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Geographic Information Systems Analysis of Walkability Data for the Atlanta Beltline Communities

Michale Kanchik

ABSTRACT

A MASTERS OF PUBLIC HEALTH CAPSTONE PROJECT:
GEOGRAPHIC INFORMATION SYSTEMS ANALYSIS OF WALKABILITY DATA FOR THE ATLANTA BELTLINE COMMUNITIES

By

MICHALE HAIA KANCHIK

July 21, 2017

INTRODUCTION: As a means of combating the growing obesity epidemic in the United States, public health experts are promoting the building of walkable communities. Using walkability data initially collected for the CDC's Atlanta Beltline Project, this study will examine select features of the built environment and their relationship to active people. This capstone is seeking to explore factors present in the built environment that are related to physical activity

AIM: Using the Atlanta Beltline Project's segment-level walkability data, this capstone will aim to deliver a micro-scale analysis of pedestrian walkability features. The author believes that completing a spatial analysis of the data, will allow developing a tangible product that will further enhance and benefit the works of the CDC's Atlanta Beltline Project. In addition, by utilizing Geographic Information Systems (GIS), this capstone hopes to deliver valuable information on the physical environments and walkability patterns that most currently portray Atlanta Beltline segments.

METHODS: Methods used in this study include an extensive review of existing literature, descriptive analysis of environmental attributes, mapping, and spatial analysis using Geographic Information Systems (GIS) technology.

RESULTS: Overall, Atlanta Beltline segments with a bus stop exhibited the highest presence of active people (26.3 percent). Beltline segments that had broken/boarded windows/vacant buildings/homes demonstrated the second highest presence of active people (21.21 percent). Streets with trees for shade had the lowest presence for active people (17.99 percent). Substantial differences in the presences of active people were found when making a comparison between the control (Westside) and experimental (Southside) Beltline communities. Study findings are all based on the descriptive nature of the analysis performed, and as a result, do not intend to demonstrate statistical significance.

DISCUSSION: Study findings indicate that the presence of certain built environment features may promote walkability along the Atlanta Beltline communities.

INDEX WORDS: walkability indicators, built environment, walkable communities, the Atlanta Beltline, audit instruments, Geographic Information Systems (GIS)

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MICHALE HAIA KANCHIK

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30303

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MICHALE HAIA KANCHIK

Approved:

Committee Chair: Professor John Steward, M.P.H.

Committee Member: Dr. Dajun Dai

Date: July 21, 2017

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Author’s Statement Page

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Background

To combat the health risks associated with inactivity and to protect against chronic diseases, American adults should be getting at least 150 minutes of moderate-intensity aerobic activity every week, and also complete muscle strengthening exercises two or more times a week. As part of an overall healthy development, children and youth are encouraged to get at least 60 minutes of physical activity each day (U.S. Department of Health and Human Services, 2008). The latest physical activity data suggest that only 1 in 5 U.S adults and approximately 27 percent of high schoolers met these physical activity guidelines. Physical activity surveillance also suggests that activity levels decrease as children's age increases, a negative trend that carries over well into adulthood years (Davison KK and Lawson CT, 2006). Based on the 2015 Behavioral Risk Factor Surveillance System (BRFSS) data on physical activity, only 18.7 percent of Georgian adults (18 years of age or older), successfully met the prescribed physical activity guidelines (Centers for Disease Control and Prevention, 2016).

Efforts to promote physical activity in Americans of all ages are now taking place across the United States. Advocate groups, grassroots level and, national coalitions have all turned to the public health sector for guidance on ways to scientifically support the promotion of physical activity legislation and policy. Consequently, more and more empirical evidence continues to suggest that the built environment is one of the determinants of physical activity (Davison KK and Lawson CT, 2006). These findings lead to new unknowns and questions such as which aspects of the built environment act in facilitating or hindering physical activity? And which streetscape characteristics seem to be the most influential determinants of physical activity?

A neighborhood's built environment can be a strong predictor of how physically active the residents of that community are (Brownson, R. C., et al., 2001). In a study conducted in King

County, Washington, researchers collected data on the intensity levels and locations of study participant's physical activity. Physical activity was categorized by level of intensity, such as sedentary/low physical activity (SLPA) and moderate/vigorous physical activity (MVPA). The researchers concluded that subjects were most likely to engage in MVPA levels while they were "near their home" (35 percent of the total physical activity time). In comparison, the time devoted to MVPA levels dropped dramatically to 11.5 percent while individuals were "away" from home, and to merely 4.4 percent while they remained "at home" (Hurvitz, P. M., et al., 2014). Another study found that the majority of its participants perceived those 0.61 miles, or a little over half a mile, as the acceptable distance to walk from their home to their desired destination (Yang Y., et al., 2012). The findings further support how important effective design features like street connectivity and density are to encouraging physical activity in communities.

Empirical evidence has continually pointed to specific community design elements like storefronts facing the streets, well-connected destinations, and access to public transportations, as just some of the key elements to promoting walking as an active mode of transportation (Community Preventive Services Task Force, 2017). While evidence about the importance of physical attributes on walkability has been extensively documented, the same has not been true when examining perception-based aspects. Factors that influence people's decisions to get up and become active are not shaped by physical attributes alone. Understanding the influences of subjective variables on activity, such as the perception of safety, can ultimately guide future public health interventions and stakeholder collaborations. Making an argument for the design of healthy, more walkable communities is a crucial step in shaping a less sedentary United States; however, doing so will first require fully understanding all the different forces that affect physical activity decisions.

