A GIS Approach to Evaluating Streetscape and Neighborhood Walkability

By

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An Exit Project

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Thank you…you know who you are. More to come…

TABLE OF CONTENTS

CHAPTER 1

Introduction

Walking is the most used form of transportation. Pedestrian access between home, work, and urban amenities improves residents' quality of life by providing transportation options that are inexpensive and facilitate healthy lifestyles. The availability of pedestrian infrastructure (i.e., sidewalks, crossing aids, etc.) is a primary concern for citizens without access to automobile transportation. Sidewalks provide safe and efficient routes that enable residents to access employment, recreation, and education opportunities – to name a few. Thus, provision of pedestrian infrastructure that facilitates safe travel is a key issue for urban planners and public policy makers.

Middle school students are unique in their freedom of mobility on one hand, and their reliance on alternatives to automobile transportation on the other hand. In the past, walking to school was one of many opportunities for physical activity available to middle school students. However, recent research finds an increasing number of youth are being driven to school compared to students in the past. Although the loss physical activity required by walking rather than driving to school is moderate, it is one factor responsible for a nationwide rise in childhood obesity rates. By addressing these trends today, urban planners and policy makers have the opportunity to limit the future consequences these trends. It is in the best interest of communities to provide safe pedestrian access to urban amenities, thereby promoting physical activity and improving health.

BACKGROUND

Urban planning is deeply rooted in the public health profession. Public health was a major concern of Fredrick Law Olmstead who, before his career as landscape architect and urban planner, served as executive secretary to the United States Sanitary Commission, the precursor to the Red Cross (Rybczynski 1999). By the 1920's and 30's, visionary architects and planners, including Frank Lloyd Wright and Le Corbusier, were beginning to wrestle with the opportunities and challenges of industrialization, urbanization, and transportation in urban planning (Corbusier 1929). The U.S. Supreme Court ruling in the landmark case Euclid, Ohio v. Ambler Realty (1926), resulted in the Zoning Enabling Act, which allowed local governments to separate land-uses in the interest of public health, safety, and welfare. Urban planning provides residents with clean water and air, organized transportation systems, dependable infrastructure, coordinated services, and a generally improved quality of life. And yet today it remains unclear how contemporary regulations intended to improve our health and welfare are effecting physical activity and thus public health.

The Gilded Age in the U.S. was characterized later as a period of ‘social Darwinism,’ where progress necessarily meant the survival of the fittest. But by the turn of the century, Americans came to realize that society needed to be democratized to ensure everyone had a fair opportunity for liberty and the pursuit of happiness. Progressive thinkers articulated a need for controls that would preserve community values that had been smothered by materialism, greed, and the glimmer of the new America (Putnam 2000). Reformers began to see society’s ills – poverty, crime, and morbidity – as a function of societal and economic variables, rather than individual moral failings. This new perspective underpinned the Progressive movement’s intention to improve urban life.

So what action did Progressive reformers take during the first two decades of the 20th century? Frederick Law Olmsted, designer of New York’s Central Park, crusaded for parks and recreation areas as a means to increase public health and quality of life. Robert Moses pushed for public parks on Long Island to provide accessible, open space for low-income residents of the city working 10-hour days in polluted, noisy factories (Caro 1975). The Progressives were responsible for sweeping policy changes and institutional programs still in existence. Child labor laws, the eight-hour workday, the FDA, and National Park Service were all created in the nineteen-teens, thereby formalizing many of the philosophies espoused by the Progressive Movement.

In particular, Progressives were aware of the importance of educating youth – it was at this time that kindergarten and high school appeared as familiar elements in American public schooling. New youth groups were created, including the Boy Scouts and Girl Scouts, 4-H, Big Brothers and Big Sisters, and the American Camping Association. These programs helped introduce youth to the virtues of work, community, and living a healthy lifestyle (Putnam 2000).

Today parents, teachers, school administrators, and health officials are reviving the philosophies that formed the foundation of the Progressive Movement as a strategy for combating a staggering rise in childhood obesity. Recent reports by public health officials highlight a growing obesity epidemic among children in the United States. This issue is caused in part by a lack of physical activity, yet school districts across the U.S. are cutting physical education courses due to budget cuts. The Centers for Disease Control recommend adolescents be physically active daily, or nearly every day, as part of play, work, transportation, recreation, physical education, or planned exercise (CDC 2004). Whereas half of all children 5-18 years-old walked or biked to school in 1969, in 2001 nearly 85% of children 5-15 years were bused or chauffeured by their parents (Appleyard 2003). Some attribute this trend in part to automobile-oriented urban development that dominates suburban neighborhoods across the U.S (Doyle 2004; Handy 1996). Many factors conspire against walking and bicycling in America, but infrastructure that limits pedestrian and bicycle transportation is receiving considerable critical review.

Reinvigorated by their role in this debate, urban planning practitioners and academics are reevaluating the way infrastructure facilitates or hinders walking and biking – a line of inquiry predicated on the notion that the built environment influences individual behavior, and thus physical activity. Researchers are attempting to quantify the significance of the built environment on individuals' ability to walk and ride bicycles. Recently, three literature reviews by Pikora et al (2003), and Lee and Moudon (2003 and 2004) established a link between public health and transportation planning. The common theme among these reviews – safety is a primary concern of pedestrians.

The following questions guided the project presented in this paper: (1) How do fringe (i.e., suburban) schools differ in terms of walkability safety from urban core (i.e., traditional, grid) schools; (2) What is the spatial distribution of pedestrian safety amenities within individual school neighborhoods and between various school neighborhoods; and (3) Do students, when presented with two equally long routes, tend to favor more walkable/safer streets? Three methods of analysis were used to answer these research questions. First, the density and types of intersections for school neighborhoods were compared to show which neighborhoods offer students more route options between home and school. Second, the streets within ½-mile of each middle school were rated for walkability using a walkability audit instrument. Third, students actual routes to school were compared with the shortest possible route from home to school.

METHODOLOGY

Past research sought to understand pedestrian access and walkability at city and neighborhood scales using demographic and spatial information. The U.S. Census provides detailed data about the social, economic, and behavioral trends of urban residents at the block level, while TIGER files outline the street network of urban areas. By evaluating transportation behavior, street design (i.e., grid, cul de sac), and the distribution and density of land-uses, these early studies offer methods to analyze walkability on a macro-scale.

This project builds on these previously established methods by adding a new level of analysis. Using a pedestrian environment audit instrument and a household survey the results presented in this paper provide a micro- as well as macro-scale analysis of neighborhood walkability and pedestrian safety. GIS software was used to evaluate the spatial distribution of land-use types, street and intersection densities and characteristics, and student routes to school.

PURPOSE OF THIS PROJECT

The purpose of this project is three-fold: 1) to evaluate neighborhood walkability near middle schools in terms of infrastructure amenities that enhance pedestrian safety; 2) to evaluate walkability using streetscape characteristics to augment neighborhood scale variables; 3) to compare student transportation behavior with the walkability safety characteristics identified for four neighborhoods in Springfield and Bend, Oregon.

ORGANIZATION OF THIS EXIT PROJECT

The following paper is organized into 4 chapters and 7 appendices that present research precedents, research methods, findings, analysis and conclusions, and recommendations of this streetscape walkability assessment. The chapters and appendices contain the following information:

- *Chapter 2: Literature Review* provides a survey of research related to physical activity and health, pedestrian infrastructure, walkability measures, and environmental audit instruments.
- *Chapter 3: Methodology* presents the steps taken to acquire and interpret data intended to answer the research questions that guided this project.
- *Chapter 4: Findings and Analysis* outlines the data obtained for this project and an interpretation of implications based on these findings.
- *Chapter 5: Recommendations* is separated into recommendations that might improve future projects using/adapting the methods presented here, as well as recommendations for future lines of inquiry in this field of study.
- *Appendix A: PEDS Walkability Audit Instrument*
- *Appendix B: Walkability Safety Rating Methods*
- *Appendix C: Agnes Stewart Middle School Parent Transportation Survey*
- *Appendix D: Database Coding Criteria*
- *Appendix E: PEDS Audit Protocol*
- *Appendix F: Walkability Safety Rating Audit Results*

CHAPTER 2

Literature Review

Land use regulations are predicated on improving the health, safety, and welfare of residents. Over the past 80 years, land use regulations have dictated the nature and extent of the built environment in nearly all U.S. urban areas. In light of a recently identified U.S. obesity epidemic, planning and public health professionals are exploring the impacts of the built environment on physical activity (i.e., walking, biking, etc.). In particular, the influence of streetscape elements on safe pedestrian access to schools is emerging as a topic of concern for planners, school administrators, public health officials, and policy makers.

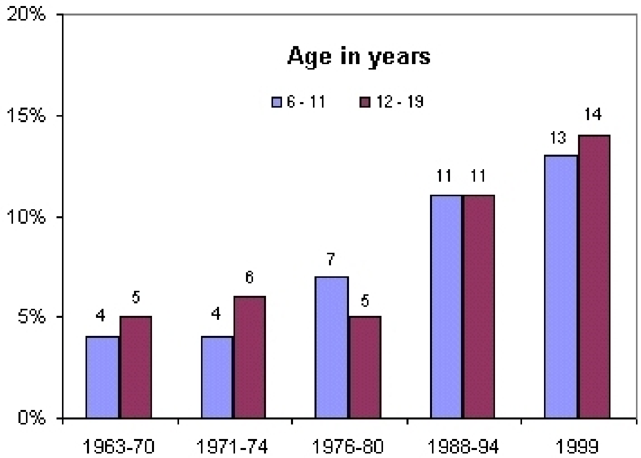
This chapter reviews links between the streetscape environment and physical activity, as well as methods of measuring characteristics of the pedestrian landscape. The chapter begins by exploring the connection between physical activity and its associated health benefits with attention to the causes and consequences of the emerging childhood obesity epidemic. One aspect in particular, the influence of the streetscape environment on perceptions of safety is reviewed. The chapter continues with an examination of recent policies implemented across the U.S. and Europe to increase pedestrian access to schools for primary and secondary school students. The chapter concludes with a summary of research approaches for evaluating walkability and methods of quantifying streetscape features using geographic information systems (GIS).

Relationship Between Physical Activity and Health

It is generally accepted that increased physical activity promotes good health and increases life expectancy. A major national study found that 42% of men and 28% of women were overweight, and 21% of men and 27% of women were obese (Must 1999) and that U.S. adult obesity rates increased from 12.1% to 17.9% between 1991 and 1998 (Mokdad 1999). In a 1993 study, 14% of all deaths in the United States were attributed to a severe lack of physical activity and poor dietary habits (McGinnis 1993). In a later study, sedentary lifestyles were linked to 23% of deaths resulting from major chronic diseases (Hahn 1998). That is to say, people who exercise reduce their risk of developing or dying from heart disease, diabetes, colon cancer, and high blood pressure. In fact, long-term changes in obesity and being overweight are more closely correlated to physical activity than dietary changes (Prentice 1995). Thus, people who exercise tend to have longer lives than less active individuals (Kushi 1997; Lee 1999; Wei 1999). These results suggest policies and programs aimed at increasing physical activity will prove to be effective in addressing the current obesity epidemic in the U.S.

Although physical activity is a critical component of stable mental health, balanced energy levels, stress management, and overall health youth are exercising less today than their counterparts 35 years ago (U.S. Department of Health and Human Services 2002). More than one-third of adolescents in grades 9-12 do not regularly engage in vigorous physical activity – rates significantly higher than in the past (Figure 2-1). Some contributing factors to this trend are thought to include physical education policies, automobile use, television and computer access, neighborhood safety, and access to recreation. One study showed 43% of students in grades 9-12 watch television more than two hours per day (Kahn 2000). And although parents and teachers overwhelmingly support daily physical education courses at all grade levels, only Arkansas, California, Mississippi, and Texas have passed legislation to encourage improvements at the local level (U.S. Department of Health and Human Services 2002). Moreover, only 8% of elementary schools, 6% of middle/junior high schools, and 6% of senior high schools provide daily P.E. during the entire school year at all grade levels (Centers for Disease Control 2000). In light of these figures, the U.S. Department of Health and Human Services (USDHHS) and the Surgeon General support increasing the proportion of adolescents who engage in moderate physical activity for at least thirty minutes, five days a week and recommend increasing the proportion of trips made by walking and biking as a means to improve health in all Americans (U.S. Department of Health and Human Services 2002).

Figure 2-1. Prevalence of Overweight Children and Adolescents ages 6-19



Source: CDC/NCHS, NHES and NHANES[1]

SIDEWALKS AND PHYSICAL ACTIVITY

Walking is by far the preferred means of physical activity for most people in part because no special equipment is required and it is easily accessible (Ball 2000; Bull 2000; Giles-Corti 2002). Accessibility of streets may have something to do with their popularity as places for physical activity. Residents can walk out their door to enjoy a brisk walk when it is convenient and return when their available time has expired. Sidewalks are common locations for transportation to work, school, and other local facilities. In a study of western Australian adults, Seaton (2001) found that 42% of residents walked to local facilities rather than drive or bike during the 2 weeks prior to questioning, and a second study in the same area found that one quarter of men and women walked during the previous week (Bull 2000). As destinations for recreation, Giles-Corti and Donavan (2002) found that 46% of respondents use their neighborhood streets for exercise activity, compared to just 11% employing gyms, health clubs, or exercise centers, and 9% using sport or recreation centers. In the U.S., Brownson (2001) found 66% of low-income respondents use neighborhood streets for physical activity. Other freely available public resources such as trails, parks, and open spaces are also common places for exercise (Giles-Corti 2002).

[1] Note: Excludes pregnant women starting with 1971-74. Pregnancy status not available for 1963-65 and 1966-70. Data for 1963-65 are for children 6-11 years of age; data for 1966-70 are for adolescents 12-17 years of age, not 12-19 years.

One reason neighborhood sidewalks may be so popular is their dual-purpose as both *destinations* for recreation and *routes to* places. The prevalence of walking also explains the popularity of neighborhood sidewalks for physical activity. Despite the popularity of walking for exercise and transportation research has found several limitations to pedestrian access – especially for youth.

WALKABILITY AND SAFETY

Sidewalks and bike paths are scarce in many communities, and parents worry their children will face dangerous strangers on their way to school. The perception of safety in terms of crime and traffic are crucial factors of walking and biking rates and thus community health. Jane Jacobs, a co-creator of the term 'social capital,' argues many of the same points as Robert Putnam regarding the influence of public safety on walkability. Jacobs argues that city streets must have clearly defined public and private spaces. Secondly, she insists buildings must face the sidewalk so there are many 'eyes on the street.' This ensures that strangers and residents can be seen and held accountable for their actions by anyone watching. Finally, Jacobs believes streets must have people – to increase the number of eyes, but also generate activity and life (Jacobs 1961; Putnam 2000).

Jacobs suggests that informal social control, including the shopkeeper protecting his/her customers, the couple walking to a movie, and parents running errands, collectively provide a layer of oversight that protects individuals on the street. The most essential element creating this atmosphere is a substantial number of shops, stores, restaurants, bars, and public places that attract 'good people.' The upshot of full sidewalks is that nothing goes unnoticed, including crime. Wilson and Keeling recall the effect foot patrol officers had on Newark residents when they replaced car patrols (Wilson 1982). Although foot patrols had no effect on crime per se they fooled the residents into thinking the streets were safer. The foot patrols effectively elevated the level of public order in these neighborhoods, and to the extent that residents felt free to go outside they too increased the level of order. Together they increased the number of eyes on the street. These results suggest that programs that promote walking and biking to schools may increase residents' perception of safety simply by elevating the number of people on the street. The following section highlights a sample of policies and programs developed to encourage walking and biking to schools.

Traffic safety is another primary concern for parents of school age children. Forty percent of parents polled in a 1999 national survey by the Centers for Disease Control cited traffic danger as a major barrier for children walking to school (Appleyard 2003). National rates of childhood obesity are a growing concern. In 2003, the Robert Wood Johnson Foundation conducted a national policy research project to identify opportunities for increasing physical activity and healthy food options in schools. The report found policies at the district and individual school level are most effective, yet most current school board policies are out of date and have demonstrated little initiative to make healthy eating or daily physical activity a priority (Robert Wood Johnson Foundation 2003). However, a grassroots, nationwide safe routes to schools movement has been gaining support in Europe and the U.S.

The safe routes to schools (SR2S) concept was first created in Odense, Demark in the mid-1970s as a response to extraordinarily high child pedestrian accident rates. The city created a network of pedestrian and bicycle paths, narrow streets, and traffic islands to reduce traffic speeds. Within 10 years the number of pedestrian accidents dropped 80%. In the 1990s a British group called Sustrans created 10 safe routes programs employing bike lanes, traffic calming, and raised crossings. Two years after the program was initiated the rate of bicycle use tripled and pedestrian casualties decreased 77%. The first U.S. SR2S program was started in the Bronx, New York in 1999. The program has improved pedestrian access to 38 elementary schools through collaborative efforts of parents, teachers, principals, community leaders, and city agencies (Appleyard 2003).

California's Safe Routes to School Program inspired officials and community members in Marin County to create a grassroots initiative which increase walking and biking to school (Staunton 2003). The state program provides materials, training manuals, and guidance for community members. The program typically involves mapping of routes and infrastructure improvements to improve access to schools by foot and bike. The program also sponsors special events, contests, and innovative concepts[2] such as "walking school buses" and "bike trains" to generate and maintain the interest of the community. Moreover, committees were formed in Marin County that involved public safety, public works, education, and health

[2] These include a walkability checklist, sample letters to parents in 13 languages, a "guide to success" with instructions on how to create a walking school bus and a bike train, and a guide on how to create safe drop-off points for children walking to school (www.cawalktoschool.com/dropoff_zones.php).

officials. The committees created improvement plans, applied for funding, and enhanced crosswalks and signage to make it easier for kids to walk and cycle to school. And after two years the program appears to be working. Fifteen participating public schools reported an increase in walking (64 percent), bicycling (114 percent), and carpooling (91 percent) and a decrease in private vehicles carrying only one student (39 percent) (Staunton 2003).

The key to success for these programs was a multi-disciplinary approach to improving pedestrian access to schools. Overall these programs have had varying amounts of success based on the level of support. However, the successes highlighted above show pedestrian travel to schools can be increased while student/car collision rates are reduced concurrently. These results beg the question, what role should transportation professionals play in proactively creating streetscapes that are safe for walking? And in particular, what approaches to street design would be most successful?

URBAN DESIGN AND WALKABILITY

For many years, transportation engineers and planners recognized the effect of land use on travel behavior (Olmstead 1924; Mitchell 1954). Trip generation rates and other transportation behaviors are often estimated or calculated as indicators of transportation efficiency when comparing alternative development patterns (Institute of Transportation Engineers 1997). In effect, the people who actually build our streets and highways believe that the built environment has some influence on travel behavior.

Planning professionals have begun to reevaluate their role as urban designers in light of the recent obesity epidemic and recommendations from health professionals promoting non-motorized transportation. Transportation systems, including roads, bike lanes, and sidewalks, are the arteries of urban areas – offering residents the ability to easily reach work, schools, parks, homes, and other destinations. These circulation systems are designed to provide safe and efficient access through thoughtful use of materials, location, and design. Insofar as planners design transportation systems they have the opportunity to influence residents' mode choice by creating pedestrian- and bicycle-accessible infrastructure.

The concept of accessibility is frequently cited in the literature and it is worth providing a brief description of this oft-used term. Accessibility has been defined as the "intensity of the possibility of interaction" (Hansen 1959). The level of accessibility is reflected in both the nature of nearby destinations and characteristics of the routes themselves – the ease of use and appeal of those destinations. There is a wide range of variables that can be measured regarding destinations, including both quantifiable data as well as highly qualitative information, ranging from the quantity of destinations to the appeal of shopping areas. The second group of variables, which are related to routes and are equally wide ranging include such measures as route distance, travel time, and variety of scenery along the route.

In general, a variety of measures have been explored in recent years to better understand factors that influence neighborhood accessibility and walkability. Common measures include population density, proximity of employment opportunities to residential areas, household density, age, race, land use mix, and urban design (i.e., street network, landscaping, views, proximity of parks) (Cervero 1997). Other measures include transportation infrastructure (i.e., number of vehicle lanes, bike lanes, and sidewalks), street design (i.e., cul-de-sacs, grid), neighborhood design (i.e., traditional, suburban, neo-traditional), and accessibility (i.e., proximity of destinations and number of destinations within a given distance) (Transportation Research Board 2005).

It is helpful to understand the relationships between these variables as elements within a larger framework; a number of researchers have developed theoretical frameworks for evaluating pedestrian environments. These frameworks seek to define the significant variables of urban form that influence pedestrians' decision to walk. At a macro scale, for example, Cervero (1997) has characterized these variables as the 3Ds of urban form – diversity, density, and design. At the street level, Pikora (2003) defines environmental factors that influence physical activity in terms of safety, convenience, aesthetics, and functionality. Lee and Moudon (2003) employ the Behavioral Model of Environments to describe streetscape characteristics of routes, origins/destinations, and area.

In his review of neighborhood accessibility research Krizek (2003) classified three themes commonly addressed in walkability research literature: neighborhood density, land-use mix, and street network patterns. Density measures include population, housing units, or employees per unit area, as well as the intensity of land uses. Land-use mix measures are the most used category and include, for example, household distance to groceries, non-residential activities in the immediate vicinity, and distance of travel to buy convenience goods. Analysis of street network patterns incorporate measures of transportation system characteristics in the built environment and compare them to observed transportation behavior. The following section reviews these themes in past walkability research.

DENSITY AND WALKABILITY

The U.S. Census compiles data on the characteristics and locations of citizens across the county. Therefore, density measures such as population, housing units, and employees per unit area are the most readily accessible and oft used urban form variable in neighborhood accessibility research. In addition to census data, neighborhood accessibility research frequently relies on household survey results and personal daily trip diaries (Cervero 1997; Audirac 1999; Krizek 2003). These data collection methods are designed to spatially locate residents' characteristics and behaviors.

In her 1999 article, Ivonne Audirac (1999) explored the likelihood that housing consumers would trade-off living on smaller lots for pedestrian proximity to community amenities. Her analysis of the University of Florida, Bureau of Economic and Business Research (BEBR) consumer attitude survey found residents of single-family homes were willing to trade smaller lot sizes for improved pedestrian access to 2 of 5 types of neighborhood amenities. Residents of apartments and condos, for whom the spatial costs of reduced lot size are minimal, were willing to accept smaller lots for improved access to any community facility. These results suggest higher residential densities may instill a greater appreciation of walkable neighborhoods.

