impaired pedestrians from crossing curb ramps which have a cross slope steeper than 1:48. It was calculated with the following formula in a similar fashion as the same attributes in the pedestrian network line dataset:

[MI_TravTime] = [SHAPE_Length] * 0.264

<u>Point Barrier Integration</u>

The point barriers dataset was integrated into the line dataset of the pedestrian network. Points attributed as Type = 1 (Surface Height Change) were associated with the nearest line segment. That line segment was assigned the Linear Barrier attribute 2 (Poor Path Surface). One point barrier within a quarter mile of Audubon Park was attributed as a mailbox that made the pedestrian path narrower than thirty-two inches. The nearest line segment was attributed with the Linear Barrier value of 1 (Too Narrow). The impedance values assigned to linear network features nearest to these points was 99, serving as absolute barriers.

Adjustments for ADA Retrofit Network

Attributes were created within the line dataset of the pedestrian network to represent a network in which all existing ADA non-compliant features have been changed to be ADA compliant. The [MIo_Linbar] attribute was assigned by finding all road crossing features with [Lin_Bar] values of 7 (2 non-ADA compliant ramps) and 8 (1 non-ADA compliant and 1 ADA compliant ramp). These features were assigned a [MIo_LinBar] value of 1 to show the retrofit of both curb ramps to be ADA compliant. For all features other than road crossings, the [MIo_Linbar] was assigned a value of 1 if the [Lin_Bar] value is 1, 2, 3, or 4. This represents retrofitting of all pedestrian facilities to be ADA compliant.

The [MIo_XingMrkng] attribute shows the change from non-ADA crosswalk markings to ADA compliant markings. This involves repainting the markings to include ample space for entering and exiting the curb ramp. All road crossings with [XingType] = 1 were assigned a [MIo_XingMrkng] value of 1 instead of 3, the value in [MI_XingMrkng]

The [MIo_ImpedMins] attribute was calculated in the same manner as was the [MI_ImpedMins] attribute, as shown in the VBScript above.

Similarly, [MIo_Rate] and [MIo_TravTime] were calculated in an identical manner as was [MI_Rate] and [MI_TravTime].