In recent years, there has been an increased surge in reviving the physical environment across entire communities around the United States. In fact, many state and federal planning grants are now being awarded to communities that include information on ways the sought after redevelopment projects may benefit the health of residents. For example, the Atlanta Regional Commission (ARC) has been awarding communities with grant funding and assistance through its Livable Centers Initiative (LCI) program (Atlanta Regional Commission, 2017). The program focuses on aiding communities in rebuilding their current infrastructure to promote pedestrian activity, focus on the connectivity of streets, enhancing safe and visually appealing streetscapes, and improved transit options. The ARC has awarded over $194 million dollars in LCI funds to more than 112 metro Atlanta communities since 1999. Funding opportunities such as the LCI program, have significantly contributed to the growing collaborations between public health workers and urban planners on the development of healthy and livable communities.

The Atlanta Beltline Project

The Atlanta Beltline is an urban redevelopment project that aims to connect 45 Atlanta neighborhoods via a 22-mile multi-use trail and a 33-mile light rail network. The Beltline seeks to improve mobility and alternative travel options within the city, construct parks and affordable housing units, and spur economic development across Beltline communities (The Beltline Project, 2013). This major urban redevelopment project presents researchers with an opportunity to assess the ways the ongoing physical changes to the environment may influence the health of surrounding Beltline communities. A comprehensive, multilevel study, "*Individual and Community Health in Low-Income Neighborhoods: An Evaluation of the Atlanta's Beltline Project,"* was spearheaded by principal investigators from the Centers for Disease Control and Prevention (CDC) and Georgia State University (Centers for Disease Control and Prevention, 2016).

Work on the Atlanta Beltline Project commenced with the following aims in mind:

Aim 1: Construct a comprehensive picture of the built environment and individual and community health in two Beltline communities.

Aim 2: Identify facilitators and barriers to using the Beltline for improving individual and community health.

Aim 3: Examine use of the Beltline trails and parks for individual and community health activities (Centers for Disease Control and Prevention, 2016).

Out of the specified aims, the author of this capstone found aims number one and two to have the most relevance to the objectives of this study.

The project's investigators developed a unique walkability audit tool that was used in obtrusive rating measures of the built environment for Beltline neighborhoods. The Atlanta Beltline neighborhood audit tool, which is included in Appendix 3, uses 35 measures to assess the features found in street segments that were related to walkability located across Beltline communities. This instrument captures information on streetscape characteristics such as availability of light fixtures and sidewalks, social environment aspects, transportation components, etc. The data collected through in-person observations of these street features for the Atlanta Beltline Project were used by the author of this capstone for secondary analysis.

Initially, the author of this capstone project worked as a practicum student with the Centers for Disease Control and Prevention (CDC), collecting walkability audit data for the Atlanta Beltline Project (CDC 2016). While brainstorming potential ideas for a capstone project topic, the author became interested in analyzing the segment data collected for the Atlanta Beltline Project. Survey data gathered for the two Beltline communities would be used to develop GIS mapping and spatial analyses. These communities are referred to as the Westside and Southside study areas, neighborhoods that both border portions of the Atlanta Beltline West End trail.

It is important to note that all the maps contained in this capstone report were created as part of a Master's of Public Health capstone project at Georgia State University, and are only intended for educational use. As part of the disclaimer statement, the author also expresses that the findings and conclusions in this report are those of the author only, and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Research Question

The concept of a health-promoting environment has been well documented in public health literature and frameworks (Moudon, A., & Lee, C., 2003). Using these theoretical frameworks for guidance, the goal of this capstone project is to explore factors present in the built environment that are related physical activity. An objective of this study is to use spatial analysis and GIS to inform policymakers, municipalities, and researchers at the Atlanta Beltline Project about preferred aspects of the built environment as related to active people in the Atlanta Beltline area. The second objective of this study aims to assess the variability present along the built environments of the Beltline Westside and Southside communities. To meet the objectives of this study, the author built on existing public health research by exploring the following question: What are the features of the built environment that are related to the facilitation or hindrance of physical activity along the Atlanta Beltline study area?

To answer this question, the author of this capstone employed the following methods: secondary analysis of the survey data, descriptive analysis, an extensive review of existing literature, and performing spatial analysis and mapping using Geographic Information Systems (GIS) technology. This capstone's author believes that the findings of this study may have beneficial implications that will further enhance and benefit the works of the CDC's Atlanta Beltline Project.

CHAPTER 2: LITERATURE REVIEW

Introduction

The prevalence of rising obesity among adults and youth in the United States has been well documented since the early 1960's when the emerging issue gained national media coverage and later was deemed as a public health epidemic (Benjamin Caballero, 2007). The latest statistics on U.S. obesity rates show that approximately 36.5 percent of all adults and 17 percent of all youth across the nation are obese. Furthermore, there have been no improvements in obesity prevalence rates from the time data collected between 2003–2004 and 2011–2012 (Ogden CL., et al., 2015). Extensive research in the field has shown that prevalent obesity has been linked to some additional health related issues, including heart disease, high blood pressure, stroke, and even type 2 diabetes, the seventh leading cause of death for U.S. adults (Centers for Disease Control and Prevention, 2011).