In 1997, Cervero and Kockelman used density measures to conduct a study of urban design variables believed to affect travel behavior (Cervero 1997). In addition to socio-demographic densities from the U.S. census, Cervero and Kockelman used a database of dominant land uses for the 9-county San Francisco Bay area. By combining population and land-use densities they were able to create an accessibility index for access to jobs (via automobile) and to sales and service jobs in particular (via walking). Their findings offer moderate support for the claims of New Urbanists who argue that compact, mixed-use, pedestrian-friendly designs can reduce vehicle trips, vehicle miles traveled (VMT) per capita, while encouraging non-motorized travel. Densities proved to exert the strongest influence on personal business trips. Residential neighborhoods with easily accessible commercial activities tended to average significantly less VMT per household. Interestingly, the dimension of ‘walking quality’ was moderately associated with travel demand. That is to say, the influence of attractive sidewalks on mode choice for non-work trip making was stronger than that of density. Moreover, neighborhoods with high shares of four-way intersections tended to average less single-occupant vehicular travel for non-work purposes, which indicates grid street patterns may reduce VMT.

These results indicate that density – in terms of overall population and household densities – affect neighborhood accessibility and the frequency of walking and biking. However, proximity to neighbors is only one aspect of the neighborhood accessibility equation. People are likely to walk more frequently in high-density neighborhoods in part because local amenities and destinations tend to be close by and more accessible by foot or bike. The following section explores a second variable of neighborhood accessibility, namely the influence of street network design.

Land-use Mix and Walkability

There is a plethora of evidence that suggests the effects of induced travel demand are substantial. Induced travel demand is based on the possibility that new roads might induce sprawl and the extra automobile trips associated with it. Some evidence suggests that auto-oriented planning has actually increased commute distances and thus commute times. This issue has given rise to such clichés as “you can’t pave your way out of congestion” and “if you build it they will come.” Several studies have provided substantial support for this concept. Hansen and Huang studied 18 years worth of data from 14 California metropolitan areas and found that for every 10% increase in vehicles lane miles there was an associated 9% increase in vehicle miles traveled 4 years after road expansion, controlling for other factors (Hansen 1997). A similar study of 70 U.S. metropolitan areas over the course of 15 years found that areas investing highly in transportation infrastructure did not fare any better in easing traffic congestion than areas that did not (Surface Transportation Policy Project 1998). In a study of 100 road expansion projects Goodwin found that proportional savings in travel time were matched nearly one-to-one with proportional increases in traffic – a finding that prompted the U.K. government to remove its “predict and provide” policy of responding to congestion forecasts by planning new roads (Goodwin 1996).

Street Network Pattern and Walkability

A central point of contention among urban planners and transportation engineers is the issue of street network design and pedestrian travel options. In particular, neighborhood street patterns (e.g. traditional, modern, neo-traditional) have been a consistent topic of study in terms of neighborhood walkability (Cervero 1995; Handy 1996; Crane 1998; Schlossberg 2004). In designing road networks with the primary goal of increasing automobile efficiency, critics argue transportation planners have built mode choice out of the built environment equation. The development of cul-de-sacs, for example, represent an approach to design efficiency for automobile transportation, but they have the opposite effect on pedestrian access and efficiency; pedestrians often have to take out-of-the-way, circuitous routes because direct routes are truncated by cul-de-sacs, and transit vehicles cannot efficiently serve curvilinear neighborhoods or branch roads. Therefore, many modern suburbs limit pedestrian and transit access in exchange for increased automobility (Cervero 1997; Crane 1998). Reform-minded urban designers argue that walking will increase in neighborhoods designed with more pedestrian friendly features, such as connected sidewalk layouts, increased mixed-use development, and high density commercial and residential development (Calthorpe 2001; Duany 2001). Street design is one example of measures commonly used to assess neighborhood walkability – researchers also frequently employ provision of sidewalks, streetscape design, miles of street, and access to activities.

In some locations neighborhood street networks were deliberately planned to minimize the social costs of pollution, traffic, and sprawl by decreasing the distance between households and common destinations, including school, work, and shopping sites (Handy 1996; Schlossberg 2004). On the other extreme, many neighborhoods have grown organically over time with little attention paid to maintaining a consistent street network scheme. Research has tended to focus on neighborhoods that typify previously defined 'styles,' such as traditional, modern, and neo-traditional, yet in general most neighborhoods do not fit neatly within these designations. In fact, some studies have shown marginal support for the influence of street patterns on neighborhood walkability.

Crane and Crepeau found little evidence for the argument that neighborhood street pattern has any significant effect on car or pedestrian travel when controlling for land use, trip costs, traveler characteristics, and land use densities (1998). Transit oriented developments (TODs) in Portland exhibit varying levels of pedestrian access despite having been designed with pedestrian travel in mind (Schlossberg 2004), and Handy found that motivation to walk and the distance to destinations were more significant than neighborhood street patterns in Austin (Handy 1996). Furthermore, Krizek modeled household transportation behaviors and found that households tend to maintain their travel preferences after moving to new neighborhood types. That is to say, Krizek's model suggests that a family who moves from a suburban to a traditional neighborhood will go to the corner store to buy a dozen eggs, but they tend to go more often and are less likely to link the trip with another errand.

Cervero (1995) on the other hand found street pattern design to have a significant impact on travel behavior. Cervero compared transit oriented neighborhoods with auto-oriented travel in terms of household density, neighborhood design, single occupant vehicle trips, transit trips, and pedestrian trips in San Francisco and Los Angeles. The study compared travel behavior between residents of traditional grid neighborhoods to residents of auto-oriented residential neighborhoods. Interestingly, the study found that when controlling for other factors the distinction between traditional neighborhoods, designed around transit stations, and new automobile oriented developments could be measured. In fact, transit neighborhoods produced fewer single-occupant automobile trips and lower trip generation rates than their auto-oriented counterparts. Furthermore, transit neighborhoods averaged higher rates of bicycling and walking trips than their corresponding auto-oriented neighborhoods. These studies are far from conclusive and highlight the complexity associated with attempts to characterize neighborhood walkability.

PEDESTRIAN LEVEL ENVIRONMENTAL AUDIT INSTRUMENTS

Whereas previous research sought to understand neighborhood walkability at regional, metropolitan, or neighborhood scales, this research paper attempts to define a methodology for evaluating walkability at the street level. Past research tended to focus on the inter- and intra-personal determinants of physical activity – that is to say, the relationship between people and the physical environment. For example, Handy (1996) argues that better links between private space in buildings and the public space of the street encourages more street activity and makes for a more interesting pedestrian environment. Appleyard (1981) found that building types, in terms of height, continuity, and solidarity, affect the amount of street life and thus walking. Rappaport (1987) emphasizes the importance of visual complexity in the landscape, which adds interest and thus supports activity.

To understand the complex relationships between pedestrians and their environment it is helpful to have a theoretical framework for how variables relate. In response to their comprehensive survey of audit instruments, Lee and Moudon (2003) outlined a theoretical framework called the Behavioral Model of Environments (BME) that seeks to account for personal characteristics, physical environmental factors, and internal responses to the environment – components included in audit instruments. The BME framework is unique in that it comprehensively incorporates these three important components. According to studies by Pikora, Lee, and Moudon, safety is the primary concern for people deciding whether to walk, bike, transit, or drive to their destination. Yet at the pedestrian level everything from the presence of curb-cuts to land use development types can affect the perception of safety for pedestrians (Lee 2003; Pikora 2003). However, *Chapter 3* outlines how Pikora's (2003) prioritized list of streetscape features and Lee and Moudon's BME framework were synthesized into criteria to identify safety related measures from the audit tool used for this project.

The audit tool employed for this project was adapted from an instrument piloted in Timberlyne, NC (Clifton). The tool included 78 measures of streetscape characteristics that have been shown to influence walkability (Appendix A). Clifton and Livi studied the inter-rater reliability of the instrument using trained audit administrators who debriefed with one another at the end of daily auditing sessions. The team experimented with a variety of approaches to the street auditing method and refined their protocol daily in response to unique situations, issues, or comments that arose during fieldwork. Despite a wide range of street segment uses, conditions, and aesthetics, the team found relatively high reliability scores for the audit instrument. Not surprisingly, objective measures tended to have high reliability ratings, while a small selection of objective measures of pedestrian features exhibited low Kappa scores. Despite their low reliability scores, the analysis of objective measures suggests these objective measures need further research before discarding them from the audit.

Research of streetscape features in the past was often limited by the amount of time required to conduct block by block assessments, the dizzying number of features along a street segment that affect pedestrian safety, and difficulties weighing the relative importance of individual features on the overall safety of the street segment (Emery 2003; Lee 2003; Pikora 2003). In their study of two pedestrian and bicycling environmental audit tools, Emery (2003) found it challenging to reliably evaluate road segments (Emery 2003). Lack of data, time, training, and fields to record supportive environmental characteristics (e.g., benches, water fountains) were just a few of the limitations Emery mentions. These results highlight the challenge researchers face in gathering adequate data to reliably evaluate the safety of street segments for pedestrians.

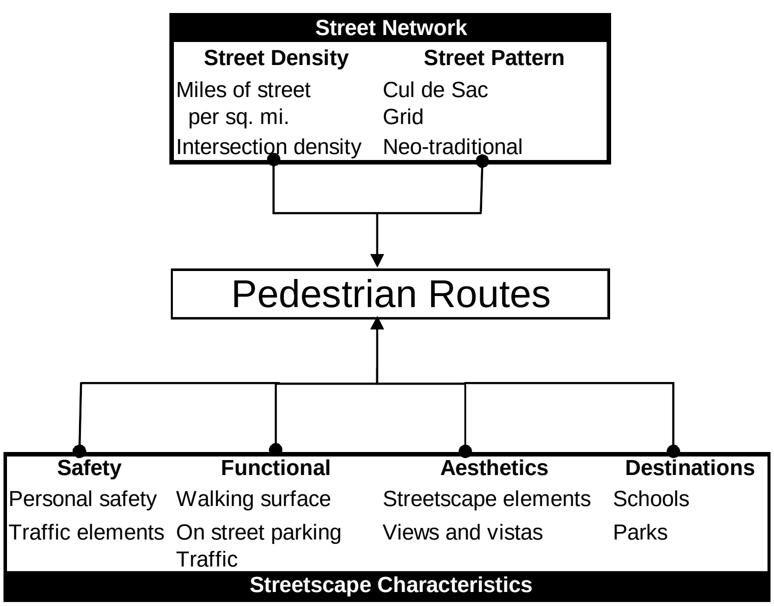
However, recent technological innovations have enabled researchers to employ GIS to quickly record and analyze streetscape features that are important elements of pedestrians' perception of safety. GIS-equipped personal digital assistants (PDAs) significantly enhance the speed with which data are collected in the field and later processed. This GIS approach to data collection enables researchers to quickly record measures of pedestrian safety without the limitations of past data entry methods (Clifton). In this case data collection and data entry are seamlessly combined. However, the ability to collect a robust dataset only complicates the process of identifying and weighting streetscape features important to pedestrian safety. This issue is addressed more fully in *Chapter 3: Methods.*

CHAPTER 3

Methodology

As discussed in *Chapter 2: Literature Review*, a variety of methods have been employed in the past to evaluate neighborhood walkability, including analyses of street design, land-use mix, and street network patterns (Cervero 1995; Handy 1996; Emery 2003). However, little research on record identifies or quantifies features at the pedestrian level. The myriad details that color the pedestrian landscape (i.e., sidewalks, cross walks, tree corridors, buffers) are elements that pedestrians, including youth, take into account when walking for travel. The scope of this project involves descriptions of neighborhood walkability at two levels of analysis – through a combination of macro-scale street network features used in past research and new micro- or pedestrian-level characteristics (Figure 3-1). The distinction between these two levels of analysis is critical to understanding the trade-offs between potential routes from home to destination.

Figure 3-1. Examples of street network and streetscape characteristics



Note: Streetscape characteristics adapted from Pikora, 2003.

The following questions guided this research: (1) How do fringe (i.e., suburban) schools differ in terms of walkability with urban core (i.e., traditional, grid) schools; (2) What is the spatial distribution of pedestrian amenities within individual school neighborhoods and across various schools; and (3) Do students, when presented with two equally long routes, tend to favor more walkable/safer streets? To answer these questions, a walkability audit, household survey, and Geographic Information Systems (GIS) were employed.

Three methods of analysis were used to answer these research questions. First, the density and types of intersections for school neighborhoods were compared to show which neighborhoods offer students more route options between home and school. Second, the streets within ½-mile of each middle school were rated for pedestrian safety using a walkability audit instrument (Appendix A). Third, students' actual routes to school – provided by a previously administered household survey[3] – were compared with the shortest possible route from home to school.

Geographic Information Systems (GIS) are well suited for this analysis. Research of streetscape characteristics in the past was often limited by the time required to conduct block by block assessments, the dizzying number of features along street segments that affect pedestrian safety, and difficulties weighting the relative importance of features on the overall safety of the street segment (Pikora 2003; Lee and Moudon 2004). At the pedestrian level everything from the presence of curb-cuts to land use types can affect pedestrian safety. GIS-equipped personal digital assistants (PDAs) significantly enhanced the speed with which data were collected and processed. The content of this chapter details the methods of data collection, findings, interpretation, and analysis presented in *Chapter 4: Findings*.

MEASURING ACCESSIBILITY

There are five common components of analysis for evaluating accessibility (Talen 2002; Lee 2003; Transportation Research Board 2005). The first two are the physical locations of trip origins and destinations. Both locations can be spatially referenced – origins are typically places of residence while destinations may be schools, places of employment, parks, or shopping areas.

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[3] Developed and administered by the Community Service Center, University of Oregon, 2004 (Appendix C).

Measures of accessibility also address the characteristics of the individuals who seek access. In many studies the characteristics of individuals are associated with a spatial unit (e.g., census blocks, neighborhoods) to describe geographic relationships between residences, transportation services, and destinations. Important individual characteristics include socioeconomic status, age, car ownership, gender, and employment status. Travel mode availability is a critical aspect of accessibility because, for example, lack of transit service can impact accessibility among low-income residents while it may have less effect on middle- to high-income residents. The scope of this project is limited geographically to four neighborhoods surrounding middle schools in Springfield and Bend, Oregon. The narrow scope of this project – focusing on middle school student travel behavior – is intended to limit the effects of other confounding variables on the analysis and findings.

The fourth accessibility measure is the travel route from trip origin to destination. Analysis of travel routes commonly includes measures of travel distance based on the physical characteristics of the area. Travel distance can be measured 'as the crow flies,' or using more complex network analysis tools. Other measures of travel routes include the quality of the route and mode of travel that occur along the route. Factors that affect the route include topography, travel lanes, travel speed, and mode.

The final factor of walkability and access includes characteristics of destinations. In particular, the number of destinations, as well as the quality and nature of destinations, can be quantified and evaluated. In this case, the destinations were held constant to limit the influence of intervening variables.

GEOGRAPHIC SCOPE

Middle school students enjoy a unique level of mobility while at the same time they frequently use non-automobile transportation. On one hand they enjoy a higher level of independence and freedom of movement than elementary school students, yet they are unable to drive vehicles like many high school students. Thus, middle school student as a group are more likely to walk to/from school than other cohorts.

The middle schools studied in this project include Pilot Butte M.S. and Sky View M.S. in Bend, Oregon, and Springfield M.S. and Agnes Stewart M.S. in Springfield, Oregon. These schools provide a cross-section of two street design approaches. Agnes Stewart and Sky View

Middle Schools represent neighborhood design typical of post-WWII suburban development, while Springfield and Pilot Butte Middle Schools are indicative of traditional (i.e., grid) street design. The audit was conducted within one ½-mile of each school – a distance considered to be at the edge of walking to school. However, the boundary for residents that attend Springfield MS truncates the ½-mile limits of the walkability audit area. While the study area for Pilot Butte, Sky View, and Agnes Stewart Middle Schools is 0.87 sq. mi. the Springfield study area was reduced to 0.79 sq. mi.

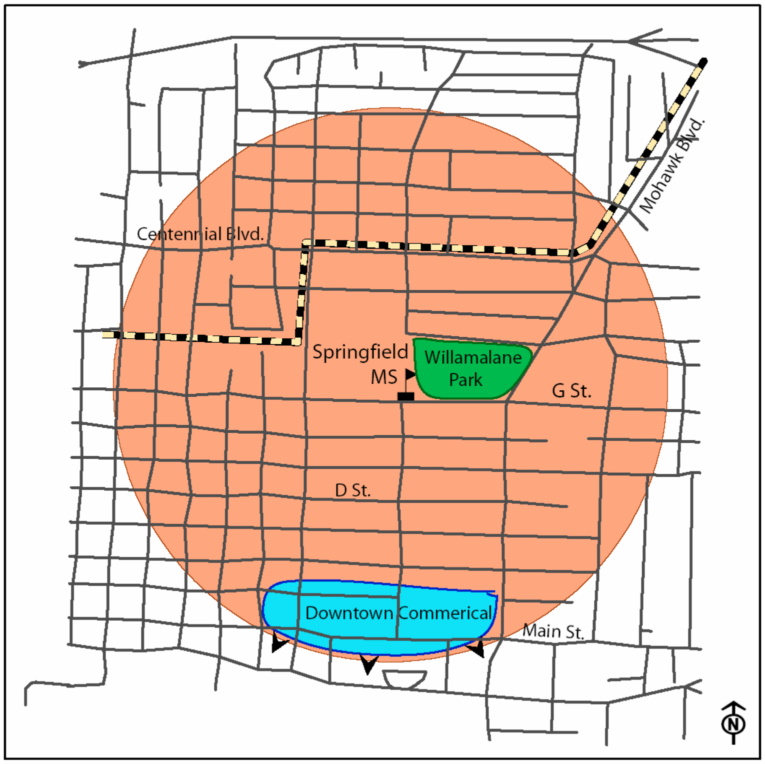
Springfield Middle School shares a 12-acre campus with Springfield High School and is situated approximately ¾-mile north of downtown Springfield. The Washburne Historic District is located between the school and the downtown area. Therefore, the District is within the area of study of this project. The District is a well-preserved example of an early working class neighborhood. The construction dates of homes in this neighborhood range from the 1890s through the 1940s (Figure 3-2).

Agnes Stuart M.S. is located on a north-south collector road separating a heavy-industrial area to the west from residential development, built between approximately 1970 and 1990, to the east. The survey area contains a broad range of pedestrian amenities ranging from single lane gravel roads with no sidewalks to well-lit, paved pedestrian/bicycle-only paths. A railroad running east-west bisects the site north of the school, and an elementary school and park are situated one ¼-mile east of the Middle School (Figure 3-2).

Bend, Oregon is undergoing a significant period of growth that started in the mid-1980s and continues today. The diverse character of the Pilot Butte M.S. neighborhood is due in large part to the layers of accumulated development types in the area. Pilot Butte Middle School was built on the urban fringe of Bend, Oregon in the 1960s, but today is surrounded by homes built between 1930 and 2004. In addition to residential, the area includes commercial properties, the local hospital – the largest employer in Bend – and Pilot Butte Park (Figure 3-3).

Sky View Middle School was built in the late 1990s to serve a burgeoning residential population in Northeast Bend. Homes near Sky View M.S. are typically 10-25 years old. The neighborhood around Sky View M.S. is primarily residential and small commercial, including corner stores (Figure 3-3).

Figure 3-2. Springfield (top) and Agnes Stewart (below) Middle Schools



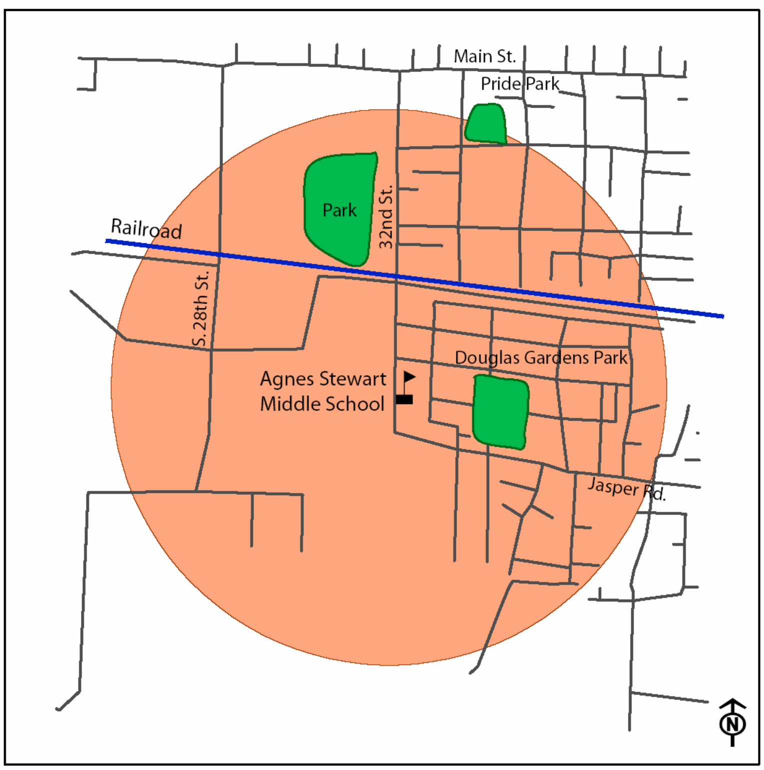
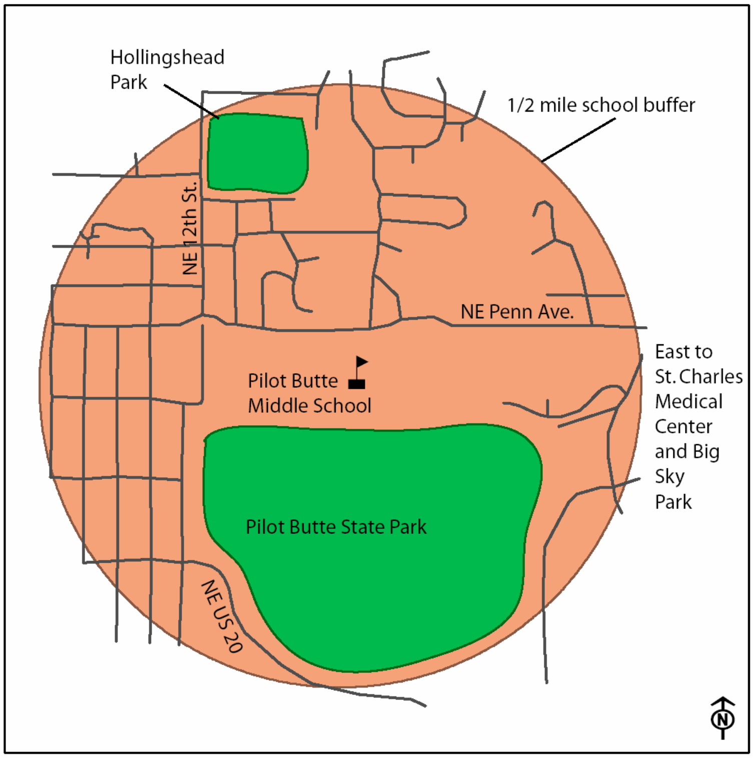
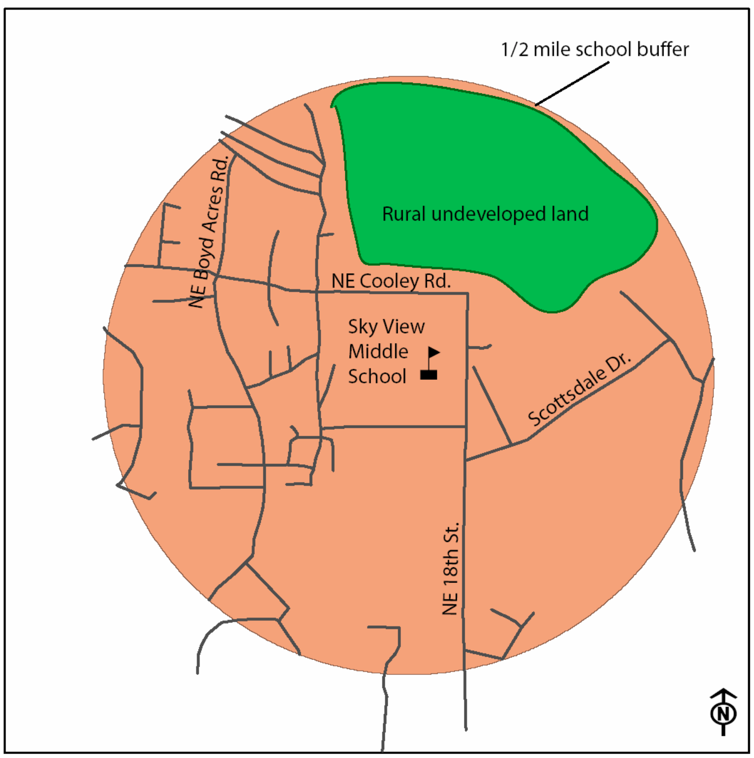


Figure 3-3. Pilot Butte (top) and Sky View (below) Middle Schools



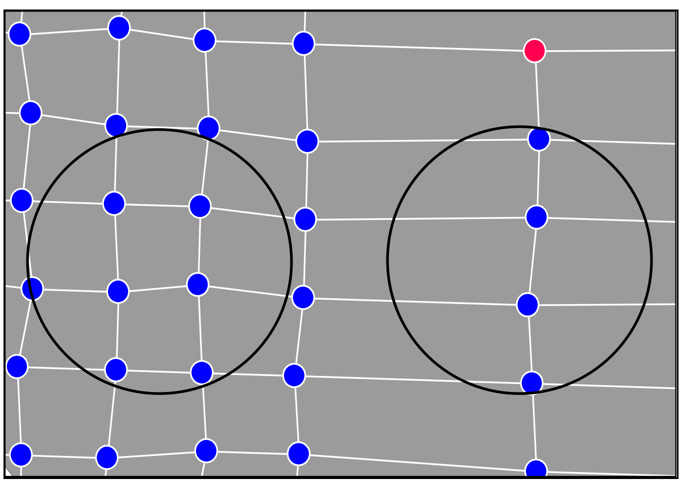


INTERSECTION DENSITY

Intersections are a neighborhood-level measure of walkability that proxy for the *variety of route choices* available to pedestrians within a given area. The following methods of intersection analysis examine the types (i.e., dead-ends, 3-way, 4-way) of intersections, the density of intersections per study area, and intersection amenities (i.e., stop signs, crosswalks, curb cuts).

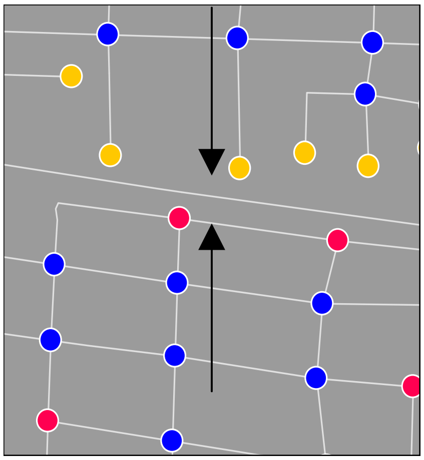
The types of intersections within a study area can provide a glimpse of the extent of the pedestrian pathways. Figure 3-4 shows how students following a hypothetical street network in the circular area on the left would have access to more locations within the its radius than someone navigating the area on the right. Theoretically, areas with higher densities of intersections offer more destinations (i.e., shops, restaurants, parks, schools) within walking distance of home (Appleyard 1981; Cervero 1997) and are more amenable to pedestrians. Therefore, intersection density is one indicator of neighborhood walkability.

Figure 3-4. Example of intersection densities



Additionally, the hierarchy of intersection types helps describe the walkability of an area. Areas with more dead-end tend to provide less pedestrian access than neighborhoods with more 4-way intersections, and therefore can be an indicator of 'poor' walkability. Three-way intersections are an indication of 'moderate' walkability and four-way intersections are an indicator of 'good' walkability. From the pedestrian's perspective neighborhoods can be divided into disconnected areas by dead-ends and three-way intersections (Figure 3-5). The high number of dead-ends, in this case, illustrates how high dead-end-densities reduce pedestrian (as well as bike and automobile) through-traffic. It is believed that neighborhoods with high numbers of dead-end streets and few intersections require students to take longer routes to school – thereby discouraging students from walking.

Figure 3-5. Intersection types and densities

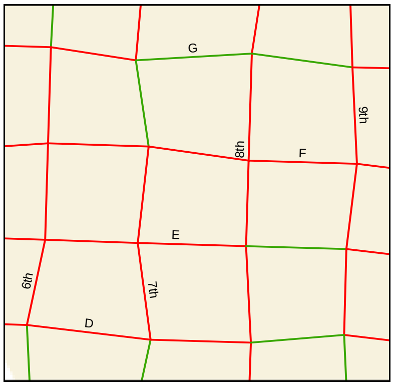


Source: U.S. Census TIGER files

Intersections are the most common site of pedestrian/automobile collisions, and as such the extent of pedestrian amenities that aid street crossing serve as indicator of pedestrian safety and walkability (Ossenbruggen 1984) (Figure 3-6). Eight types of crossing aids were recorded per street segment using the walkability audit instrument, including:

- Pavement marking
- Yield to pedestrian sign
- Pedestrian signal
- Median/traffic island
- Curb extension
- Overpass/underpass
- Pedestrian crossing street sign
- Flashing warning

Figure 3-6. Street segments with (red) and without (green) stop signs



One limitation of the TIGER file based approach used for this project is that data is stored per street segment. Since each segment includes two intersections the intersection data is generalized for each street. For example, street segments with stop signs were classified as "with stop signs" if at least one end of the segment contained a stop sign. Although this method assigns the same value to segments with one or more stop signs it still holds value as measure of traffic calming devices and pedestrian safety.

LAND USE MIX INDEX

The types of land use extant in neighborhoods can significantly change the streetscape walkability of the area. Thus, recording details about land use along street segments helps create a complete picture of the contextual character of neighborhoods. The ArcPad-equipped PDA audit instrument was equipped to record eight types of land-use, including single-family residential, multi-unit residential, mobile home, office/institutional, industrial, restaurant/café/commercial, recreation, and vacant found along each surveyed street segment. Yet it is difficult to summarize the overall extent of land use across broad areas. Creating an index representing the total land-use mix around each study school enables comparisons of land use, and thus, walkability. This land-use mix index is a simple calculation of the number of land-uses extant on the segment (i.e., recreation, industrial, and vacant = 3) divided by the total number of street segments within ½ mile of the school (Figure 3-7). As the variety of land-uses increases so does the land-use mix index.

Figure 3-7. Land-use mix index formula

$$\frac{\text{Sum of all segments per land use}}{\text{Total number of street segments at school}} = \text{Land-use Mix Index}$$

Vacant properties may provide opportunities for students to take shortcuts to school. However, research indicates that vacant land reduces walkability because it lowers the number of destinations per unit area. Table 3-X shows that Sky View has the lowest index when vacant land is not considered beneficial to walkability, and therefore is not included in the land-use calculation. The same calculation with vacancies included increases the index for Sky View above Pilot Butte – a disparity that highlights the importance of accounting for unique tendencies of the sample population.

Table 3-1. Comparison of potential land-use mix indices, with and without vacancies included

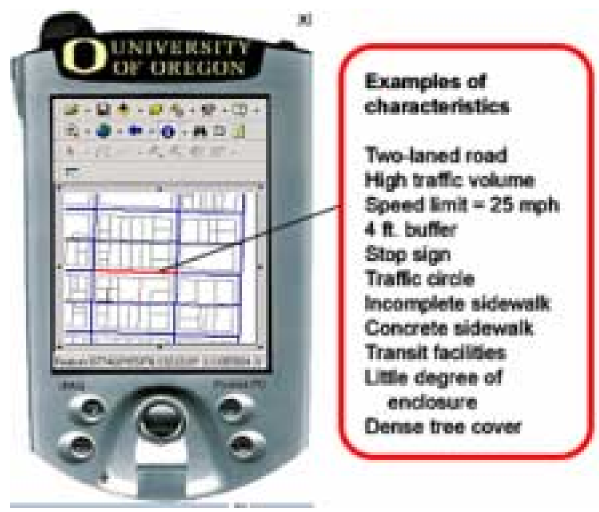
Middle School	Land-use Mix Index with Vacant	Land-use Mix Index without Vacant
Pilot Butte	1.18	1.07
Sky View	1.21	0.76
Springfield	2.21	2.01
Agnes Stewart	1.32	1.12

WALKABILITY AUDIT INSTRUMENT

Finding and adapting a walkability audit instrument to survey streetscapes was a significant component of this research project. The first step involved obtaining a walkability audit instrument and conducting fieldwork to gather streetscape data. The PEDS walkability audit instrument used for this project was developed by researchers at the University of North Carolina and the University of Maryland and contains 78 measures of street walkability (Appendix A) (Clifton). In general, it is impossible to comprehensively capture the scope of street characteristics that sway pedestrians' route choice, but Clifton's instrument provides a thorough and systematic method to assess streetscape walkability. Clifton found the instrument to have a high level of inter-rater reliability, in part due the simplicity of its measures. Most measures have a discrete data response (i.e., true/false, Likert scales), while 3 questions allow for text responses when "other" is selected. The audit instrument has an accompanying tutorial that was reviewed prior to commencing the audit fieldwork (Livi 2004).

To improve the speed of data collection and management the audit instrument was programmed into ArcPad[4] – enabling digital data collection in the field using ArcPad-equipped[5] personal digital assistants (PDAs) (Figure 3-8).[6] Additionally, equipping the PDA with a digital camera enabled ArcPad to attach digital photographs to each street segment for later analysis. TIGER files were used for street data and superfluous segments, including driveways and other areas closed to student through-traffic, were easily identified in the field and later deleted.

Figure 3-8. ArcPad equipped PDA



Source: Adapted from Marc Schlossberg, University of Oregon.

ArcMap 9.0 geographic information system (GIS) software was used to analyze geo-spatial distributions of intersections, streetscape characteristics, and surveyed student routes.[7]

Two graduate students at the University of Oregon collected the field data in the fall of 2004. One student conducted the walkability audit in Bend, Oregon and the second student compiled data at Springfield and Agnes Stewart Middle Schools.

Application of Criterion A – *Safety Measures*

A delicate balance must be struck to accurately describe the walkability of streetscapes as components of neighborhood walkability. Between 6 and 9 hours were required to audit streets within one ½-mile of each middle school. Given limited time, prior planning can help determine how much data is needed sufficiently describe each *street segment* while at the same

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[4] A product of Environmental Systems Research Institute (ESRI).

[5] A product of Environmental Systems Research Institute (ESRI).

[6] Adaptation of audit instrument to ArcPad provided by Dr. Marc Schlossberg, University of Oregon, 2005. Information available online at http://www.uoregon.edu/~schlossb/arcpad/walkability/walkability.htm.

[7] A product of Environmental Systems Research Institute (ESRI).

time capturing an adequate number of segments to describe the *neighborhood*. That is to say, time spent collecting data per street segment may limit the number of street segments audited. For that reason a two-tiered criteria system was created to narrow down the 78 measures collected in the field to those related specifically to safety in terms of walkability. In the future this system may help researchers accurately describe streetscape walkability at a larger neighborhood scale by increasing the number of streets audited.

Criterion A, implemented to select safety measures from the walkability audit instrument, was based on research that prioritized street characteristics that affect pedestrian safety (Appendix B). In their Delphi study of transportation, planning, and health professionals, Pikora et al. identified four overarching features of the built environment that impact walkability: 1) functional features include such elements as walking surface, traffic, permeability; 2) safety features consist of personal safety and traffic elements; 3) aesthetics include tree corridors and views; and 4) destinations are separated into schools and parks. The results of their research showed that safety is the principal issue for pedestrians in local neighborhoods. Safety features were categorized as personal elements (lighting, surveillance, and path obstruction) and traffic elements (crossings, crossing aids, verge width, driveways, marked lanes, and path continuity). The second and third most important issues for walking were streetscape aesthetics and the presence of destinations. There were two key issues for cyclists. The foremost was the presence of a continuous route with few intersections or required stops. The second concerned safety and included traffic speeds and the quantity of vehicles on the road (Pikora et al. 2003). The inconsistency between concerns of pedestrians and bicyclists highlight the difficulty planners encounter when planning for these distinct non-motorized modes of transportation.

Since safety is the chief concern of pedestrians this project used Pikora's (2003) results to identify items in the walkability audit instrument that were indicators of pedestrian/bicyclist safety. Each item in the audit instrument was compared to Pikora's classification system and only safety-related items were analyzed. Criterion A reduced the number of streetscape measures from 78 to 25 measures (Appendix B).

Application of Criteria B – Behavioral Model of Environments

After Criterion A selected safety-related audit instrument items the second-tier of criteria in this project was applied (Criteria B). The purpose of the second-tier was to ensure that the selected survey items addressed three critical aspects of walking, including physical characteristics of the environment; the interaction between pedestrians, bicyclists, and automobiles; and internal reactions to the environment such as attractiveness and perceived safety.

The Behavior Model of Environments (BME) is a theoretical framework for understanding the complex relationships between people and their surroundings (Lee and Moudon 2003). In a comprehensive review of walkability audit tools authors Lee and Moudon (2003) grouped environmental factors into spatiophysical, spatiobehavioral, and spatiopsychosocial aspects of the built environment (Table 1). This framework is unique for its holistic approach to the relationships between people and the environment. The BME framework understands human environments as “bricks and mortar,” or physical characteristics shaped by social relationships. Spatiophysical aspects of the environment are the most common element in walkability audit instruments and include such measures as the presence or absence of sidewalks and the characteristics of sidewalks. Spatiobehavioral characteristics are less frequently included in audit tools and concern the interactive nature between pedestrians, bicyclists, and vehicles. These measures seek to quantify circumstances that increase or decrease interactions between various travel modes – driveways, for example, increase the opportunities for pedestrian/vehicle collisions. Spatiopsychosocial attributes of the environment are based on human responses to the physical environment, such as perceptions of comfort, attractiveness, and safety, to name a few. The application of Criterion A provided 25 measures of safety. Of these measures, 22 were physical characteristics (spatiophysical) of the streetscape and 3 recorded potential interactions between pedestrians, bikes, and cars (spatiobehavioral).

Although the complete audit instrument includes 78 measures, only two measure internal responses (spatiopsychosocial) to the environment– asking whether the street segment was attractive for walking and biking. According to Pikora’s research these measures were identified as attributes of destinations rather than perceptions of safety, yet Lee and Moudon attribute this type of measure to perceptions of safety. The last two items in Table 3-2, regarding attractiveness, were included with the parsed list of safety measures because they convey pedestrians’ interaction with the environment, and because Lee and Moudon’s (2003) research identified them as safety measures.

Table 3-2. Pedestrian safety criteria for school neighborhood streets*

Survey Item	Pikora	Lee & Moudon	Lee & Moudon
Feels safe for walking	Safety	Safety	Spatiobehavioral
Feels safe for biking	Safety	Safety	Spatiobehavioral
Driveways	Safety	Safety	Spatiobehavioral
Traffic control devices	Safety	Safety	Spatiophysical
Bicycle lane	Safety	Safety	Spatiophysical
Path obstructions	Safety	Safety	Spatiophysical
Sidewalk completeness/continuity	Safety	Safety	Spatiophysical
Sidewalk completeness/continuity	Safety	Safety	Spatiophysical
Sidewalk condition/maintenance	Safety	Safety	Spatiophysical
Crossing aids in segment	Safety	Safety	Spatiophysical
Lighting	Safety	Safety	Spatiophysical
Way finding aids	Safety	Safety	Spatiophysical
Is attractive for walking	Destination	OD	Spatiopsychosocial
Is attractive for biking	Destination	OD	Spatiopsychosocial

* OD = origin and destination

** See Appendix B for a complete listing of path obstructions and crossing aid devises

Source: Pikora (2003) and Lee & Moudon (2004)

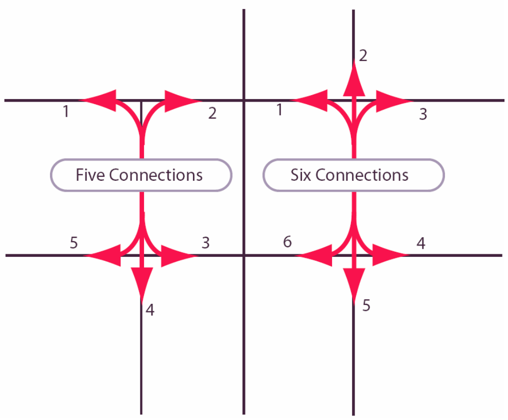
Representing the results of 25 walkability safety indictors is a challenge, especially given the spatial component of the results. To enhance interpretation of the findings it was apparent an index summarizing the attributes street segments was needed. After the safety measurements of the audit were identified and culled from the full dataset a rating for each audit entry was developed (Table 3-3). The rating system gives a score for each walkability indictor based on its indication of pedestrian safety. That is to say, streets with amenities that improve pedestrian safety received higher scores than streets with few safety amenities. The provision of sidewalks, for example, is rated as the number of sidewalk connections to adjoining sidewalks (Figure 3-9). Segments with more connections receive a higher walkability rating than segments with fewer connections. Figure 3-8 illustrates two potential sidewalk connectivity ratings – the segment on the left is given five points while the segment on the right is given six points.

Table 3-3. Survey items and rating scheme

	Potential Rating	Example Response	Corresponding Score
Is attractive for walking	0-3	Agree	2
Is attractive for biking	0-3	Strongly disagree	0
Traffic control devices	0-1	Yes	1
Path obstructions	0-1	Yes	0
Sidewalk completeness/continuity	0-2	Complete	2
Sidewalk connectivity to other sidewalks	0-7	6 connections	6
Sidewalk condition/maintenance	0-2	Good	2
Crossing aids in segment	0-1	Yes	1
Lighting	0-3	Good	3
Wayfinding aids	0-1	Yes	1
Bicycle lane	0-1	No	0
Feels safe for walking	0-3	Strongly agree	3
Feels safe for biking	0-3	Agree	2
Driveways	0-1	Yes	0
Potential Score	***Low = 0 to High = 32***	***Example Score***	***23***

Source: Adapted from Clifton's (2004) walkability audit instrument

Figure 3-9. Rating sidewalk connectivity



The walkability safety rating includes 6 measures that indicate the presence or absence of particular street features, such as traffic control devices and crossing aids. The remaining measures are weighted values ranging from 0 to 7 points. Sidewalk connectivity assesses the number of adjoining street segments with sidewalks and is the measure with the highest possible score. The provision of sidewalks greatly reduces pedestrian-automobile collisions, so streets with more sidewalk connections are safer for pedestrians and therefore received higher possible ratings (Ossenbruggen 1984; Forjuoh 2003). Five measures, including "attractiveness", "lighting", and "feeling of safety," have possible scores of zero to three. Due to the technical challenge of weighting the number of driveways (per mile per street segment) only the presence or absence of driveways was included in the walkability safety rating. Based on further research and validity testing, this overall system may need refinement to ensure that the weight assigned each measure accurately reflects the importance of each measure in terms of pedestrian safety.

The final step in creating the streetscape walkability rating entailed classifying streets as low, moderate, or high in terms of walkability relative to other street segments in the study. By combining the street segments into one database it was possible to separate the streets into three categories with equivalent quantities of street segments (Table 3-4). In absence of an established rating standard for this type of analysis, this method of comparison of all streets in the survey is thought to provide the best relative measure of walkability among streets in this study.