The obesity epidemic has received considerable attention from policymakers, with many policy initiatives aiming to combat the public health problem having been implemented at both the state and at the federal levels. While all the policies aim to help Americans in adopting healthier lifestyle choices, some legislation has directly intended to promote the public to become more physically active. For example, the Office of Disease Prevention and Health Promotion (ODPHP), specifies that one of the main goals of Healthy People 2020 includes reducing the obesity rates among U.S adults from the current 36.5 percent to a target rate of 30.5 percent by the year 2020 (Office of Disease Prevention and Health Promotion [ODPHP], 2016)

The literature strongly agrees that physical activity has a profound influence on human health. Not only does an increase in physical activity lower the risks of obesity and having excess weight, but it can also guards against many other physical and mental illnesses, including certain cancers, osteoporosis, cardiovascular conditions, depression, and even sleep-related conditions (Dannenberg, A., et al., 2011). To enhance and promote physical activity, Healthy People 2020 targets to increase the proportion of trips of 1 mile or less made by walking adults, ages 18 years or older (ODPHP 2016). But the progress of meeting physical activity goals has remained slow, with the latest data indicating that only 33.4 percent of US adults currently meet the 1-mile walking objective, while the 2020 target rate is 36.7 percent of adults (ODPHP 2016). To better understand why people are not meeting their daily recommendations for physical activity levels, researchers began looking at the potential relationship between physical activity and characteristics of the built environment

Research shows that several streetscape characteristics are positively associated with increasing the use of streets by pedestrians. For example, multiple reports indicate that the presence of continuous sidewalks, street calming features, and trees - all elements of a pedestrian oriented environment, were all also related to greater walking rates among pedestrians (Mehta, V., 2008). The significance of sidewalk connectivity has been well documented in past literature, further giving validity to the questions explored in this capstone project. Findings of previous studies show a substantial correlation between sidewalk accessibility and the promotion of pedestrian activity. In particular, this is well documented in urban communities, where green space availability can be more limited than in the surrounding suburbs (National Highway Traffic Safety Administration. 2015). Individual elements of the physical environment such as these are all part of a much broader and rather intricate system of attributes that do not directly dictate the design of our communities but consequentially influence our road to health.

Walkable Communities and the Perception of Safety

The ever-growing emphasis on promoting physical activity among Americans was highlighted in the most recent publication of the Surgeon General’s Call to Action Report, Step It Up! The Surgeon General’s Call to Action to Promote Walking and Walkable Communities (U.S. Department of Health and Human Services, 2015). Not only does the Surgeon’s Call to

Action highlight the importance of physical activity, like walking and cycling, but the report also addresses the vital role environmental characteristics of communities have in promoting physical activity. Research shows that community design plays a significant role in either facilitating or hindering physical activity, with certain streetscape characteristics potentially having a stronger impact on decisions for walking. These research findings raise the following questions, what exactly are walkable communities? Moreover, how can certain aspects of a community's built environment influence our perception to engage in physical activity safely?

Communities that exhibit higher scores on walkability audits tend to have several built environment attributes in common. Research confirms that neighborhoods with higher density, greater connectivity, and an increase in mixed land use, also demonstrated higher rates of walking and cycling, as compared with low-density, low connectivity, and single land use neighborhoods (Saelens, B. E., et al., 2003). Such findings are significant for several reasons. Walkability studies can help researchers develop a better understanding of the types of physical characteristics people found to be most favorable to increasing their total physical activity outcomes. Neighborhoods that are more compact have higher-density levels and more pedestrian networks were associated with a pedestrian and public transit oriented mode to travel, as compared to the more conventional single-occupant automobile driving approach (Cervero, R., 2002). These findings further validate that people are more encouraged to be physically active and choose a pedestrian-oriented mode of travel when they are located in a highly dense, well-connected, mixed land use neighborhood. While a well-designed community with pedestrian oriented infrastructure can promote overall physical activity, people's activity levels can often become discouraged if faced with a threat to personal safety because of a hostile social environment.

Pedestrians and cyclists can feel threatened due to some reasons. A lack of vehicle-related safety amenities along street segments can be particularly concerning for pedestrians and pedalcyclists. Enhancements to street safety can include the availability of continuous sidewalks, crossing-aids, and street designs that promote a reduction in speed and noise levels. According to Motor Vehicle Crashes, in 2015, pedestrian fatalities increased by 9.5 percent, and pedalcyclist fatalities were up by more than 12.2 percent from 2014, respectively (National Highway Traffic Safety Administration, 2015). With growing concern over adequately increasing vehicle-related safety amenities along street segments, many urban renewal projects began to include elements promoted by Complete Streets. The concept of Complete Streets encourages roads that are designed to be safe and accessible for pedestrians, cyclists, motor vehicle drivers, and alternative transit users, and has been a topic of lively discussion for multiple entities over the last 30 years in the United States (Laplante J, McCann B., 2008). Complete streets policies advocate for the safety of pedestrians and bicyclists, by promoting that all new and reconstructed street projects should include separate pedestrian and bicycle oriented facilities (Dannenberg, A., et al., 2011).

In addition to perceived safety concerns over traffic-related barriers to physical activity, individuals must also take into consideration the potential dangers associated with threats to personal safety. As a result, past research has divided the variable of safety perception into two subgroups, personal safety, and traffic related safety (Pikora, T., et al., 2003). Studies show that people living in neighborhoods that are perceived as less safe were also more likely to be physically inactive (Centers for Disease Control and Prevention, 1999).

Wilson and Kelling's famous 'broken windows theory' suggested that with the presence of broken windows in a neighborhood came a potential of more broken windows, an increase in vandalism, and eventually a likelihood of more severe crimes (Kelling, George L., Wilson, James Q., 1982). In addition, when police officers began patrolling Newark's streets on foot rather than by car, residents felt an increased perception of safety, when in all reality, crime rates never actually decreased. As their perception of safety increased the residents of Newark began to come outside their homes, actions that proved to Wilson and Kelling how important safety perception was to the human decision-making process. Regarding being an attribute of the walking environment, the perception of safety is one of the more challenging features to measure along a community's built environment. This is mainly due to a lack of a single, direct way to reliably quantifying a segment's 'perceived safety' levels. This is particularly evident when using a walkability audit instrument to rate the variables and unobtrusive measures across segments of a study area.