Table 3-4. Streetscape walkability classifications

	Rating	Frequency of Segment Rating	Percent	Cumulative Percent
Low Walkability	12	1	0.29	0.29
	13	1	0.29	0.58
	14	2	0.58	1.16
	15	3	0.87	2.03
	16	1	0.29	2.32
	17	3	0.87	3.19
	18	4	1.16	4.35
	19	11	3.19	7.54
	20	11	3.19	10.72
	21	15	4.35	15.07
	22	6	1.74	16.81
	23	5	1.45	18.26
	24	2	0.58	18.84
	25	5	1.45	20.29
	26	2	0.58	20.87
	27	12	3.48	24.35
	28	18	5.22	29.57
	29	9	2.61	32.17
	30	5	1.45	33.62
Moderate Walkability	31	10	2.90	36.52
	32	14	4.06	40.58
	33	10	2.90	43.48
	34	12	3.48	46.96
	35	17	4.93	51.88
	36	12	3.48	55.36
	37	22	6.38	61.74
	38	16	4.64	66.38
High Walkability	39	17	4.93	71.30
	40	20	5.80	77.10
	41	26	7.54	84.64
	42	10	2.90	87.54
	43	11	3.19	90.72
	44	3	0.87	91.59
	45	6	1.74	93.33
	46	4	1.16	94.49
	47	10	2.90	97.39
	48	6	1.74	99.13
	49	3	0.87	100.00
Total		**345**	**100**	

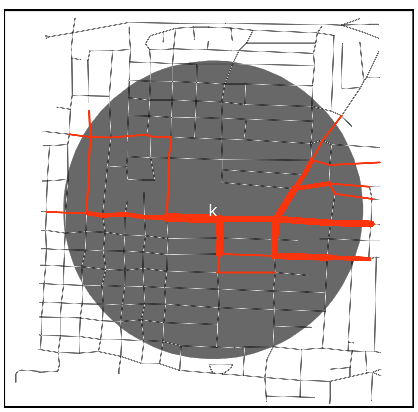
MIDDLE SCHOOL STUDENT SURVEY

The walkability rating permitted two types of analysis – both macro and micro level evaluations. At the *street*-level it enabled analysis of the distribution of street characteristics within independent school neighborhoods. This capability proved valuable in evaluating two or more potential routes between locations. In particular, a previously administered householder survey of Pilot Butte, Sky View, Agnes Stewart, and Springfield Middle School students asked respondents to plot their typical walking/biking route from home to school (Appendix C).[8] Survey responses provided the basis for comparing potential pedestrian routes with actual routes taken. The survey response rates for each school were:

- Springfield Middle School – 15 respondents
- Sky View Middle School – 28 respondents
- Agnes Stewart Middle School – 29 respondents
- Pilot Butte Middle School – 43 respondents

By plotting students' actual routes to school it was possible to analyze and compare the *shortest* and *most walkable* routes from home to school. Furthermore, the arrangement of student routes submitted in the survey indicates which streets students use more frequently than others (Figure 3-10). This data illustrates which streets experience the most pedestrian traffic and may help administrators locate crossing guards or other crossing aids.

Figure 3-10. Frequently traveled streets by student pedestrians*



Note: Red paths indicate pedestrian paths.

Thicker paths indicate more pedestrian use.

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[8] Developed by the Community Service Center, University of Oregon, 2004 (Appendix C).

The walkability safety rating, combined with the student household survey results, enabled *macro*-level comparisons between school neighborhoods. By assembling composite measures of walkability (i.e., crossing aid density, intersection density, composite walkability ratings) it was possible to compare school neighborhoods. It is believed the outcomes of this analysis may shed light on the way traditional and suburban development patterns may influence pedestrian routes between home and school.

MAPPING THE RESULTS

Through a thoughtful and deliberate process, this project seeks to better understand the spatial distribution, character, and use of sidewalks by middle school students walking to and from school. In the past, walkability research recognized the importance of pedestrian–level details in the built environment, but due to a lack of data it focused instead on neighborhood- and city-level measures using GIS and census data. Graphically presenting streetscape characteristics is rather straightforward. However, the purpose of creating a walkability safety rating was to condense the presentation of data collected. Without a method of viewing all 27 measures of walkability simultaneously it would be difficult to understand the nature of the pedestrian landscape. The following evaluations of intersections, street segment walkability, and sidewalk usage trends may improve the way we understand streetscape design and maps are the most appropriate way to present these findings.

CHAPTER 4

Findings and Analysis

This study evaluated the distribution of pedestrian safety amenities and the walkability of student routes between home and school to determine whether walkability had a discernable influence on students' chosen routes. No single indicator adequately describes neighborhood walkability, thus this analysis includes five indicators of walkability, including comparisons of: 1) intersection characteristics and densities; 2) road classifications; 3) land-uses; 4) walkability safety ratings; 5) and student routes.

LAND-USES

While many students walk or bike *directly* from home to school, or vice versa, the land use along their path can influence their route choice. Students are potentially swayed from their shortest route home by corner stores, parks, or a friend's house. The PEDS walkability audit tool records whether street segments contain up to eight unique land uses, including single family residential, multi-unit residential, mobile home, office/institutional (e.g., offices, churches, schools, etc.), restaurant/cafe/commercial, industrial, recreational, or vacant properties. These land-use measures are not included in the walkability safety rating, yet they describe the character of the neighborhood and quantify potential destinations therein, thus they are included here as an indicator walkability.

Table 4-1 highlights the frequency of various land-uses within the four middle school neighborhoods. Overall, Springfield has a significantly higher land use mix index than other schools in the study. Both Springfield and Agnes Stewart contain a broad range of activities, including industrial, recreational, commercial, institutional, and residential, which makes sense because Springfield MS is situated near the downtown commercial district while Agnes Stewart is located on the border of a residential neighborhood and industrial timber mill. More than 1 in 10 street segments around Agnes Stewart contain recreation facilities because two parks and one elementary school are located within 1/2 mile of the school. In Bend, Pilot Butte includes a high rate of multi-unit housing. Although Pilot Butte MS is across the street from Pilot Butte State Park few streets in this neighborhood actually abut the park. Sky View has just three land use types: single family residential, vacant, and office/institutional. Both fringe schools, Agnes Stewart and Sky View, contain more vacant properties than their centrally located counterparts. The high percentage of vacant lots at Sky View is due to its location on the urban fringe – the city limits wrap around the north, east, and south boundaries of the Sky View neighborhood. However, these vacant properties may provide cut-through routes (not included in TIGER coverages) for students at these schools.

Table 4-1. Land-use rates and Land-use Mix Index by school

	Middle School			
	Pilot Butte	Sky View	Springfield	Agnes Stewart
Total Street Segments	112	87	154	100
Single Fam. Res.	89%	94%	84%	94%
Multi-unit	8%	0%	1%	2%
Mobile Home	0%	0%	1%	2%
Office / Institutional	6%	3%	33%	4%
Restaurant / Café / Commerical	2%	0%	19%	4%
Industrial	1%	0%	3%	8%
Recreation	1%	0%	6%	11%
Vacant	11%	59%	14%	23%
Land-use Mix Index	**1.18**	**1.21**	**2.21**	**1.32**

To better interpret the assortment of land-use types at any given school it is helpful to use a single measure that takes into account these various land-uses. The Land-Use Mix Index (LUMI) is the sum of all land uses divided by the total number of streets (see *Chapter 3: Methodology*). A high index means there is a diversity of land-uses, which suggests the area is attractive to pedestrians. The LUMI is significantly higher at Springfield MS (2.21) compared to the other schools in the survey (Table 4-1). Pilot Butte and Sky View have comparable scores (1.18 and 1.21), while Agnes Stewart (1.32) has slightly more land-uses per segment than the Bend schools.

ROAD CLASSIFICATIONS

U.S. Census TIGER road files contain a hierarchical typology that can be used to describe the character of the road network. The different road designations are based on the design speed, road width, number of lanes, and traffic control devices provided. Three road types can be found within the study areas, including secondary, connecting, and neighborhood streets (Table 4-2). For the most part, neighborhood streets are the predominant road type, which makes sense given the residential locations of these schools. However, the two centrally located schools also contain arterial roadways. Arterials are intended to carry more traffic at higher speeds than neighborhood streets, which leads to a more dangerous walking environment for students. The Pilot Butte study area includes a ¾-mile stretch of US Highway 20, and a ½-mile stretch of Main Street (US Highway 126) passes though the southern portion of the Springfield site.

Table 4-2. Percent of streets by TIGER road classification and school

	Secondary Road*	Connecting Road**	Neighborhood Road**	Unknown	Total
Central					
Pilot Butte	4%	0%	96%	0%	100%
Springfield	0%	5%	95%	0%	100%
Fringe					
Sky View	0%	0%	93%	7%	100%
Agnes Stewart	0%	0%	100%	0%	100%

* A21 Secondary road, U.S. highway not classified A10, and state roads, undivided

** A31 Connecting road, county roads, and roads not classified as A10 or A20, undivided

A41 Neighborhood roads, city streets and unimproved roads, undivided

If there were a more diverse collection of road types within these study areas it might have been feasible to evaluate the relationship between walkability and road class, but in this case the streets are primarily neighborhood streets.

ROUTE OPPORTUNITY ANALYSIS

Intersection densities and characteristics are proxies for neighborhood walkability because they quantify the number of potential pathways available between home and school. Neighborhoods with more streets and intersections per square mile offer students a greater variety of routes. This section provides a comparison of schools based on the density and types of intersections found in each neighborhood.

Street Density

A comparison of street densities reveals that both centrally located schools (Springfield MS and Pilot Butte) have more streets per square mile than fringe schools (Agnes Stewart and Sky View) (Table 4-3). These results suggest that on a neighborhood level, centrally located schools are more walkable than those situated on community fringes because students have more direct, and therefore shorter, routes to school. However, these findings do not indicate the quality of the walking experience. Moreover, schools with high street and intersection densities may actually increase the chances of pedestrian/vehicle collisions because students cross more streets on their way to school.

Table 4-3. Miles of street and street density

	Total Street Miles	Density (mi./sq.mi.)
Central		
Pilot Butte	8.9	11.3
Springfield	14.1	24.0
Fringe		
Sky View	6.9	8.7
Agnes Stewart	8.5	10.8

Intersection Density

Like street densities, intersection densities are indicators of the variety of route options. Neighborhoods with high rates of 3- and 4-way intersections offer more choices than neighborhoods with dead end streets because dead ends limit access to through-traffic. Both centrally located schools (Springfield and Pilot Butte) and Agnes Stewart contain approximately the same number of intersections, even though Springfield contains more than twice as many streets per square mile (Table 4-4). This disparity may be partially explained by the high number of dead ends at Agnes Stewart, Pilot Butte, and Sky View. In terms of three- and four-way intersections, both centrally located schools have higher intersection densities than their urban fringe counterparts.

Table 4-4. Intersection types and densities by school

		Percentage by Type		Density per sq. mi.	
School	**Intersections per school**	**Dead ends**	**Three- and Four-way**	**Dead ends**	**Three- and Four-way**
Central					
Pilot Butte	73	36%	62%	35.7	57.3
Springfield	78	**6%**	**94%**	**8.5**	**124.4**
Fringe					
Sky View	60	48%	52%	36.9	**39.5**
Agnes Stewart	77	30%	70%	29.3	68.8

Intersection Characteristics

Although intersections hint at the variety of route choices they are not categorically beneficial to pedestrians. Intersections are the most common site of pedestrian/vehicle collisions. Therefore, an analysis of intersection characteristics at the streetscape level is a valuable indicator of walkability. The audit tool records the presence of nine crossing aids that help improve intersection safety by alerting drivers to pedestrians, slowing or stopping vehicles, and separating pedestrians from traffic.

Nearly half of all street segments in this study include at least one stop sign – by far the most common traffic-calming device (Table 4-5). Traffic lights are the second most common crossing aid. In the Sky View area there are fewer stop signs, pedestrian crossing signs, pavement markings, and traffic lights to slow and manage traffic than at other schools – findings that suggest Sky View is less walkable than the other schools. A high number of streets at Springfield MS (39 percent) contain pavement markings that specify where vehicles should stop for pedestrians. As cars approach intersections these markings remind drivers that they must heed to pedestrians. Overall, the intersections at Springfield MS have more crossing aids than other schools, while Pilot Butte and Agnes Stewart have comparable crossing aid provisions.

Table 4-5. Crossing-aid frequency

	Central		Fringe	
	Pilot Butte	**Springfield**	**Sky View**	**Agnes Stewart**
Traffic Light	6%	15%	0%	7%
Stop Sign	50%	66%	49%	50%
Traffic Circle	0%	0%	1%	0%
Chicanes	0%	1%	0%	0%
Pavement Markings	5%	39%	3%	5%
Ped. Signal	3%	1%	0%	0%
Traffic Island	4%	1%	1%	2%
Over / Underpass	0%	0%	0%	0%
Pedestrian Crossing Sign	6%	6%	4%	12%

Provision of sidewalks is possibly the most important indicator of walkability because without sidewalks pedestrians are often forced to walk in the street. Yet over time the municipal regulations requiring sidewalks often change. Some neighborhoods have complete sidewalks on both sides of all streets while others do not provide sidewalks at all – in most instances the provision of sidewalks falls somewhere between these extremes.

Streets surrounding Springfield MS tend to have between 4 and 6 sidewalk connections while Agnes Stewart and Pilot Butte contain a wide range (0 to 6) of connections (Table 4-6). Cul de sac streets limit the number of connections because sidewalks terminate at one end. The low number of dead ends around Springfield may explain the high number of sidewalk connections at this school. One-in-ten streets at Sky View have no sidewalk connections, which indicate this school is not well connected to the neighborhood in terms of walkability.

Table 4-6. Percent of street segments containing sidewalk connections

	Number of Sidewalk Connections									
	0	1	2	3	4	5	6	7	8	Total
Central										
Pilot Butte	3%	3%	24%	14%	20%	6%	30%	0%	0%	100%
Springfield	0%	0%	1%	3%	12%	16%	64%	1%	3%	100%
Fringe										
Sky View	10%	4%	19%	6%	23%	12%	27%	0%	0%	100%
Agnes Stewart	0%	0%	3%	20%	16%	25%	32%	0%	4%	100%

WALKABILITY SAFETY RATINGS

The previous section highlights the provision of crossing aids – key pedestrian safety amenities. But a discussion of pedestrian safety is not complete without addressing several other critical components of the streetscape that increase pedestrian safety. A total of 26 measures were recorded at the four middle schools to help identify differences in walkability between centrally located schools (Pilot Butte and Springfield) and those built on the urban fringe (Sky View and Agnes Stewart). Maps of the results are presented in *Appendix F* for review, while the following discussion highlights the most telling findings. To aid discussion and interpretation these 26 measures are grouped into the following seven categories:

- Pedestrian and bicycle safety
- Attractive for walking and biking
- Traffic calming devices
- Crossing aids and sidewalk connections
- Sidewalk completeness, condition, and
- Path obstructions
- Way-finding aids, lighting, and driveways

Pedestrian and bicycle safety

Springfield has the highest overall ‘safety for walking?’ rating with 95 percent of streets rated as ‘safe’ or ‘very safe.’ The Bend schools tend to have lower pedestrian safety ratings than those in Springfield (Figure 4-1). Ninety-three percent of streets at Pilot Butte and 78 percent at Sky View were rated as ‘unsafe’ or ‘safe.’ Half of streets at Agnes Stewart were rated as 'unsafe' for pedestrians, yet another 24 percent were rated as 'very safe.' The bicycle safety ratings are comparable to the pedestrian ratings at all four schools (Figure 4-2).

Figure 4-1. Safe for walking

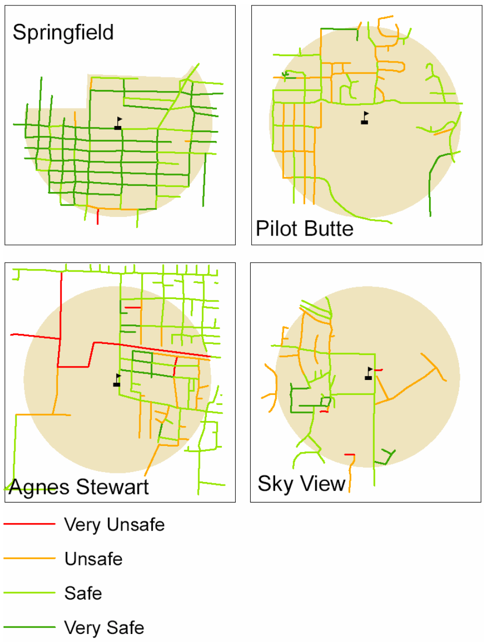
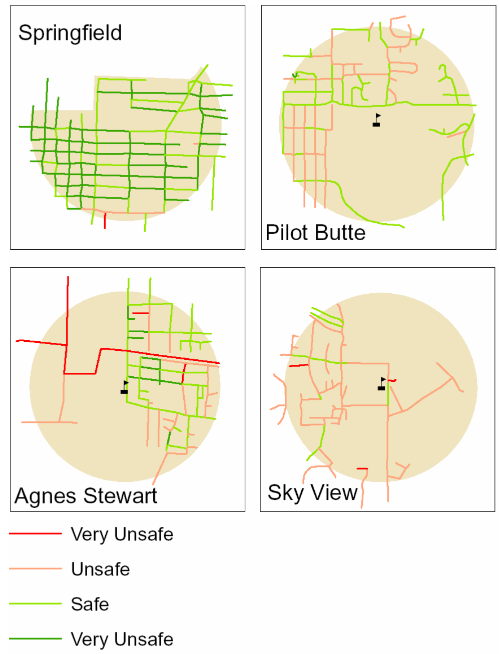


Figure 4-2. Safe for biking



These findings suggest that the neighborhoods in Bend are less safe for pedestrians than those in Springfield, but standing alone these measures are inconclusive, in part because they are subjective. Furthermore, the audit tool did not measure pathways in parks. Thus these findings do not take into account the presence of trails and paths through Pilot Butte State Park south of Pilot Butte MS. In fact, 6 of 11 students who live west of Pilot Butte MS and south of Neff Road use short cuts through the State Park for a portion of their route to/from school. If this issue is factored into the analysis one could reasonably conclude that both centrally located schools, Pilot Butte and Springfield, are safer for pedestrians than fringe schools, but the findings presented in subsequent subsections suggest otherwise.

Attractive for walking and biking

Results in this section are based on responses to the subjective question: "would you want to walk/bike this segment? This includes finding the area aesthetically pleasing and the density of destinations. A significant number of streets (95 percent) around Springfield MS were rated as 'very attractive' and 'attractive' for walking. Pilot Butte, Sky View, and Agnes Stewart have comparable scores with 96 percent, 82 percent, and 81 percent of segments rated as 'unattractive' or 'attractive' for walking. However, a significant number of streets at Pilot Butte (75 percent) were rated as attractive. Ratings for attractiveness in terms of biking are similar to the 'walking' results outlined here.

Springfield may have rated higher on this measure for several reasons. The proximity of this school to a downtown commercial area increases the number of destinations near this school, and the historic district contained within the study area is well maintained and attractive. The relatively high number of streets rated as attractive is high for both centrally located schools, which may be a function of the character that these neighborhoods acquire over time or their proximity to various land-uses may increase their appeal. These results suggest the centrally located schools are more attractive for walking and biking.

Traffic calming devices

Five traffic calming devices were noted for street segments in the four study areas. Traffic calming devices either slow or stop traffic, thereby increasing pedestrian safety. Of all the streets in this study, only five segments contained traffic circles, speed bumps, or chicanes – these are the most infrequent traffic calming devices. One of two chicanes, however, is located adjacent to the school driveway entrance at Springfield MS, which was presumably installed to manage vehicle speeds near the school (Figure 4-3). The other instances of these three devices are not located adjacent to school properties (*Appendix F*).

Figure 4-3. Traffic calming: Chicanes

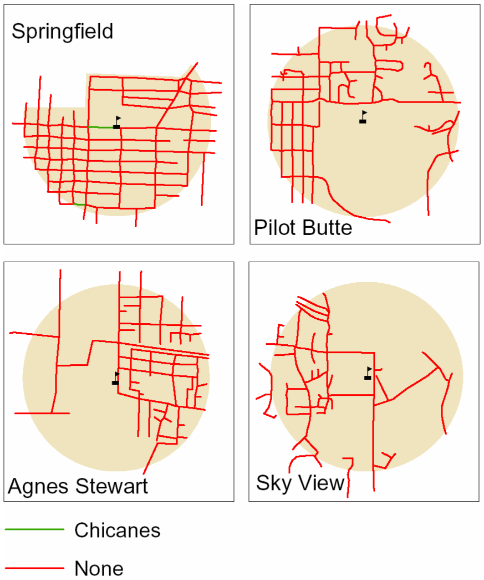
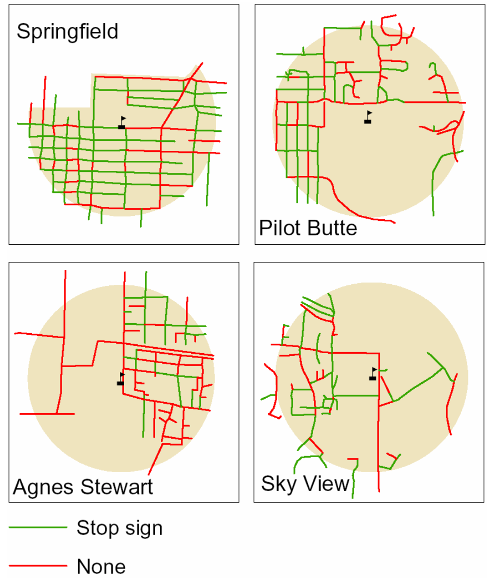


Figure 4-4. Traffic calming: Stop signs



Stop signs and traffic lights are common traffic calming devices. The only schools that contain stop lights within the 1/2-mile study area are Springfield and Pilot Butte Middle Schools with 15 percent and 6 percent of street segments, respectively, having lights (*Appendix F*). Stop signs are the most common traffic calming device. Half of streets at the Bend schools have stop signs, while 65 percent of streets at Springfield MS have stop signs (Figure 4-4). Of all schools, Agnes Stewart rates the lowest in terms of traffic calming devices with just ¼ of streets containing stop signs.

Crossing aids and sidewalk connections

A summary of crossing aids and sidewalk connections is provided in the preceding section titled, ROUTE OPPORTUNITY ANALYSIS.

Sidewalk Completeness and Condition

A sidewalk is incomplete only if it contains breaks within the segment. Segments that end or contain gaps may force students to walk in the street or cross the street mid-block, which is unsafe. However, sidewalk gaps may also be traversed by simply cutting across properties lacking sidewalks. The vast majority of streets at Springfield (97 percent) and Agnes Stewart (63 percent) are complete, while approximately 45 percent of streets at the Bend schools are incomplete or non-existent (Figure 4-5).

Figure 4-5. Sidewalk completeness

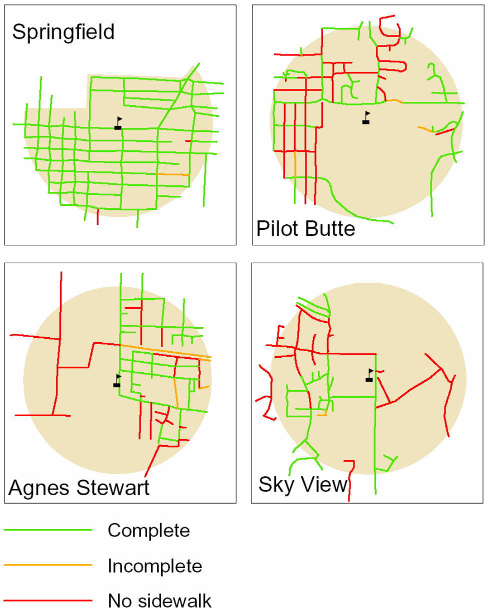
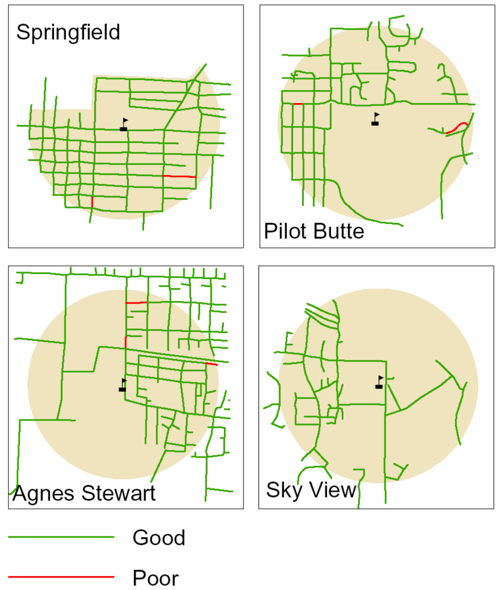


Figure 4-6. Sidewalk condition



In general, sidewalk conditions were good across all four schools. Agnes Stewart had the highest frequency of segments with poor sidewalk conditions (10 percent). More than 85 percent of segments at each school were in good condition (Figure 4-6).

Path obstructions

Path obstructions include parked cars, trash cans, poles/signs, and trees. Few streets contained trees or garbage cans that obstructed the path of pedestrians, but a large percent of sidewalks were obstructed by cars and poles/signs. Springfield and Pilot Butte contained the highest percent of streets obstructed by cars (92 and 97 percent, respectively). These neighborhoods probably have shorter driveways, which mean that households with two cars often block the sidewalk.

Way-finding aids, lighting, and driveways

At least 94 percent of streets at each school contain way-finding aids, such as street signs. The degree of street lighting varies greatly from school to school, which may be an issue for students who walk early in the morning or late in the afternoon. However, it is important to note that the subjective nature of this measure may have influenced the findings.

Furthermore, the streetscape audits were completed during daylight hours, which make it challenging to determine the degree of lighting.

Overall, Springfield has the best street lighting with 61 percent of segments rated 'good' (Figure 4-7). Streets at Agnes Stewart are evenly distributed with 'poor,' 'fair,' and 'good' street lighting. More than 95 percent and 70 percent of streets at Sky View and Pilot Butte have 'fair' street lighting.

Figure 4-7. Lighting

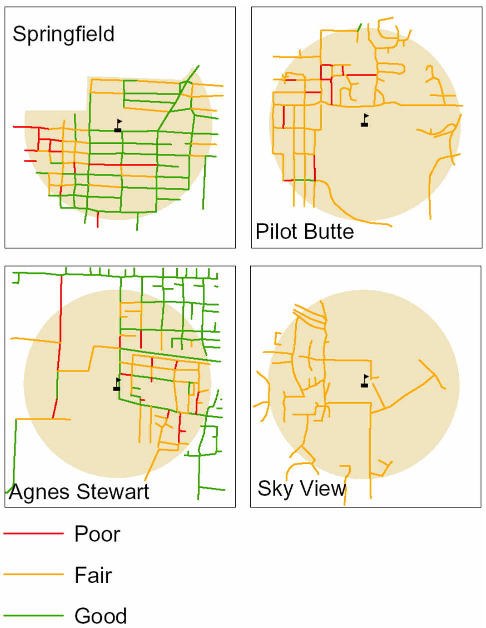
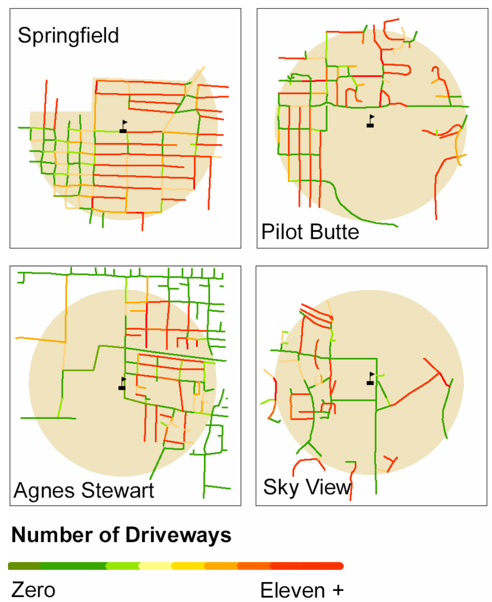


Figure 4-8. Number of driveways



Driveways are a common location of pedestrian/vehicle collisions. The number of driveways per segment is highly dependent on the length of the segment. Longer streets tend to have more driveways than shorter streets. The average lengths of street segments are nearly equivalent at each school and the distribution of driveways is similar among all four schools (Figure 4-8).

Overall walkability safety ratings

To improve analysis and interpretation of these findings it is helpful to combine the results of all 26 measures presented above into a single index of walkability safety. Two approaches were developed to address this need.

The first approach is simply a comparison of the average walkability rating per segment (Table 4-7). Springfield MS streets tend to have higher walkability ratings than the other three schools. However, this method does not account for the density or length of street segments at each school. Is Pilot Butte, for example, less walkable than Sky View because it has lower walkability ratings, or should this decision include consideration of the length of each segment?

Table 4-7. Average walkability safety ratings

	Total Street Miles	Density (mi./sq.mi.)	Average Walkability Rating per Segment
Central			
Pilot Butte	8.9	11.3	24.6
Springfield	14.1	24.0	39.0
Fringe			
Sky View	6.9	8.7	27.9
Agnes Stewart	8.5	10.8	30.2

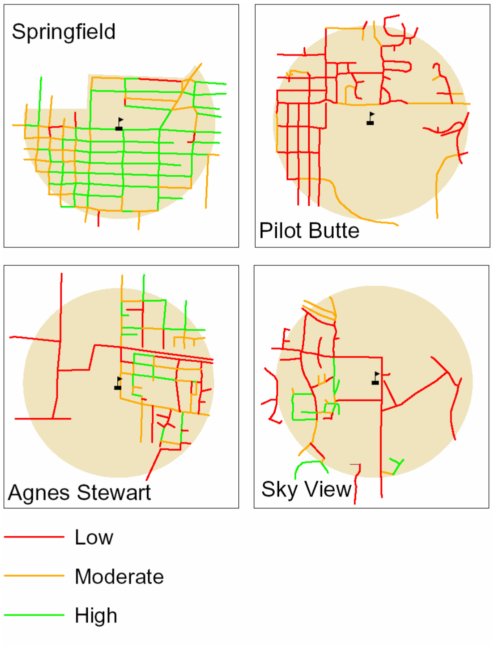
The second approach to summarize the 26 measures addresses this question by weighting the walkability rating with the length of each segment. The segment rating was multiplied by its length to create a weighted score. These ratings were classified as low, moderate, high in terms of walkability. Ninety-six percent of streets around Springfield and 36 percent near Pilot Butte have moderate to high walkability ratings, while Agnes Stewart and Sky View have 66 percent and 56 percent, respectively (Table 4-8) (Figure 4-9). The low ratings at Pilot Butte could reflect the fact that two people conducted the street audits, yet Clifton (2004) found the audit instrument has a high level inter-rater reliability. Instead, it is likely that Pilot Butte and Sky View have the lowest levels of walkability compared to the other schools.

Table 4-8. Walkability classification by school

		Percent of Streets		
	Total Segments	Low Walkability	Moderate Walkability	High Walkability
Central				
Pilot Butte	51	64%	36%	0%
Springfield	154	3%	23%	73%
Fringe				
Sky View	91	44%	40%	16%
Agnes Stewart	100	34%	32%	34%

The maps in Figure 4-9 help illustrate the disparity in overall walkability ratings between the four schools in this study.

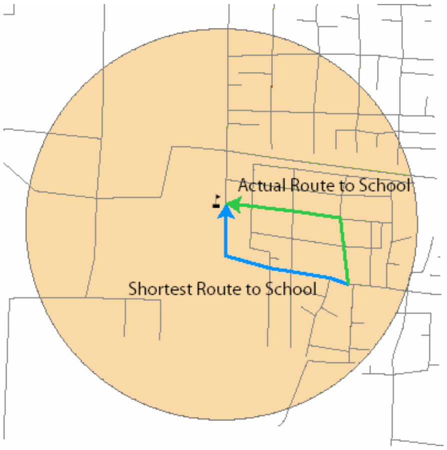
Figure 4-9. Total walkability safety rating



SHORTEST ROUTE VS. ACTUAL ROUTE

A key component of this project was an evaluation of students' routes to/from school in terms of walkability safety. Middle school students have discretion over the routes they walk. There is one shortest route between each student's home and school, but there are longer alternative routes as well. Figure 4-10 shows that students have the option to choose from multiple routes with similar lengths. Students were asked to map the route they use to get to/from school – these routes were evaluated on two levels. First, the student routes were compared to the shortest possible route. Second, the walkability of the alternative routes taken by students was compared to the shortest routes.

Figure 4-10. Example of shortest route and actual route to school



Approximately half of students at Pilot Butte, Sky View, and Agnes Stewart take the shortest route to school, while less than 30 percent of Springfield students take the shortest route (Table 4-9). Thus, a significant portion of students vary from the most direct route between home and school. Of those that take alternatives to the shortest route, the data suggests the alternative routes tend to be *less* walkable than the shortest route. Sky View is the only school where students who take alternatives to the shortest route tend to take *more* walkable routes. These results indicate that a large contingent of students take the shortest route to school and, therefore, are not influenced by streetscape characteristics when choosing their route. This makes sense because the alternatives tend to be less walkable and longer.

Table 4-9. Walkability of shortest and actual routes to schools

		Students that take alternative to shortest route that is:	
	Student that take shortest route to school	**More walkable**	**Less walkable**
Central			
Pilot Butte	52%	15%	33%
Springfield	29%	29%	43%
Fringe			
Sky View	54%	33%	13%
Agnes Stewart	46%	8%	46%

One explanation for the trends identified above is outlined in Table 4-10. On average the walkability safety rating of students' routes to school tend to be higher than the school-wide average rating. That is to say, students tend to take the most walkable streets to school. The walkability safety rating of students' routes at Pilot Butte, Agnes Stewart, and Springfield are approximately 3 points higher than each schools' average rating, while Sky View students take routes with ratings equivalent to the school average. This raises an intriguing conclusion, namely, that students tend to walk along neighborhood collector streets, and that these collectors are more walkable than the surrounding neighborhood streets. Although the street classifications are not helpful in validating this conclusion the density of student use per segment sheds light on this theory.

Table 4-10. Student route and average street ratings

	Student Routes	Overall School Average
Pilot Butte	28.1	24.7
Sky View	27.8	27.9
Agnes Stewart	34.8	30.2
Springfield	42.6	39.2

STUDENT ROUTE DENSITIES

As students walk to school their paths converge on a few common blocks near each school. As students come together certain streets tend carry more pedestrian traffic than others. The pedestrian traffic patterns identified in this summary are helpful in identifying which street segments experience the most pedestrian use.

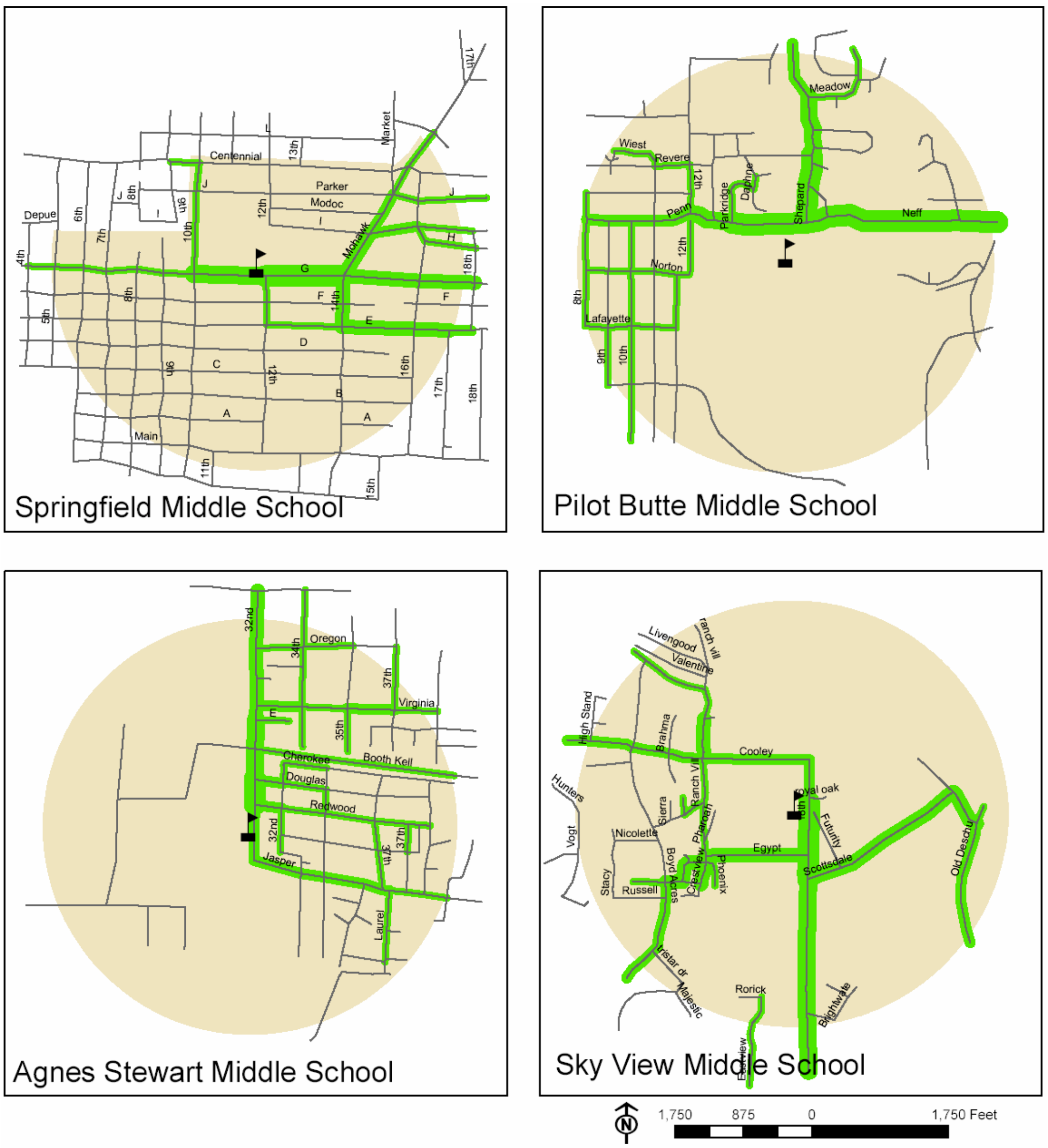
The combination of commercial streets south of C Street and the truncated school district boundary mean most students at Springfield Middle School live east or west of the site (Figure 4-11). It is noteworthy that E, G, H, I, J, and Mohawk Streets are used by students walking and biking to school – results that suggest no path is more walkable than the others.

Nearly one-third of respondents at Pilot Butte approach the school from the east along Neff Street (Figure 4-11). The siting of Pilot Butte near the intersection of Neff, Shepard and Penn turns these streets into 'pedestrian collectors.'

The same holds true at Agnes Stewart where 32^{nd} Avenue and Jasper Road carry a large volume of pedestrian traffic (Figure 4-11). It appears most students at Agnes Stewart avoid dead ends by approaching school from the east along streets with direct access to 32^{nd} Ave., which supports the theory that dead ends deter student pedestrians.

At Sky View, Cooley, 18th, Scottsdale, and Egypt streets are the primary pedestrian collectors because they are the only continuous streets in the immediate vicinity of the campus (Figure 4-11). Interestingly, students walk along all streets east of Ranch Villa; probably because they are the only non-dead end paths available to students beyond the ½ mile study area.

Figure 4-11. Student route densities



CHAPTER 5

Analysis and Recommendations

In recent years public health officials and urban planners have been earnestly exploring the relationship between the built environment and physical activity. Walking is the most popular exercise activity, but research has shown that certain streetscape elements, including provision of sidewalks, safe cross-walks, and continuity of the sidewalk network may have a significant influence on whether people walk, bike, or drive to nearby destinations. Increasing rates of obesity in the U.S. have elevated interested in this topic because walking is the most accessible form of physical activity. Thus, it's in the best interest of any community to ensure that adequate pedestrian infrastructure is provided because these facilities enhance the physical, social, and economic wellbeing of residents. One way to achieve this goal is to develop sidewalk, trail, and footpath networks within communities. This study was conceived as a way to increase our understanding of streetscape variables and enhance the methods available to conduct walkability research.

The remainder of this chapter presents key findings and analysis related to the research questions of this project, in addition to reviewing limitations of the methodology. The chapter concludes with a general discussion of broader research questions to guide future study.

ANALYSIS OF KEY FINDINGS

This project sought to quantify and evaluate streetscape variables that influence pedestrians' decision to walk, bike, or drive. In particular, the following questions guided this research: (1) How do fringe (i.e., suburban) schools differ in terms of walkability from urban core (i.e., traditional, grid) schools; (2) What is the spatial distribution of pedestrian amenities within individual neighborhoods and between schools; and (3) Do students, when presented with two equally long routes, tend to favor more walkable/safer streets? The analyses for the first two questions are presented together while the final research question is addressed individually.

Spatial distribution of pedestrian amenities

Some of the key findings related to the distribution of pedestrian amenities are:

- ***Land-use:*** Centrally located schools contain a more diverse mix of land-uses; and, the high rate of vacant property at Sky View and Agnes Stewart may conceal from the analysis opportunities for students to take short cuts.
- ***Road Classification:*** More than 90 percent of roads in the study are neighborhood streets, but the centrally located schools (Pilot Butte and Springfield MS) contain a few higher traffic volume roads.
- ***Street Density:*** Pilot Butte and Springfield MS have more streets per square mile than the urban fringe schools.
- ***Intersection Density:*** Both centrally located schools (Springfield and Pilot Butte) and Agnes Stewart contain approximately the same number of intersections, even though Springfield contains more than twice as many streets per square mile.
- ***Intersection Characteristics:*** Intersections at Springfield MS have more crossing aids than other schools, while Pilot Butte and Agnes Stewart have comparable crossing aid provisions.
- ***Walkability Safety Ratings:*** In terms of pedestrian safety, attractiveness for walking, sidewalk condition, and provision of traffic calming devices and crossing aids, the centrally located, traditionally planned neighborhoods are more safe for pedestrians than the urban fringe schools.

Conclusions

According to the results of multiple walkability indicators employed in this study, the schools located in traditionally designed (i.e., grid) neighborhoods are more walkable and safer for pedestrian travel than urban fringe schools. They tend to be more attractive, contain a diverse array of land-uses, and provide more traffic calming devices. When viewed independently these results seem relatively conclusive, but several other key indicators shed a different light on this conclusion. Namely, this conclusion disregards the number of sidewalk connections, the number of dead ends, or the overall walkability safety ratings developed to compare streets in this study. The significance of these indicators are discussed in the next section of this summary.

Student Routes and Walkability

Some of the key findings related to student routes and walkability are:

- ***Shortest Routes vs. Actual Routes:*** A large contingent of students takes the shortest route to school and, therefore, is not influenced by streetscape characteristics when choosing their route.
- ***Walkability Safety Rating:*** The low number of dead ends around Springfield may explain the high number of sidewalk connections at this school. One-in-ten streets at Sky View have no sidewalk connections, which indicate this school is not well connected to the neighborhood in terms of walkability.
- ***Walkability Safety Rating:*** On average the walkability safety rating of students' routes to school tends to be higher than the school-wide average rating. That is to say, students tend to take the most walkable streets to school.
- ***Student Route Densities:*** Students gravitate to neighborhood collector streets.

Conclusions

Although in many instances Pilot Butte and Springfield Middle Schools rank higher in terms of walkability safety than their urban fringe counterparts, the number of dead end streets at Pilot Butte significantly reduces the walkability of this school. Dead end streets, as it turns out, are one of the most important indicators of pedestrian safety when viewed through the lens of the PEDS audit instrument. Dead end streets limit the number of sidewalk connections, crossing aids, traffic calming devices (because the streets are already calm), and they are less attractive for walking and biking because they limit access to destinations. Furthermore, dead end streets tend to have fewer sidewalks and those with sidewalks have more gaps and breaks. Thus, dead end streets have limited walkability potential and often receive low walkability ratings. Therefore, neighborhoods with high dead end densities, such as Pilot Butte, Sky View, and Agnes Stewart, tend to be rated as poor for pedestrian safety.

Two facts support this conclusion. One of the most significant reasons Springfield MS has such high walkability is the fact that there are very few dead end streets around the school. Thus, each street segment contains more sidewalk connections, which leads to higher walkability ratings. Second, students tend to take the shortest route to school and, for the most part, these routes are more walkable than other routes. The reason they are more walkable is because neighborhood collector streets have fewer dead ends and are more developed in terms of pedestrian amenities (i.e., provision of sidewalks, crossing aids, traffic calming devices, access to destinations, etc.).