Overall, the literature strongly agrees that an individual's perception of safety has a strong association with health related outcomes. Research findings show that neighborhoods with higher levels of greenery and lighting fixtures were correlated with a more favorable perception of safety among both adults and their children; furthermore, having an increasing influence on health benefits (Centers for Disease Control and Prevention, 2013). Good lighting, which can aid to boost pedestrians' overall sense to security, was one of the perception indicators identified by Moudon and Lee (2013) in the *Variables in the Spatiopsychosocial Aspects of Walking and Bicycling* (see Appendix 2). Also, collecting information of the presence of light fixtures, which are associated with the availability of lighting during nighttime hours, is easily accomplishable via segment surveys. As the majority of all walkability tools contain an item on the presence of street lighting fixtures, this is one of the useful approaches to measure safety perceptions potentially.

Measuring Walkability via Audit Tools

Quantifying how conducive a community's built environment is to encourage physical activity can be rather challenging. As a result, walkability audits have become analytical instruments for assessing a community's physical environment via observation and primary data collection. When rating the built characteristics and social environment as related to facilitating or hindering physical activity, observers can measure and record a broad range of walkability variables.

Among the best developed and most frequently utilized walkability audit instrument is the Systematic Pedestrian and Cycling Environmental Scan (SPACES) Instrument (Pikora T., et al., 2000). Originally developed by researchers in Austria, the SPACES tool has been credited with being one of the earliest walkability instruments created. All the items in the SPACES instrument are aimed at assessing the overall community "feel," making it a rather easy method to evaluate a community's social and physical environment using a paper form. The SPACES instrument served as a basis on which the Atlanta Beltline Neighborhood audit tool was developed. In addition to the SPACES instrument, the Beltline audit tool contains items from the CDC-HAN tool and the Irvine Minnesota Inventory (IMI) instrument. The segment data used in the analysis portion of this capstone was collected using the Beltline audit instrument.

The processes of data collection and analysis tend to range from simple surveys to more complex forms of audit administration. While the SPACES tool constitutes a far more simplified approach to gathering walkability data, the Pedestrian Environment Data Scan (PEDS) audit tool contains 78 measures of street walkability (Schlossberg, M. 2007). Depending on the research question, investigators will often decide which walkability audit instrument to employ. For example, a study looking at the possible association between exposure to walkable park routes and an increased use of the park selected a walkability audit tool in which only 12 elements of the pedestrian environment were evaluated (Dills, J. E., et al., 2012). Dills, Rutt, and Mumford (2012), found that individuals that lived in proximity to a park entrance were more likely to engage in physical activity, such as walking or cycling, throughout their neighborhood. Study findings also indicate that the relationship between parks and walking is bilateral, as routes to parks with higher walkability scores supported a higher volume of park users and overall physical activity. The authors were completely in control of which variables they wanted to assess, rate, and to determine how to assign elements their scores adequately.

Behavioral Model of Environments

A theoretical framework can often be employed to make better sense of complex variables that at first glance appear to be unrelated. Theoretical frameworks, such as the Moudon and Lee's (2003) Behavioral Model of Environments (BME), can also aid in guiding the structuring of audit instruments from an ecological and behavioral approach (Moudon, A., & Lee, C., 2003). Moudon and Lee (2003) provide a comprehensive review of 31 walkability-audit tools, defining them as environmental instruments used to inventory and assess conditions of the physical environment that are associated with walking and biking. The authors also provide an explanation for and identify the various variable used to define environmental factors.

Having assessed and reviewed all individual characteristics of the built environment, Moudon and Lee (2003) proceed to group these variables into the following four distinct classes: spatiophysical, spatiobehavioral, spatiopsychosocial, and policy-related variables. Aspects of the built environment that fall under the spatiophysical category tend to capture roadway and roadside characteristics that are easier to survey; they include items such as the presence of sidewalks and crossing-aids. Social systems tend to shape each community's surrounding environment, consequentially laying out the foundation for surrounding spatiophysical indicators. Spatiobehavioral characteristics reflect roadway behavior, capturing aspects such as vehicle speed or the posted speed limit. Quantify perceptions on the environment, spatiopsychosocial characteristics are subjective and tend to have the most variability. Policy-related aspects of the environment encompass objective variables in the area of policy that influences walkability levels. Examples of policy related variables include transportation plans, new developments, and renovation projects (Moudon, A., & Lee, C., 2003).

Moudon and Lee categorize each general street feature as a variable belonging to one of the four groups. The authors use the BME framework to explain how each independent variable is understood as "bricks and mortar" of the human environment. The majority of past walkability research largely only focused on the physical aspects of the environment, such as roadway and sidewalk characteristics. This is reflected in the majority of walkability audit instruments, which mainly concentrate on measuring the spatiophysical aspects of the surrounding environment. The BME framework is unique for considering all attributes of the physical environment, including social and personal characteristics related to walking and bicycling that are otherwise rarely addressed (Lee, C., Moudon, A.V., 2004). Because of their subjective nature, spatiopsychosocial variables are rated using the simplest of walkability audit instruments, a self-reported survey form (Moudon, A., & Lee, C., 2003).

Following their review of over 31 environmental audit instruments, Moudon and Lee assembled a comprehensive table of environmental factors grouped into four classes (Moudon, A., & Lee, C., 2003). Complete tables containing Moudon's and Lee's groupings of spatiophysical or spatiopsychosocial environmental factors and variables are included in Appendix 1 and Appendix 2.

CHAPTER 3: METHODS AND PROCEDURES

Introduction

To obtain the rights to use the dataset, the author needed to develop and sign a *Data Use Agreement Form for the CDC Data Set*. This data usage agreement is to ensure that all the data remain confidential, and be handled by the author appropriately and privately. An IRB application for this study was approved on March 23, 2017, and designated as not human subjects' research (IRB ID H17508). This chapter outlines the methods and procedures used in data analysis and the creation of GIS mapping.