A second conclusion, with implications for future research in this field, is the fact that a large portion of students take the shortest route to/from school. Although shorter routes tend to be more walkable than longer routes, which is one reason students take them, it's more likely students are drawn to the shortest route simply because they are shorter. Handy (1906) found that people are less concerned with walkability when walking to a destination than times when they are walking for exercise (no destination); the findings of this study appear to support her conclusions. Alternatively, students may take the shortest route only because it is the only route to school. In the case of Pilot Butte, Sky View, and Agnes Stewart middle schools, the disjointed and disconnected street network, in addition to low road densities, limit the potential pathways to schools.

These findings suggest that neighborhoods containing schools and scores of cul de sacs should significantly enhance the number of crossing aids and traffic calming devices on neighborhood collector streets – these streets tend to collect cars as well as pedestrians. And since collector streets carry more vehicular traffic at higher speeds it is imperative that safety measures are taken to ensure pedestrians are safe on these streets.

METHODOLOGY FINDINGS

It is important at this point to highlight three limitations of this project with the hope that future research will address these barriers and improve on the methods outlined in *Chapter 3: Methodology*. The three primary concerns include the potential biases inculcated by multiple people collecting data, the relative weight of subjective measures compared to objective measures in the walkability safety rating, and limitations of U.S. Census TIGER coverages that are the foundation of the data in this approach.

Multiple field recorders and subjectivity. As a matter of efficiency and functionality it is crucial that any walkability audit instrument be insured against potential biases of the people collecting data. The audit tool must be designed to filter out the personal preferences and inclinations that characterize people conducting the walkability audit. Limiting the number of subjective responses is a first step, but excising these measures completely may actually diminish the instrument's ability to capture subtle characteristics of streetscapes that influence walkability. The nature of vacant lots, for example, range from unkempt, litter strewn properties to vast landscaped open spaces with aesthetically pleasing views. Asking data collectors to respond to the question, "Is the street segment attractive for walking?" likely improves the overall quality of the streetscape data by engaging the auditor's ability to interpret and distill vast amounts of detail that indicate the walkability of a street segment.

The PEDS audit tool includes five subjective measures of walkability safety, including "Feels safe for walking?" "Feels safe for biking?" "Degree of lighting provided?" "Is attractive for walking?" and "Is attractive for biking?" One potential issue with these measures does not pertain to the questions themselves, rather it concerns the relative value or importance placed on these measures by the walkability safety rating devised to interpret audit data. These five subjective measure have individual scores of up to 3 points – three times the 'present vs. absent' measures, which are limited to 0 or 1 point. Thus, a high score on these five subjective measures may overshadow the value of up to 10 objective measures. It is not clear from the data whether that this might have been an issue with this project, but refinement of the weighting system will be worthy of rigorous review for future studies.

A tangentially related issue is the inclusion of *bicycle safety* and *bicycle attractiveness* given that biking and walking are distinct travel modes each having specific safety concerns. The extent of overlapping safety concerns is largely unknown and correlations between these modes have not been studied extensively, yet past research found safety is the primary concern of both pedestrians and bicyclists (Pikora 2003). However, future research in this field may need to study accessibility concerns of these modes separately.

US Census TIGER files. U.S. Census TIGER files – GIS coverages of road networks – formed the foundation of this research by providing line segments upon which a multitude of streetscape attributes could be attached. It is not insignificant that these freely available datasets exists. The time necessary to create road network files is substantial, and while other organizations including state departments of transportation also offer similar, sometimes more accurate, data sets they are rarely consistent between jurisdictions. By and large ease of access to TIGER files make them a likely starting point for streetscape walkability research – despite their limitations.

Chief among the limitations are validity and reliability concerns. Too often TIGER files contain street segments that do not exist on the ground – frequently because they are out-of-date – or conversely they omit park trails, alleys, and vacant lots, which are clearly used by students. For example, 6 of 11 students who live west of Pilot Butte MS and south of Neff Road use short cuts through Pilot Butte State Park for a portion of their route to/from school. The extent that this phenomenon at the other three schools – in particular at Sky View which contains a high rate of vacant properties – remains unclear, but the case at Pilot Butte underscores this boundary of TIGER file data.

Extent of walkability audit study areas. Finally, as mentioned previously in *Chapter 3: Methodology*, the PEDS audit instrument includes as many measures of walkability as necessary (Clifton 2004). So many, in fact, it became apparent that a streamlined instrument will enable future research to assess streetscape walkability of bigger geographic areas given the same amount of time in the field. In reviewing students' actual routes to school it is clear that a ½-mile study radius underestimates the true distances students walk to school, and while this does not limit the findings and analysis here it suggests future research may want to explore larger geographic areas.[9]

Future Research Recommendations

One potentially interesting evaluation of the walkability safety rating developed here includes comparing the safety rating (25 measures) with the 'complete' PEDS instrument results (78 measures). Do they produce the same results? The answer is most likely no, which makes sense given the safety rating quantifies elements identified as contributing to pedestrian safety in particular. In fact, one of tools could be used based on the amount of time available

[9] The walkability safety rating in this project is a streamlined adaptation of the PEDS audit instrument that may be employed for projects with limited field work time (Clifton 2004).

for fieldwork, or the results a ‘complete’ audit could include a walkability safety sub-score. That being the case, the audit tool protocol (Levi 2004) could incorporate guidance for those deciding whether to use the ‘complete’ version, the ‘safety’ version, or both.

Revision and refinement are critical steps in developing research tools, but the benefits of updates and revisions must be balanced with the benefits of settling on instrument(s) that provide adequate data to describe walkability. I recognize the irony of this recommendation in light of the methods employed for project, but the potential benefits of a robust data set containing the same streetscape walkability information holds significant promise. As more audits are completed these data could be incorporated into a master database that would serve to normalize walkability ratings. The relative infancy of this line of study will probably relegate this opportunity to those far into the future, but the concept is intriguing to note.

With that said, the use of GIS technology for this project could enhance future studies. While the approach outlined above focuses on attributes of street segments (lines), there is potential to synchronize streetscape data with intersection (point), destination/origin (point), and region (polygon) characteristics. For example, opportunities to cross-tabulate U.S. Census and streetscape walkability data will likely produce interesting insights into transportation behavior.

As a tool for planners the audit instrument could help professionals meet the needs of diverse populations in urban to suburban locations, as well as those walking to unique destinations such as hospitals, college campuses, or parks, to name a few. How does walkability around these institutions and other destinations influence travel behavior? What are the most important streetscape characteristics for pedestrians walking to these locations? Moreover, pedestrians choose routes differently depending on the purpose of the trip – people with a specific destination tend to take direct routes, while those taking stroll for leisure or exercise seek more walkable areas (Handy 1996). What is the upshot of increased walkability on rates of walking for exercise? Do residents or employees in neighborhoods with superior walkability exhibit improved fitness, or are they more likely to walk rather than exercise at a gym? Answers to these questions will likely be forthcoming as research in this field continues, and the outcomes could have dramatic sway over policy makers and urban planning practitioners. Although the degree to which the built environment influences travel mode and route choice will be debated endlessly, this project offers a new approach to the issue.

Appendix A
PEDS Walkability Audit Instrument

Name: ____________ Date: ____________ Study Area: ____________ PEDS

Segment Number: ____________ Time: ____________ Weather: ____________

0. Segment type
- Low volume road 1
- High volume road 2
- Bike or Ped path - skip section C 3

A. Environment

1. Uses in Segment *(all that apply)*
- Housing - Single Family Detached 1
- Housing - Multi-Family 2
- Housing - Mobile Homes 3
- Office/Institutional 4
- Restaurant/Cafe/Commercial 5
- Industrial 6
- Vacant/Undeveloped 7
- Recreation 8

2. Slope
- Flat 1
- Slight hill 2
- Steep hill 3

3. Segment intersections
- Segment has 3 way intersection 1
- Segment has 4 way intersection 2
- Segment has other intersection 3
- Segment deadends but path continues 4
- Segment deadends 5
- Segment has no intersections 6

B. Pedestrian Facility *(skip if none present)*

4. Type(s) of pedestrian facility *(all that apply)*
- Footpath (worn dirt path) 1
- Paved Trail 2
- Sidewalk 3
- Pedestrian Street (closed to cars) 4

The rest of the questions in section B refer to the best pedestrian facility selected above.

5. Path material *(all that apply)*
- Asphalt 1
- Concrete 2
- Paving Bricks or Flat Stone 3
- Gravel 4
- Dirt or Sand 5

6. Path condition/maintenance
- Poor (many bumps/cracks/holes) 1
- Fair (some bumps/cracks/holes) 2
- Good (very few bumps/cracks/holes) 3
- Under Repair 4

7. Path obstructions *(all that apply)*
- Poles or Signs 1
- Parked Cars 2
- Greenery 3
- Garbage Cans 4
- Other 5
- None 6

8. Buffers between road and path *(all that apply)*
- Fence 1
- Trees 2
- Hedges 3
- Landscape 4
- Grass 5
- None 6

9. Path Distance from Curb
- At edge 1
- < 5 feet 2
- > 5 feet 3

10. Sidewalk Width
- < 4 feet 1
- Between 4 and 8 feet 2
- > 8 feet 3

If no sidewalk, skip now to section C.

11. Curb cuts
- None 1
- 1 to 4 2
- > 4 3

12. Sidewalk completeness/continuity
- Sidewalk is complete 1
- Sidewalk is incomplete 2

13. Sidewalk connectivity to other sidewalks/crosswalks
- number of connections ____ 1

C. Road Attributes *(skip if path only)*

14. Condition of road
- Poor (many bumps/cracks/holes) 1
- Fair (some bumps/cracks/holes) 2
- Good (very few bumps/cracks/holes) 3
- Under Repair 4

15. Number of lanes
- Minimum # of lanes to cross ____ 1
- Maximum # of lanes to cross ____ 1

16. Posted speed limit
- None posted 1
- (mph) ____ 1

17. On-Street parking *(if pavement is unmarked, check only if cars parked)*
- Parallel or Diagonal 1
- None 2

18. Off-street parking lot spaces

0-5	6-25	25+
1	2	3

19. Must you walk through a parking lot to get to most buildings?
- Yes 1
- No 2

20. Presence of med-hi volume driveways
- < 2 1
- 2 to 4 2
- > 4 3

21. Traffic control devices *(all that apply)*
- Traffic light 1
- Stop sign 2
- Traffic circle 3
- Speed bumps 4
- Chicanes or chokers 5
- None 6

22. Crosswalks
- None 1
- 1 to 2 2
- 3 to 4 3
- > 4 4

23. Crossing Aids *(all that apply)*
- Yield to Ped Paddles 1
- Pedestrian Signal 2
- Median/Traffic Island 3
- Curb Extension 4
- Overpass/Underpass 5
- Pedestrian Crossing Warning Sign 6
- Flashing Warning Light 7
- Share the Road Warning Sign 8
- None 9

24. Bicycle facilities *(all that apply)*
- Bicycle route signs 1
- Striped bicycle lane designation 2
- Visible bicycle parking facilities 3
- Bicycle crossing warning 4
- No bicycle facilities 5

D. Walking/Cycling Environment

25. Roadway/path lighting
- Road-oriented lighting 1
- Pedestrian-scale lighting 2
- Other lighting 3
- No lighting 4

26. Amenities *(all that apply)*
- Public garbage cans 1
- Benches 2
- Water fountain 3
- Street vendors/vending machines 4
- No amenities 5

27. Are there wayfinding aids?
- No 1
- Yes 2

28. Number of trees shading walking area
- None or Very Few 1
- Some 2
- Many/Dense 3

29. Degree of enclosure
- Little or no enclosure 1
- Some enclosure 2
- Highly enclosed 3

30. Powerlines along segment?
- Low Voltage/Distribution Line 1
- High Voltage/Transmission Line 2
- None 3

31. Overall cleanliness and building maintenance
- Poor (much litter/graffiti/broken facilities) 1
- Fair (some litter/graffiti/broken facilities) 2
- Good (no litter/graffiti/broken facilities) 3

32. Articulation in building designs
- Little or no articulation 1
- Some articulation 2
- Highly articulated 3

33. Building setbacks from sidewalk
- At edge of sidewalk 1
- Within 20 feet of sidewalk 2
- More than 20 feet from sidewalk 3

34. Building height
- Short 1
- Medium 2
- Tall 3

35. Bus stops
- Bus stop with shelter 1
- Bus stop with bench 2
- Bus stop with signage only 3
- No bus stop 4

Subjective Assessment: Segment...

Enter 1,2,3, or 4 for 1=Strongly Agree 2= Agree, 3=Disagree, 4=Strongly Disagree
- ...is attractive for walking. ____ 1
- ...is attractive for cycling. ____ 1
- ...feels safe for walking. ____ 1
- ...feels safe for cycling. ____ 1

Source: Clifton, 2004

Appendix B
Walkability Safety Rating Methods

Walkability Audit Instrument (Appendix B) items organized by classifications established for the Behavioral Walkability Model (Lee & Moudon 2004) (Criteria B). Functional classifications based on research by Pikora et al. (2003) (Criteria A). Items included in the safety analysis of this project are in **bold**.

Lee and Moudon BME classifications	Audit Instrument Questions	Pikora classifications
Origin/Destination	Uses in segment	Destinations
Origin/Destination and Area	Uses in segment	Destinations
Area	**Cul de sac/Dead-end**	Functional
	Off-street parking	Functional
	Transit facilities	Convenience
Route/Area	**Is attractive for walking**	Aesthetics/Safety
	Is attractive for biking	Aesthetics/Safety
	Slope	Functional
	Traffic control devices	Safety
	Articulation in building designs	Aesthetics
Route	Low volume/High volume	Functional
	Type(s) of pedestrian facility • Footpath (worn dirt path) • Paved trail • Sidewalk • Pedestrian street (closed to cars)	Functional
	Path material • Asphalt • Concrete • Paving bricks or flat stone • Gravel • Dirt or sand	Functional

<table>
<tr><td></td><td>Path obstructions
Poles or sign
Parked car
Tree
Garbage can
Other</td><td>Safety</td></tr>
<tr><td></td><td>Sidewalk completeness/continuity</td><td>Safety</td></tr>
<tr><td></td><td>Sidewalk connectivity to other sidewalks</td><td>Safety</td></tr>
<tr><td></td><td>Sidewalk condition/maintenance</td><td>Safety</td></tr>
<tr><td></td><td>Condition of the road</td><td>Functional</td></tr>
<tr><td></td><td>Number of lanes</td><td>Functional</td></tr>
<tr><td></td><td>Posted speed limit</td><td>Functional</td></tr>
<tr><td></td><td>On-street parking</td><td>Functional</td></tr>
<tr><td></td><td>Off-street parking</td><td>Functional</td></tr>
<tr><td></td><td>Driveways</td><td>Safety</td></tr>
<tr><td></td><td>Traffic control devices
Stop sign
Traffic light
Traffic circle
Speed bumps
Chicanes or chokers
Median/traffic island
Curb extension
Overpass/underpass
Pedestrian crossing street sign
Flashing warning</td><td>Safety</td></tr>
<tr><td></td><td>Lighting</td><td>Safety</td></tr>
<tr><td></td><td>Amenities</td><td>Aesthetics</td></tr>
<tr><td></td><td>Number of trees shading walking area</td><td>Aesthetics</td></tr>
<tr><td></td><td>Degree of enclosure</td><td>Aesthetics</td></tr>
<tr><td></td><td>Power-lines along segment</td><td>Aesthetics</td></tr>
<tr><td></td><td>Cleanliness</td><td>Aesthetics</td></tr>
<tr><td></td><td>Building setbacks from street</td><td>Aesthetics</td></tr>
<tr><td rowspan="4">Origin/Destination and Route</td><td>Sidewalk completeness/continuity</td><td>Functional</td></tr>
<tr><td>Sidewalk connectivity to other sidewalks</td><td>Functional</td></tr>
<tr><td>Must you walk through a parking lot to get to most buildings</td><td>Functional</td></tr>
<tr><td>Bicycle lane</td><td>Safety</td></tr>
</table>

	Way finding aids	Safety
Safety (Origin/Destination and Area and Route)	**Feels safe for walking**	Safety
	Feels safe for biking	Safety

Appendix C
Agnes Stewart Middle School
Parent Transportation Survey

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Appendix D
Database Coding Criteria

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Appendix E
Pedestrian Environment Data Scan
Audit Protocol

PEDS

Pedestrian Environment Data Scan

AUDIT PROTOCOL

CONTENTS

Audit Protocol written by Andréa D. Livi - Spring 2004.

GENERAL DIRECTIONS:

Surveyors will go out each day with their team. Maps of segments and a list of segments will be given each morning to direct surveyors regarding which segments they should survey. Surveyors will return to Caroline Hall each day to upload completed entries.

In case of inclement weather, the Undergraduate and Graduate Fellows will assess the situation and decide whether surveying should be postponed.

SUPPLIES:

- Map of area with segments detailed
- Master list of segments
- PDA

PROCEDURES AT EACH SEGMENT:

1. Identify the segment on your map and check it against the master list. Start a new entry and input the segment number, your name, the time, day and weather.
2. Make sure you locate the beginning and endpoint of the segment. Look at the map to find the information.
3. Walk the segment once WITHOUT writing anything on the survey form. You should look around in all directions, without forgetting to look up and down as well.
4. Walk the segment again, this time while filling out the survey (as explained below). Go back and forth as often as necessary in order to fill in each question. Make sure you are in agreement with your teammate about your choices.

NOTE: The audit only consists of "check" (boxes) and "fill in number" (line) questions. For the numeric answer, use integers only. If you need to round the number, always round up.

5. When you have filled each question, go over the entire survey again to make sure you have completely answered the form and that you are satisfied with your answers (in the paper audit, this means you will have at least one check mark per cluster of boxes). You can then move on to the next segment, following the same procedure.
6. Make sure to record any modifications such as segments that are merged or do not exist. Also, make note of any questions or problems that arose while surveying the segment.

QUESTION BREAKDOWN:

The following section of the protocol describes each question and response category to aid the administrators in dealing with variations in the environment. The administrators are encouraged to read through this section and use it as a reference while surveying the segments.

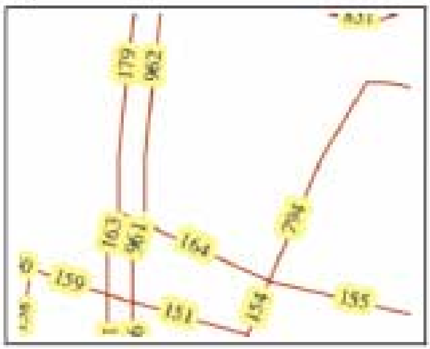
For each question, the name and number are in **bold**, the answer options are in *italics* and the comments, definitions or directions in regular text.

SECTION 0: SEGMENT NUMBER & TYPE

0. Segment Type

Low volume road – audit both sides
High volume road – audit this side only
Bike or ped path – skip section C

Options 1 and 2 will be defined prior to the administration of the survey. If the segment on the map has two lines instead of one, it will be considered a "high volume road".



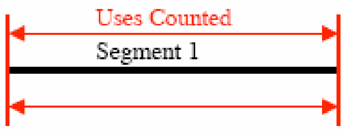
In the illustration at left, segment 164 is a low volume road and segments163 and 961 are a high volume road.
"Bike or ped path" is to be checked off if there is no automobile access roadway in the segment.

High volume roads will only be audited on one side for all questions except questions 3. Segment Intersections (count ALL intersections) and 15: Number of Lanes (count ALL lanes).

SECTION A: ENVIRONMENT

1. Uses In Segment

Count EVERY USE within the segment. That is: every use within the boundary formed by making a right-angle line from the beginning and end of the segment. Uses only count if there is access to it in the segment, like a driveway, walkway, or entrance. Access to a back door or a loading dock would count as access. Abandoned buildings do not qualify as vacant. Instead, count them under their intended use.



Answer Options

Housing – Single Family Detached
Housing – Multi-Family: attached housing, apartments, duplexes.
Housing – Mobile Homes
Office/Institutional: office parks, corporate campuses, public buildings, schools, churches, hospitals etc. This also includes professional offices in residential buildings (dentist, lawyer, doctor, accountant, etc.)
Restaurant/Café/Commercial: restaurants, stores, malls, gas stations etc.
Industrial: factories, mills, industrial complexes, etc.
Vacant/Undeveloped: cleaned or cleared off lots, naturally occurring vegetation, natural features such as lakes and rivers.
Recreation: parks, golf courses, basketball courts etc. Official paths coming off a segment can count as recreation.

2. Slope

Answer Options

Flat: there is no discernable hill walking the segment.
Slight Hill: there is a slight hill in the segment, but not enough to make walking uphill difficult.
Steep Hill: the hill in the segment makes walking or biking it difficult.

3. Segment Intersections (check all that apply)

Answer Options

Segment has 3-way intersection
Segment has 4-way intersection
Segment has other intersection
Segment deadends
Segment deadends but path continues
Segment has no intersections

SECTION B: PEDESTRIAN FACILITY

If there is no pedestrian facility in the segment, skip to section C

Note: A pedestrian facility does not count if it is a private walk in front of a single family house. It would count if it is a facility in front of a commercial center intended to be used as a sidewalk. An incomplete sidewalk in front of a residential home counts if it looks as though it was built by the city.

4. Type(s) of Pedestrian Facility (check all that apply)

Answer Options

Footpath (worn dirt path)
Paved Trail: a paved trail is any paved walkway that is not associated with a roadway.
Sidewalk: a walkway will only be considered a sidewalk if it is associated with a roadway.
Pedestrian Street (closed to cars)

NOTE: The rest of the questions in this section refer to the BEST pedestrian facility selected above.

5. Path Material

Select all that apply. Even if one material is just a patch in the sidewalk, please mark it.

Answer Options

Asphalt
Concrete
Paving Bricks or Flat Stone
Gravel
Dirt or Sand

6. Sidewalk Condition/Maintenance

Answer Options

Poor (many bumps/cracks/holes): A sidewalk will be considered "poor" if a stroller cannot be pushed along the sidewalk without many jarring motions and/or if it clearly needs to be replaced (patches would not be sufficient)

Fair (some bumps/cracks/holes): A sidewalk will be considered "fair" if a stroller can easily be pushed along the sidewalk with few jarring motions to the passenger and/or it only needs patches or other minor repair.

Good (very few bumps/cracks/holes): A sidewalk will be considered "good" if a stroller can easily be pushed along the sidewalk without jarring motions to the passenger and/or it needs no repair at this time.