The walkability data collected for the CDC's Atlanta Beltline Project was the primary source of data utilized the author of this capstone for spatial analysis (CDC 2016). Using environmental audit tools, researchers collected data for the physical environments of both the control and the experimental Beltline communities. Methods used to develop the products of this capstone project included a review of the literature, secondary analysis of the Atlanta Beltline walkability data, and a development of Geographic Information Systems (GIS) spatial analysis maps and visuals. To deliver a micro scale analysis of pedestrian walkability patterns, the author first needed to combine the Atlanta Beltline's tabular data set with its corresponding unique segment ID within the GIS .mpk data set file.

The .mpk data set file contained all the individual shapefiles from the Atlanta Beltline Project (Appendix 5). Data collected for all surveyed segments were a part of a GIS shapefile named "StreetSegments_v2" (SDE_tomtom_2015). This shapefile, created by the CDC's Geospatial Research, Analysis and Services Program (GRASP) and TomTom, included segment indicators for 168 segments that were outside the Atlanta Beltline's study area. The shapefile containing the outside 168 segments is named "Outside50". To preserve data for as many completed segments as possible, the author of this capstone decided it would be best not to exclude the data collected for the "Outside50" segments. Having a larger segment sample size ultimately reduces the influences of data outliers, and also allows for the data to represent a broader population better. In addition, it is important to note that each side of the segment was assessed individually.

Variable Selection Criteria

To develop a more comprehensive picture of the built environment for the Beltline Project's study area, the author of this capstone selected several attributes from the Beltline audit tool to aid in assessing activity prevalence rates across surveyed segments. Variables selected for spatial analysis included the presence of sidewalks, bus stops, the presence of active people, light fixtures, segment trees that offer shade, and vacant buildings/broken windows. This section further outlines the author's reasoning for selecting each of these independent descriptors.

Using Moudon's and Lee's (2003) Behavioral Model of Environments, environmental variables categorized as spatiophysical, spatiopsychosocial, or spatiobehavioral, were selected for this project's GIS analysis. Table 1 identifies the Behavioral Model of Environments (BME) category type for each of the six variables, in addition to each variable's subsection of the Beltline audit instrument.

Table 1: BME Environmental Variables Selected for Capstone Analysis

Variable Name	Behavioral Model of Environments Category Group	Atlanta Beltline Neighborhood Audit Tool Category
Presence of a Sidewalk	Spatiophysical	Transportation Environment
Presence of a Bus Stop	Spatiophysical	Transportation Environment
Trees that can offer Shade	Spatiophysical	Facilities
Active People	Spatiobehavioural	Social Environment
Vacant Buildings/Broken Windows	Spatiopsychosocial	Aesthetics, Incivilities
Presence of Light Fixtures	Spatiophysical/ Spatiopsychosocial	Street Characteristics

Using a walkability audit tool allowed for a systematic gathering of information on observational measures along the segments of the Beltline study area. Rather than using a comprehensive scoring mythology to assign an overall walkability score for each surveyed segment, each variable scored a '0' when not being present, and a score of '1' for being present. In the Atlanta Beltline neighborhood audit, item number (Q11) or the 'presence of sidewalk' captures a spatiophysical, transportation feature of the built environment. Data collectors assigned a score of (0) for NO sidewalk present along surveyed segment, and a score of (1) for YES sidewalk answers. An additional spatiophysical variable used in assessing the transportation environment for the Beltline Project's study area asks whether a bus stop was present along the surveyed segment (item number Q19). The Beltline walkability instrument instructs data collectors to assign no points (0) for no alternative transportation, a score of 1 point for the presence of a bus stop, and 2 points for any other transit stops that might be present along the street segment. The third spatiophysical feature of the built environment included in this capstone's analysis is a variable categorized in the Beltline audit tool as a streetscape amenity. Item number Q29_8 of the Qualtrics key asks surveyors to specify if the segment surveyed was equipped with the amenity of "trees that could offer shade" (1 = Selected, 0 = Not Selected).

The availability of streetlight fixtures along the street segment was selected to represent the spatiopsychosocial, street characteristic variable. Item number Q27_4 of the Beltline neighborhood audit focuses on this variable, where surveyors were asked to indicate whether light fixtures are present along the street. A score of (0) indicates that NO, no light fixtures are present, and a score of (1) for YES, light fixtures was present along the segment. The author of this capstone chose light fixtures to embody the spatiopsychosocial aspect of the physical environment for some reasons (see Chapter II: Literature Review). Good lighting, which can aid boost pedestrians' overall sense to security, was one of the perception indicators identified by Moudon and Lee under the *Variables in the Spatiopsychosocial Aspects of Walking and Bicycling* (see Appendix 2).

Another spatiopsychosocial variable included in this capstone pertains to the attractiveness, aesthetics, and to the perception of security and safety of the walking environment. Item number Q32_2 of the Beltline audit tool, asks observers to indicate if "broken/boarded windows/vacant buildings/houses" were observed along the street segment. The variable was assigned points as based on the surveyor's indication (1 point = Selected, 0 points = Not Selected).

Active people, categorized as a spatiobehavioral feature, were treated by Beltline researchers as independent descriptors of the social environment. This attribute is captured under item number Q9_2 of the Beltline audit tool by asking observers to identify "Active people (e.g., playing a sport, running, climbing, walking, biking)?" (CDC 2016). Data collectors would then choose between the following three answers: None (0 points), A Few/Some or approximately 1 to 6 people (1 point), or A Lot or about 7 or more individuals (2 points).

Data Extraction Analysis

Spatial analysis was performed using ArcMap version 10.3. Analyzing the Atlanta Beltline walkability data required employing several types of selection analysis using the ArcGIS software tools. All data was projected using Geographic Coordinate System GCS_North_American_1983, Datum D_North_American_1983, and Projected Coordinate System NAD_1983_StatePlane_Georgia_West_FIPS_1002_Feet. Appendix 5 displays a table with all shapefile names and sources originally included in the Beltline study's GIS data. The selected streetscape features were included in the spatial analysis and GIS maps. GIS data was extracted from the "StreetSegments_v2" shapefile using SQL queries, allowing the author to map the selected attributes.

CHAPTER 4: RESULTS

Analysis Results and Findings

Using the unique Atlanta Beltline neighborhood audit instrument, the Atlanta Beltline Project collected data on a total of 3144 street segments (see Chapter 1 for more detail on the Atlanta Beltline audit tool). Descriptive analysis results for each selected walkability related attribute, along with percent associated with other designated attributes, are displayed in Table 2.

An alternative way of showing the results related to each selected attribute is also featured in a table attached as Appendix 6.

Table 2: Walkability-related Attributes Present along Streets, Percent Associated with Second Attribute

Attribute	N	Broken/boarded windows/homes %	Sidewalk %	Light Fix. %	Bus stop %	Shade Trees %	Active People %
Broken/boarded windows/homes	806		73.6%	48.7%	27.3%	29.6%	21.2%
Sidewalk	1889	73.6%		74.2%	93.8%	57.8%	20.9%
Light Fix.	806	48.7%	74.2%		61.1%	46.5%	19.7%
Bus Stop	307	27.3%	93.8%	61.1%		9.5%	26.3%
Shade Trees	1584	29.6%	57.8%	46.5%	9.5%		17.9%
Active people	468	36.5%	84.4%	58.3%	26.3%	17.9%	

In addition to highlighting descriptive statistics for the overall Beltline study area above, the author knew it was important to paint comparison profiles for the experimental, Southside study community, and the control community located in the Westside study depicted in each of the GIS maps. For each community, the author extracted the numerical data for the specified environmental feature, in addition to also calculating prevalence rates for physical activity as related to each of the environmental variables. Tables 3, 4, and 5, display the prevalence rates for each environmental feature present in the overall Beltline study area, the Westside, and the Southside communities.

Table 3: Prevalence Rates for Environmental Features for the Overall Atlanta Beltline Study Area

Variable Name	Number of Segments with Characteristics Present	Number of Variable-Present Segments Associated with Active People	Prevalence Rates
Sidewalks	1889	395	0.2091
Light Fixture	1389	273	0.1978
Trees that offer shade	1584	285	0.1799
Bus Stop	307	81	0.2638
Broken/Boarded Windows/Vacant Buildings/Homes	806	171	0.2121

Table 4: Segment Prevalence Rates for Environmental Features for the Atlanta Beltline Project's *Westside* Community

Variable Name	Number of Segments with Variable Present	Number of Variable-Present Segments Associated with Active People	Prevalence Rates
Sidewalks	1015	259	0.2551
Light Fixture	818	183	0.2237
Trees that offer shade	802	173	0.2157

Bus Stop	188	56	0.2978
Broken/Boarded Windows/Vacant Buildings/Homes	481	119	0.2474

Table 5: Segment Prevalence Rates for Environmental Features for the Atlanta Beltline Project's *Southside* Community

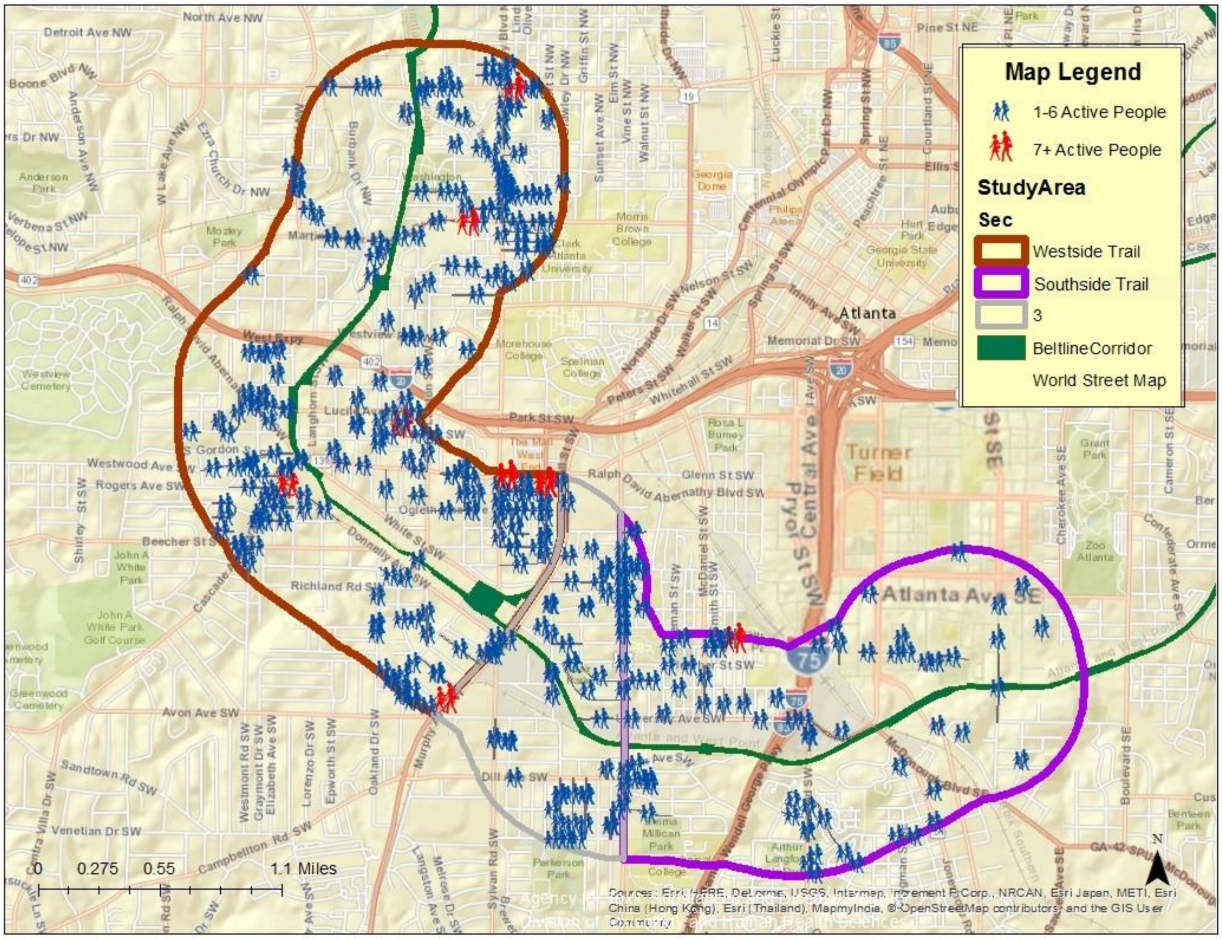
Variable Name	Number of Segments with Variable Present	Number of Variable-Present Segments Associated with Active People	Prevalence Rates
Sidewalks	617	76	0.1231
Light Fixture	430	59	0.1372
Trees that offer shade	565	69	0.1221
Bus Stop	87	13	0.1494
Broken/Boarded Windows/Vacant Buildings/Homes	234	34	0.1452