Under Repair: A sidewalk will only be considered "under repair" if there is evidence of work being done to improve the sidewalk. Orange cones are not enough. If construction work is being done adjacent to the sidewalk, blocking it off as a result, it is considered "under repair."

7. Path Obstructions (check all that apply)

NOTE: An object is only a path obstruction if it severely reduces or completely blocks off the pedestrian facility. Threshold: Could you get by in wheelchair or while pushing a stroller?

For this question, you are looking at potential obstructions on ALL pedestrian facilities on the street. In other words, if there are two sidewalks and only one has obstructions, please write down those obstructions.

Answer Options

Poles or Signs

Parked Cars: cars in driveways that block the sidewalk should be counted.

Greenery

Garbage Cans

Other

None

If the pedestrian facility in the segment is not a sidewalk, skip now to section C

8. Buffers between road and path (check all that apply)

Answer Options

Fence

Trees: trees are only a buffer if they are part of a landscape/grass buffer or if they occur regularly enough on the street to discourage pedestrians from walking along the roadway. Trees within a grass buffer count as a buffer.

Hedges

Landscape

Grass

None

9. Distance from curb

Answer Options

At Edge

< 5 feet

> 5 feet

If possible, use a tape measure to measure the distance and round up to the next integer. If no tape measure is available, measure by using your feet and rounding to the next highest integer. If it seems too dangerous to walk to the roadway, measure by using context clues. If the sidewalk distance from the curb varies, use the average or typical distance.

10. Sidewalk width

Answer Options

< 4 feet

Between 4 and 8 feet

> 8 feet

If possible, use a tape measure to measure the distance, not including the curb, and round up to the next integer. If no tape measure is available, measure by using your feet and rounding to the next highest integer. If sidewalk width varies, use the average or typical width.

11. Curb Cuts

Answer Options

None

1 to 4

> 4

12. Sidewalk Completeness/Continuity

This refers to the completeness of the sidewalk WITHIN the segment.

Answer Options

Sidewalk is complete: a sidewalk is complete if it does not have any breaks within the segment.

Sidewalk is incomplete: a sidewalk is incomplete if it ends or has gaps within the segment.

13. Sidewalk connectivity to other sidewalks/crosswalks

This refers to the number of connections the segment sidewalk has to crosswalks and other sidewalks. Stop signs at the end of the segment can be treated as a crosswalk. This will be scored as follows:

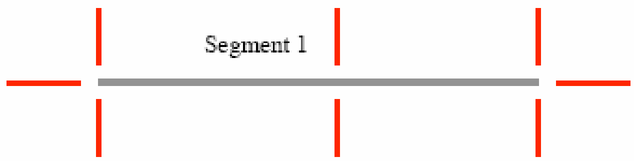
At the beginning of the segment, looking backward 180 degrees, +90 degrees and –90 degrees: how many sidewalks or crosswalks are there?

At the end of the segment, looking forward, +90 degrees and –90 degrees: how many sidewalks or crosswalks are there?

In the middle of the segment: are how many sidewalks or crosswalks are there?

These three scores should be added to make up the connectivity score.

A very well connected segment will have a score of six plus any crosswalks that may exist along the segment.



Connections to other sidewalks crosswalks in diagram above shown in red. The above diagram has 8 connections.

On a low volume residential segment there does not need to be a crosswalk in order to count as a connection.

Connections made by crossing the street to another side where a sidewalk exists does not count.

SECTION C: ROAD ATTRIBUTES

NOTE: skip this section if path only

14. Condition of Road

Answer Options

Poor (many bumps/cracks/holes): the potholes, cracks, etc. present would cause a vehicle driving the segment to rock, dip or otherwise disrupt driving.

Fair (some bumps/cracks/holes): there are potholes, cracks etc., but not enough to cause problems for a vehicle driving the segment.

Good (very few bumps/cracks/holes): there are no large potholes or other problems that would cause problems for a vehicle driving the segment.

Under Repair: A roadway will only be considered "under repair" if there is evidence of work being done to improve it. Orange cones are not enough.

15. Number of Lanes

Minimum number of lanes to cross
Maximum number of lanes to cross
Count ALL lanes (even if it is a high volume road), including turn only lanes and/or "suicide lanes" one would need to cross the road at its widest point along the segment.

16. Posted Speed Limit

Answer Options

None Posted
(mph): ______
Check the "none posted" box unless there is a sign WITHIN the segment that displays the speed limit. Even if there is a sign outside the segment, within plain view, it does not count.

17. On Street Parking

If pavement is unmarked, check "parallel" only if there are cars parked within the segment or if parking signs are present.

Answer Options

Parallel or Diagonal
None

18. Off-Street Parking Lot Spaces

Answer Options

0-5	6-25	26+

Count all off-street parking spaces in segment. Cars in single family home driveways do not count. Only cars in actual parking lots count (apartment complexes, commercial parking, office parking etc.) There must be access to the lot from the segment.

19. Must you walk through a parking lot to get to most buildings?

Answer Options

Yes

No

For this question, the origin point of walking to the buildings will be from the sidewalk. If there is no sidewalk, origin point will be the curb of the roadway.

20. Presence of High-Medium Volume Driveways

Answer Options

< 2

2 to 4

> 4

High-medium volume driveways are driveways that often have cars pulling in and out, like commercial driveways or driveways of apartment buildings. Single-family residential driveways are low volume and should not be counted here.

21. Traffic Control Devices (check all that apply)

Count only the traffic control devices within the segment, not those that are visible but outside the segment (they will be captured when the next segment is surveyed.)

Answer Options

Traffic Light

Stop Sign

Traffic Circle: counts on all the segments that go into the circle. Triangular traffic control devices can also be counted under this category.

Speed Bumps

Chicanes or Chokers: chicanes are a series of narrowings or curb extensions that alternate from one side of the street to the other forming S-shaped curves. Chokers are curb extensions at midblock or intersection corners that narrow a street by extending the sidewalk or widening the planting strip.

22. Crosswalks

Answer Options

None
1 to 2
3 to 4
> 4

Make sure to note all marked crosswalks in segment. "Marked" refers to lines on the pavement (but *not* automobile stop lines) or signs, lights or signals.

23. Crossing Aids in Segment (check all that apply)

Answer Options

Cars Must Stop
Pavement Markings
Yield to Ped Paddles
Pedestrian Signal
Crossing Aids
Median/Traffic Island
Curb Extension
Overpass/Underpass
Warnings to Cars
Pedestrian Crossing Street Sign: street sign without flashing light. Children at play signs can also be included here. Yield signs for cars do not count.
Flashing Warning
Share the Road Warning

24. Bicycle Facilities (check all that apply)

Answer Options

No designated bikeway
Bicycle route signs
Striped bicycle lane designation
Visible bicycle parking facilities: these facilities must be useable by the public, not for private use only
Bicycle crossing warning.

SECTION D: WALKING/CYCLING ENVIRONMENT

25. Roadway/Path Lighting

Answer Options

No Lighting: there is no artificial lighting in the area.

Road-oriented lighting: there are public light fixtures that aim light at the road or are very high and illuminate broad expanses.

Pedestrian-scale lighting: there are public light fixtures that aim light at the walking path.

Other lighting: lighting from stores, apartments etc. that lights the road and/or pedestrian path.

26. Amenities (check all that apply)

Must be for public use. Also, visible and accessible from the pedestrian path.

Answer Options

Garbage Cans: only public use garbage cans count. Residential garbage cans do not count.

Benches

Water Fountain

Street Vendors/Vending Machines: this includes soda machines, candy machines, public pay phones, mailboxes and newspaper dispensers.

27. Are there Wayfinding Aids Present?

Answer Options

Yes A wayfinding aid is a sign identifying the name of the cross streets. Any sign visible from the segment at the pedestrian level counts as a wayfinding aid, even if it is actually located on another segment.

No

28. Number of Trees Shading Path

Answer Options

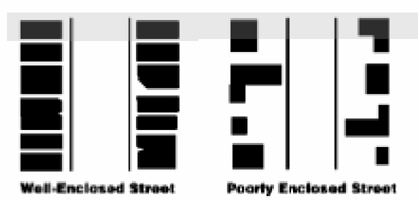
None or Very Few: the path is not shaded by any trees (or only one tree) along the segment. (less than 25% is covered)

Some: the path is covered between 25 and 75% of the way.

Many/Dense: more than 75% of the path is shaded by trees.

29. Degree of Enclosure

Answer Options



For this question, take into account both the buildings and natural features (trees, bushes etc.)

Little or no enclosure: the view from the sidewalk is open in both directions for more than 15 feet for most of the segment. It is a wide-open, unconstrained space.

Some enclosure: the view is partially enclosed, but there is still some wide-open spaces.

Highly enclosed: the buildings lining the street are within 10 feet of the sidewalk and there is a cross-sectional design ratio of approximately one (height) to two (width), or less.

30. Powerlines along segment?

Power lines that cross or run parallel to the segment all count in this question.

Answer Options

No
Low Voltage/Distribution Line
High Voltage/Transmission Line

31. Overall Cleanliness and Building Maintenance

Leaves, branches, and brush, all count towards cleanliness based on the amount and if it is clearly visible and in the pedestrian path.

Answer Options

Poor: there is noticeable garbage, graffiti and/or broken glass along the segment.
Fair: there are a few wrappers, or other litter but no graffiti or other garbage evident.
Good: there is no obvious garbage, graffiti, litter or broken glass in the segment.

32. Articulation of Building Designs

Answer Options

Little or no articulation: the façades of buildings along the segment are unadorned and do not have many window openings.
Some articulation: the façades of buildings along the segment are similar in style and/or are not very ornate.
Highly articulated: the façades of buildings along the segment are complex and varied.

33. Building Setbacks

Answer Options

At edge of sidewalk
Within 20 feet of sidewalk
More than 20 feet from sidewalk

34. Building Height

Answer Options

Short: 1-2 stories, except with big box buildings or other buildings with tall floors.
Medium: 3-5 stories (with same exceptions.)
Tall: buildings taller than 5 stories (with same exceptions.)
NOTE: Average height is to be measured here, not the maximum or minimum height.

35. Bus Stops

Answer Options

Bus stop with shelter
Bus stop with bench
Bus stop with signage only

SECTION SA: SUBJECTIVE ASSESSMENT

Enter 1, 2, 3 or 4 for:
1 = Strongly Agree
2 = Agree
3 = Disagree
4 = Strongly Disagree

Segment…
… is attractive for walking
… is attractive for cycling
… feels safe for walking
… feels safe for cycling

Response to the "attractive" question should answer the question: "would you want to walk/bike this segment?" This includes finding the area aesthetically pleasing and existence of destinations.

Response to the "safe" question for walking should take into consideration not only walking along the sidewalk but crossing the street. The administrator should think of walking the segment with a 10 year old child. Would a child be safe walking the segment?

Response to the "safe" question for cycling should take into consideration existence of a bicycle lane and speed of local traffic. A segment can only score a 1 in this question if the traffic goes below 25 miles an hour or there is a formal bicycle lane present.

For more information on the Pedestrian Environment Data Scan, please contact:

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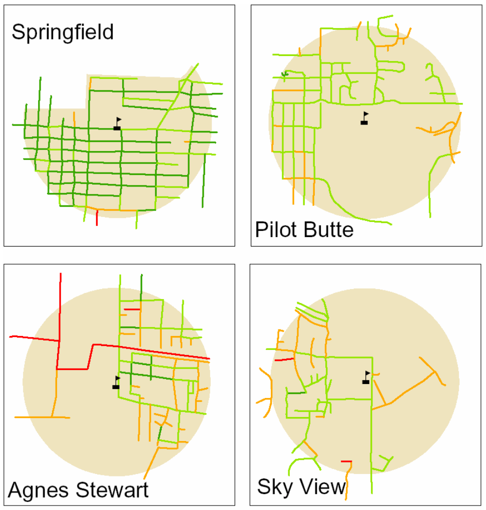
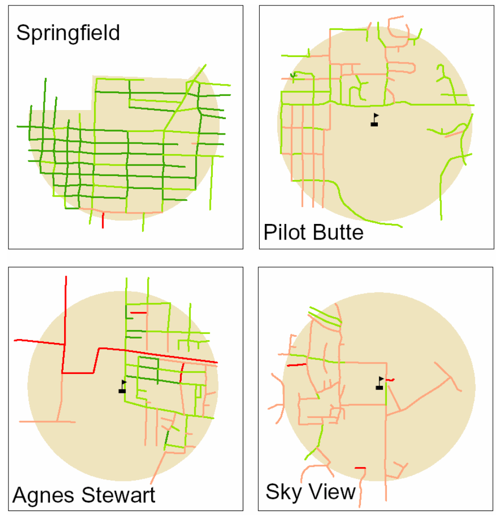
Appendix F
Walkability Safety Rating Results

Figure F-1. Attractive for biking



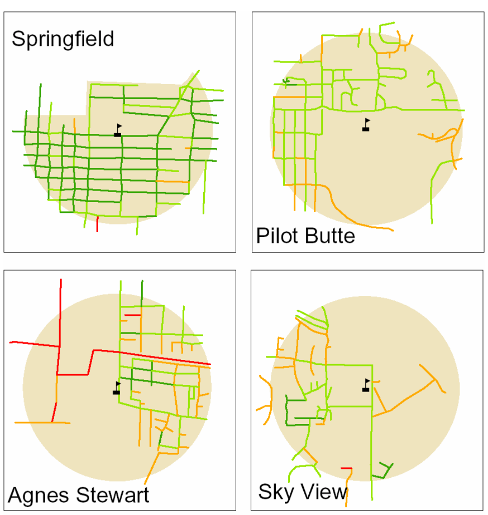
Very Unattractive
Unattractive
Attractive
Very Attractive