In the following section, *Mapping the Results*, the author of this capstone created GIS maps to display the spatial distributions and visual associations between the environmental features and active people.

Mapping the Results

In this section, the author mapped the distributions of active people as associated with a second attribute. The map in Figure 1 shows the patterns and locations of people that were visibly active along sidewalk-equipped streets at the time walkability data was being collected for the Atlanta Beltline Project.

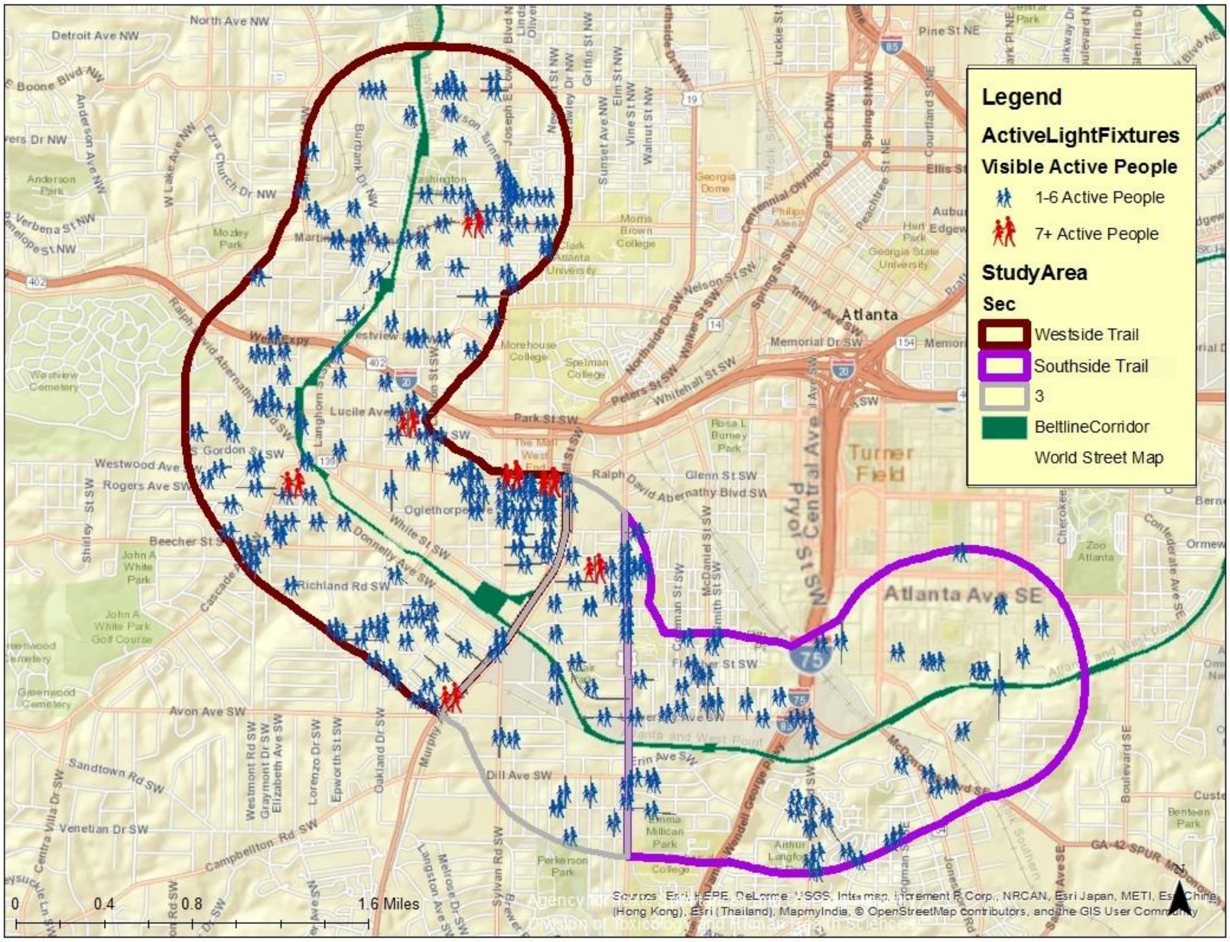
Figure 1: Distribution of Active People on Sidewalk-Equipped Beltline Street Segments



The 'walking people' symbols denoted in the color red represent segments that were used by seven or more active individuals at the time of data collection. The 'walking people' symbols indicated in the color blue represent segments that had anywhere from one to six visibly active individuals during data collection efforts. As previously mentioned in the *Analysis Results and Findings* section, 395 segments met both of these conditions, constituting approximately 84.4 percent of all segments with physically active people. Across the Southside community, the prevalence of active people along sidewalk equipped segments was 12.3 percent (n=617). In comparison, the prevalence of active people along sidewalk equipped segments was 25.5 percent in the Westside community (n=1015).