Figure F-2. Safe for biking



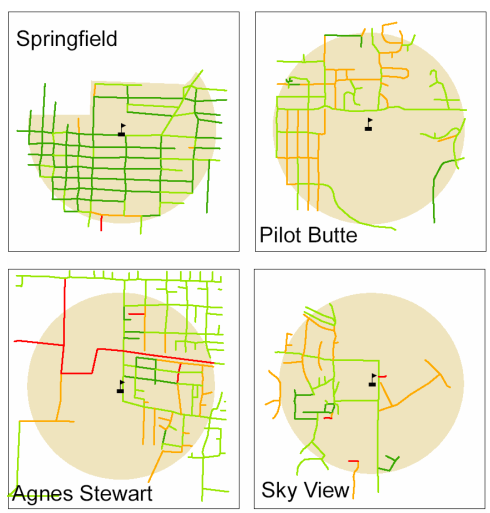
Very Unsafe
Unsafe
Safe
Very Unsafe

Figure F-3. Attractive for biking



Very unattractive
Unattractive
Attractive
Very Attractive

Figure F-4. Safe for walking



Very Unsafe
Unsafe
Safe
Very Safe

Figure F-5. Number of driveways

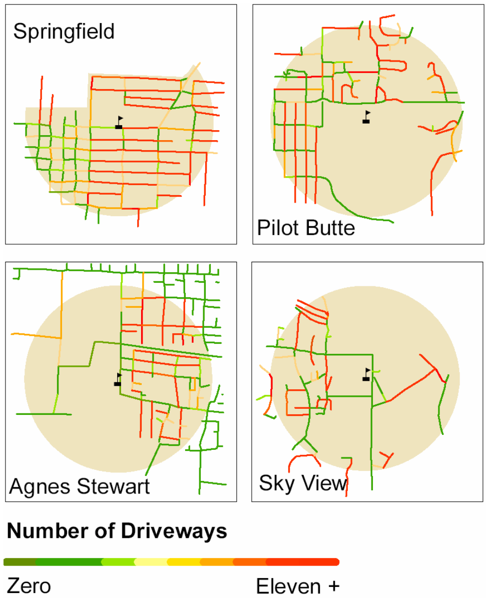


Figure F-6. Traffic calming: Traffic circles

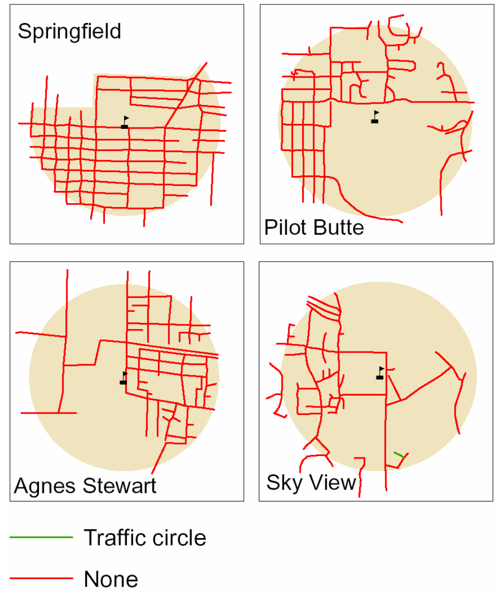


Figure F-7. Traffic calming: Traffic light

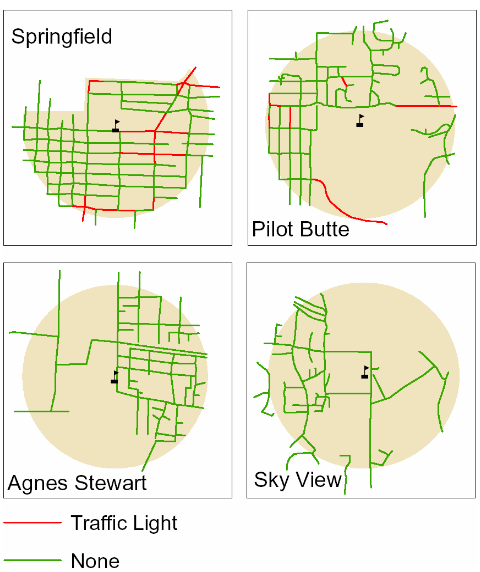


Figure F-8. Traffic calming: Speed bumps

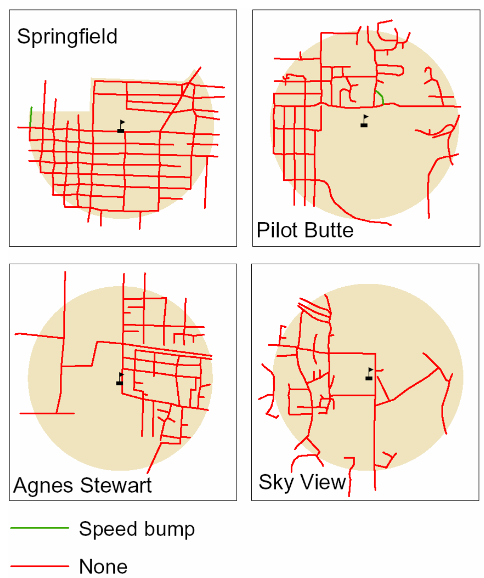


Figure F-9. Traffic calming: Stop signs

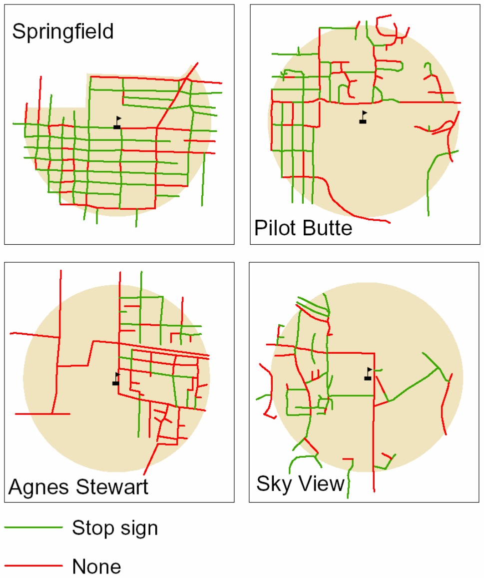


Figure F-10. Traffic calming: Chicanes

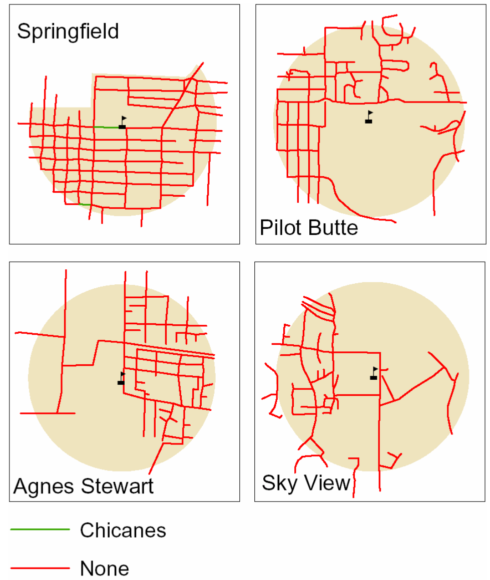


Figure F-11. Traffic calming: Pedestrian paddles

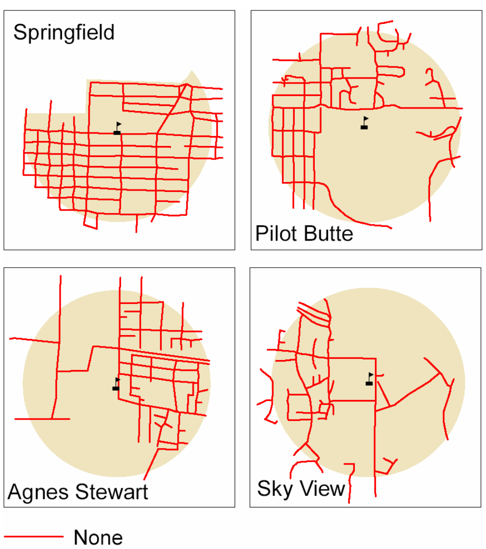


Figure F-12. Traffic calming: Pedestrian signal

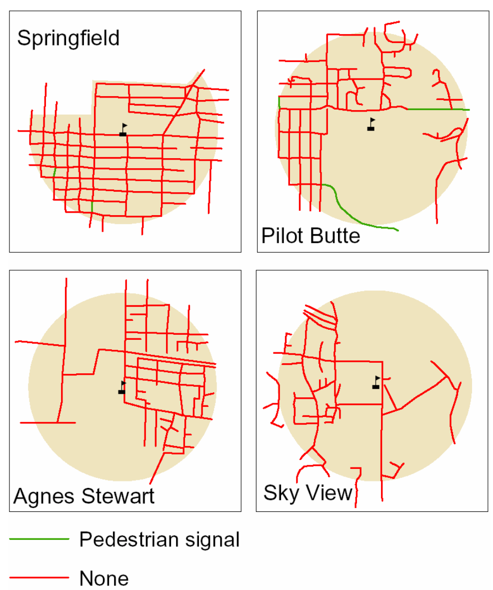


Figure F-13. Path obstruction: Tree

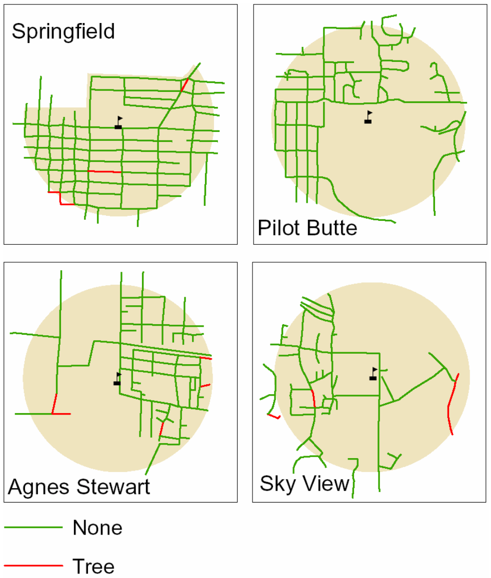


Figure F-14. Path obstruction: Parked car

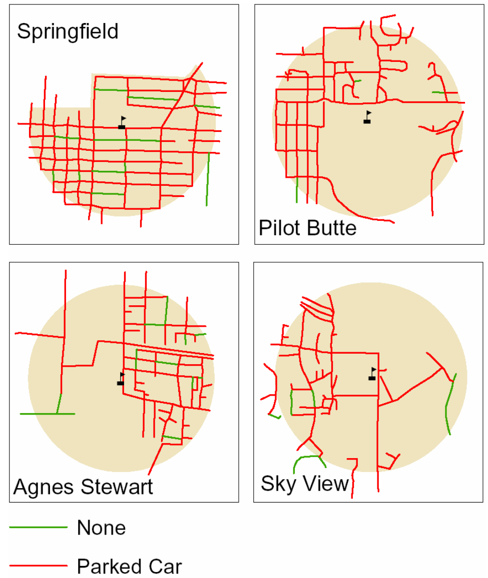


Figure F-15. Path obstruction: Pole/sign

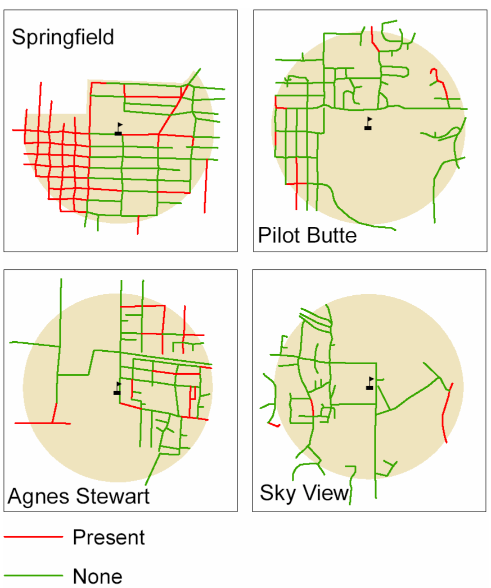


Figure F-16. Path obstruction: Garbage can

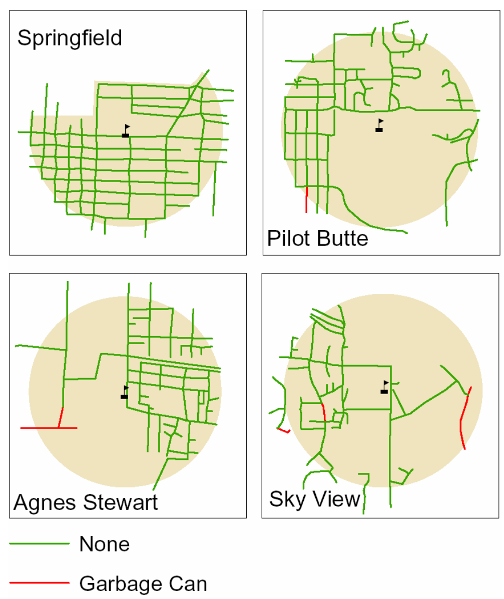
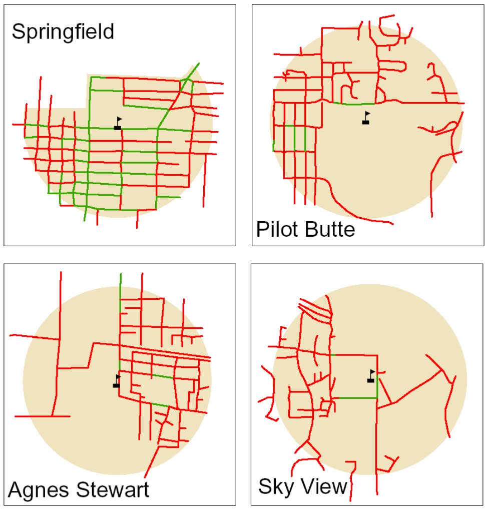


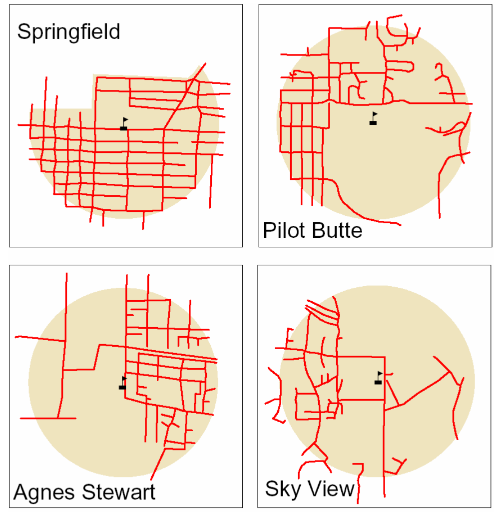
Figure F-17. Pavement markings



Pavement markings

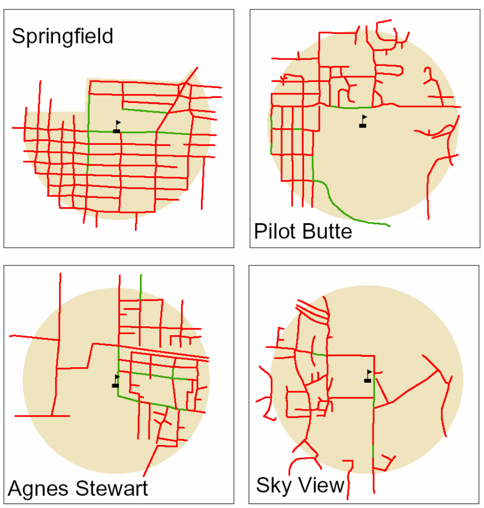
None

Figure F-18. Overpass/Underpass



None

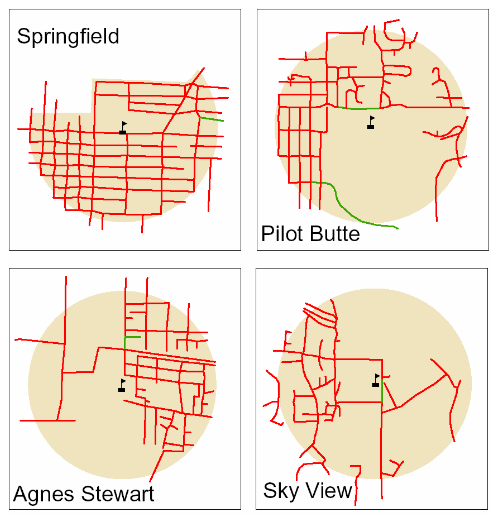
Figure F-19. Pedestrian crossing sign



Pedestrian Crossing Sign

None

Figure F-20. Median/traffic island



Median / Traffic island

None

Figure F-21. Lighting

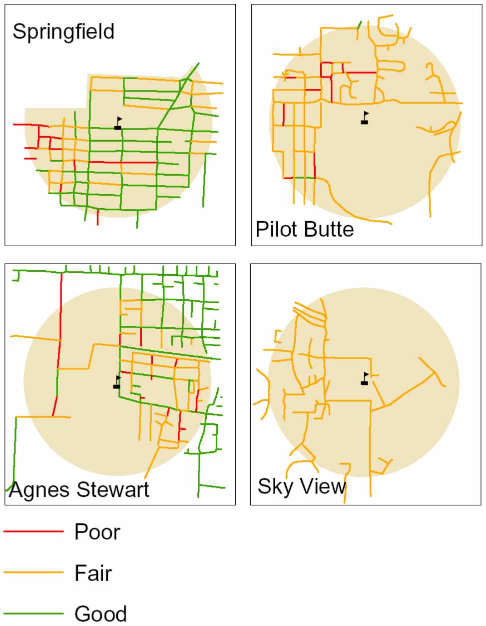


Figure F-22. Sidewalk completeness

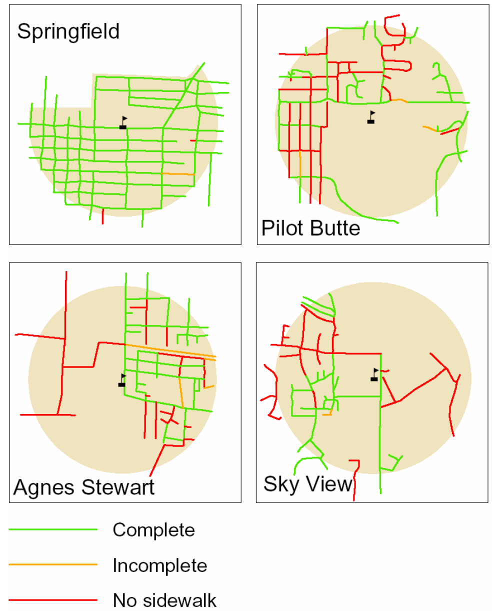


Figure F-23. Way-finding aids

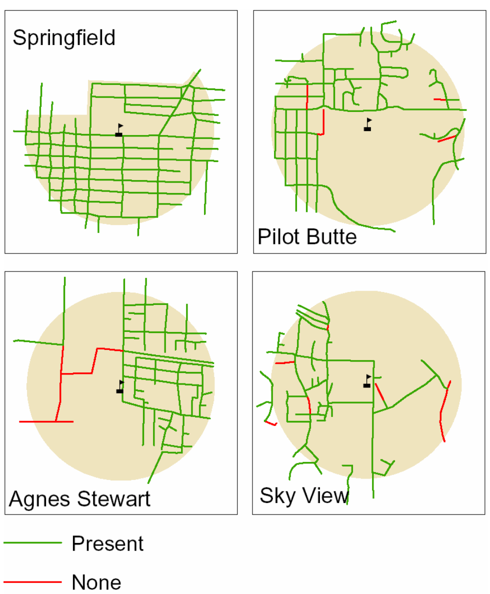


Figure F-24. Number of sidewalk connections

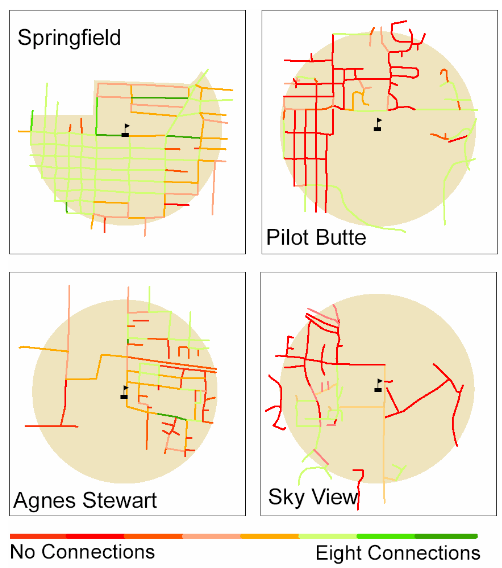


Figure F-25. Sidewalk condition

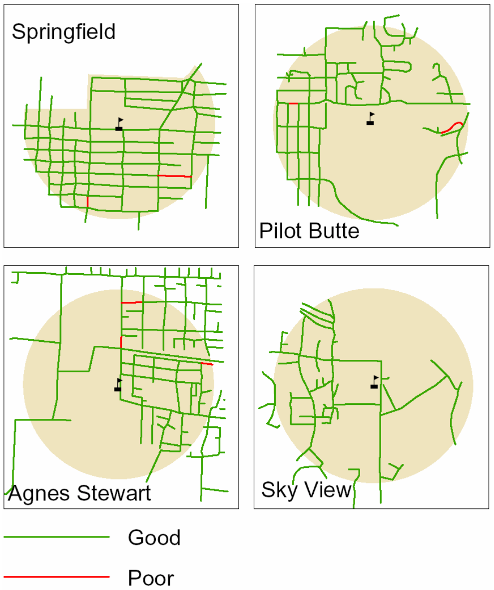
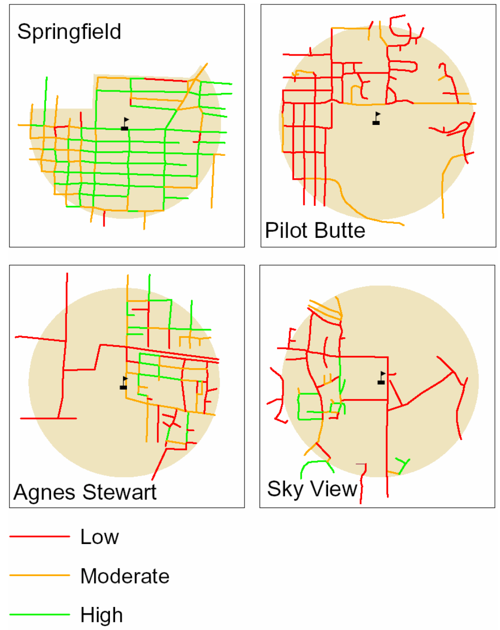


Figure F-26. Total walkability safety rating



BIBLIOGRAPHY

Appleyard, D. (1981). Livable Streets. Berkeley, University of California Press.

Cervero, R., Kara Kockelman (1997). "Travel demand and the 3 Ds: Density, Diversity, and Design." Transportation Research D: Transport and the Environment 2(3): 199-219.

Cervero, R., Roger Gorham (1995). "Commuting in transit versus auto oriented neighborhoods." Journal of the American Planning Association 61(2): 210-225.

Clifton, K., Andrea Livi The development and testing of an audit for the pedestrian environment. Unpublished.

Emery, J., Carolyn Crump, Philip Bors (2003). "Reliability and validity of two instruments designed to assess the walking and bicycling suitability of sidewalks and roads." American Journal of Health Promotion 18(1): 38-46.

Forjuoh, S. (2003). "Traffic-related injury prevention interventions for low-income countries." Injury Control and Safety Promotion 10(1-2): 109-118.

Handy, S. (1996). "Urban Form and Pedestrian Choices: Study of Austin Neighborhoods." Transportation Research Record 1552: 135-144.

Livi, A. D. (2004). Audit Protocol: College Park Audit, University of N. Carolina: 1-13.

Ossenbruggen, P. J., et al. (1984). "Roadway safety in rural and small urbanized areas." Accident Anal. Prevention 33: 104-114.

(1926). Euclid, Ohio v. Ambler Realty. 272 U.S. 365, U.S. Supreme Court.

Appleyard, B. (2003). "Planning Safe Routes to Schools." American Planning Association **69**(5): 34-37.

Appleyard, D. (1981). Livable Streets. Berkeley, University of California Press.

Audirac, I. (1999). "State preference for pedestrian proximity: An assessment of New Urbanist sense of community." Journal of Planning Education and Research **19**: 53-66.

Ball, K., Adrian Bauman, Eva Leslie, and Neville Owen (2000). "Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults." Preventative Medicine **33**(5): 434-40.

Bull, F., Rex Milligan, Michael Rosenburg, and Heather McGowen (2000). Physical activity levels of Western Australian adults 1999. Perth, Health Department of Western Australia, Sport and Recreation Way2Go, Western Australian Government.

Calthorpe, P., William Fulton, Robert Fishman (2001). The Regional City: Planning for the End of Sprawl, Island Press.

Caro, R. A. (1975). The power broker: Robert Moses and the fall of New York. New York, Vintage Books.

Centers for Disease Control (2000). School of Health Policies and Programs Study.

Cervero, R., Kara Kockelman (1997). "Travel demand and the 3 Ds: Density, Diversity, and Design." Transportation Research D: Transport and the Environment **2**(3): 199-219.

Cervero, R., Roger Gorham (1995). "Commuting in transit versus auto oriented neighborhoods." Journal of the American Planning Association **61**(2): 210-225.

Clifton, K., Andrea Livi The development and testing of an audit for the pedestrian environment. Unpublished.

Corbusier, L. (1929). A Contemporary City. The City Reader. R. LeGate, Frederic Stout. New York, Routledge**:** 317-330.

Crane, R., Richard Crepeau (1998). "Does neighborhood design influence travel? A behavioral analysis of travel diary and GIS data." Transportation Research D **3**(4): 225-238.

Duany, A., Elizabeth Plater-Zyberk, Jeff Speck (2001). Suburban Nation: The Rise of Sprawl and the Decline of the American Dream, North Point Press.

Emery, J., Carolyn Crump, Philip Bors (2003). "Reliability and validity of two instruments designed to assess the walking and bicycling suitability of sidewalks and roads." American Journal of Health Promotion **18**(1): 38-46.

Forjuoh, S. (2003). "Traffic-related injury prevention interventions for low-income countries." Injury Control and Safety Promotion **10**(1-2): 109-118.

Giles-Corti, B., Robert J. Donovan (2002). "The relative influence of individual, social, and physical environment determinants of physical activity." Social Science and Medicine **54**(12): 1793-812.

Goodwin, P. (1996). "Empirical evidence on induced traffic: A review and synthesis." Transportation **23**: 35-54.

Hahn, R. A., S.M. Teuesch, R.B. Rothenberg, et. al. (1998). "Excess deaths from nine chronic diseases in the United States, 1986." Journal of the American Medical Association **264**(20): 2554-59.

Handy, S. (1996). "Urban Form and Pedestrian Choices: Study of Austin Neighborhoods." Transportation Research Record **1552**: 135-144.

Hansen, M., Y. Huang (1997). "Road supply and traffic in California urban areas." Transporation Research Part A: Policy and Practice **31**(3): 205-218.

Hansen, W. G. (1959). "How accessibility shapes land use." Journal of the American Planning Institute **25**: 73-76.

Institute of Transportation Engineers (1997). Traditional neighborhood development: Street design guidelines: A proposed recommended practice for the ITE. Washington, D.C., Institute of Transportation Engineers.

Jacobs, J., Ed. (1961). The Uses of Sidewalks: Safety. The City Reader. New York, Routledge.

Kahn, L., et al (2000). "Youth risk behavior surveillance-United States, 1999. In: CDC Surveillance Summaries, June 9, 2000." Morbitity and Mortality Weekly Report **49**(No. SS-5): 1-96.

Krizek, K. J. (2003). Residential relocation and changes in urban travel: does neighborhood-scale urban form matter?

Kushi, L. H., R.M. Fee, A.R. Folsom, et al. (1997). "Physical activity and mortality in postmenopausal women." Journal of the American Medical Association **277**: 1287-92.

Lee, C., Anne Vernez Moudon (2003). "Walking and Bicycling: An Evaluation of Environmental Audit Instruments." Science of Health Promotion **18**(1): 21-37.

Lee, C. D., S.N. Blair, A.S. Jackson (1999). "Cardiorespiratory fitness, body composition, and all-cause and cardiovascular disease mortality in men." American Journal of Clinical Nutrition **69**(3): 373-80.

Livi, A. D. (2004). Audit Protocol: College Park Audit, University of N. Carolina**:** 1-13.

McGinnis, J. M., W.H. Foege (1993). "Actual causes of death in the United States." Journal of the American Medical Association **270**(18): 207-12.

Mitchell, R. B., Chester Rapkin (1954). Urban Traffic: A function of land use. New York, Columbia University Press.

Olmstead, F. L. (1924). A major traffic street plan for Los Angeles. Los Angeles, Prepared for the Committee on Los Angeles Plan for Major Highways and the Traffic Commission of the City and County of Los Angeles.

Ossenbruggen, P. J., et al. (1984). "Roadway safety in rural and small urbanized areas." Accident Anal. Prevention **33**: 104-114.

Pikora, T., Billie Giles-Corti, Fiona Bull, Konrad Jamrozik, Rob Donovan (2003). "Developing a framework for assessment of the environmental determinants of walking and cycling." Social Science and Medicine **56**: 1693-1703.

Prentice, A., Susan Jebb (1995). "Obesity in Britain: Gluttony or sloth?" British Medical Journal **311**: 437-39.

Putnam, R. (2000). Bowling Alone: The Collapse and Revival of American Community. New York, Simon and Schuster.

Robert Wood Johnson Foundation (2003). Active Living: Healthy Schools for Healthy Kids**:** 1-44.

Rybczynski, W. (1999). A Clearing in the Distance. New York, Touchstone.

Schlossberg, M., Nathaniel Brown (2004). "Comparing transit-oriented development sites by walkability indicators." Transportation Research Record **1887**: 34-42.

Staunton, C., D. Hubsmith, W. Kallins (2003). "Promoting Safe Walking and Biking to School." American Journal of Public Health **93**(9): 1,431-1,434.

Surface Transportation Policy Project (1998). An analysis of the relationships between highway expansion and congestion in metropolitan areas. Washington, D.C.

Talen, E. (2002). "Pedestrian Access as a Measure of Urban Quality." Planning Practice & Research **17**(3): 257-278.

Transportation Research Board (2005). Does the Built Environment Influence Physical Activity? Examining the Evidence.

U.S. Department of Health and Human Services (2002). Physical Activity Fundamental to Preventing Disease, Office of the Assistant Secretary for Planning and Evaluation**:** 1-19.

Wei, M., J.B. Kampert, C.E. Barlow, et al., (1999). "Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men." Journal of the American Medical Association **282**(16): 1547-53.

Wilson, J. Q., George Kelling, Ed. (1982). Broken Windows. City Reader. New York, Rouledge.