The map in Figure 2 illustrates the distribution results for visibly active people along surveyed Beltline segments equipped with a least a single light fixture.

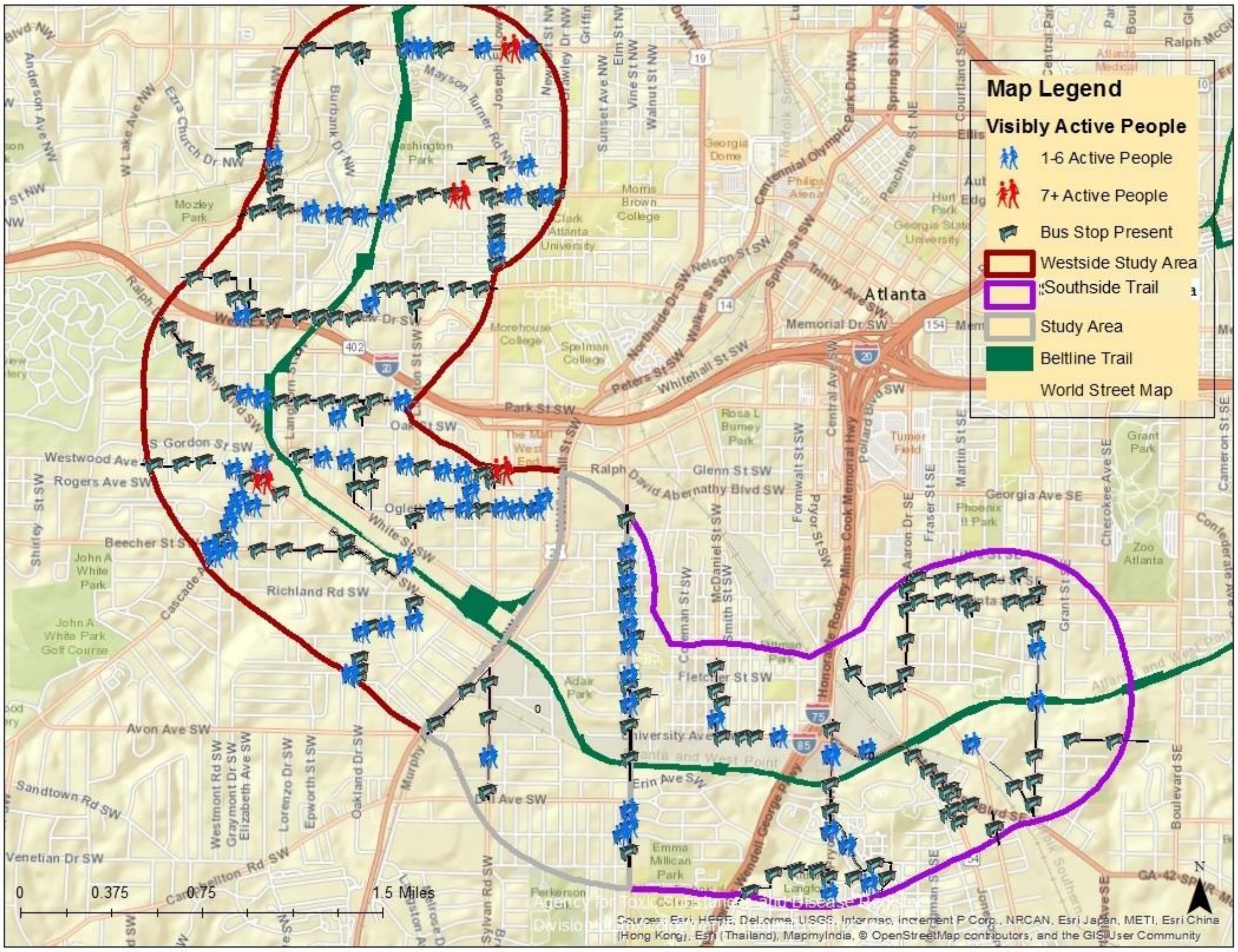
Figure 2: Distribution of Active People along Atlanta Beltline Segments Equipped with Light Fixtures



Similar to the mapping scheme portrayed in Figure 1, the map in Figure 2 shows all the surveyed segments that had both visibly active individuals and were equipped with a light fixture. Out of the 468 street segments that supported active participants, 273 or 58.3 percent were segments furnished with lights. The map in Figure 2 adequately captures these findings, were the distribution of visibly active people is far less common than that displayed in Figure 1. In the Southside community, the prevalence of active people along segments equipped with at least a single light fixture was equal to 13.7 percent (n=430). The prevalence of people active along light-fixture fitted segments was much higher across the Westside community, accounting for 22.3 percent (n=818).

The GIS data displayed in Figure 3 shows the 307 street segments that were equipped with at least one bus stop. From among these 307 segments, 26.4 percent or 81 segments also contained visibly active people. The distribution of active people in relation to the distribution of segments with a bus stop present is displayed below.

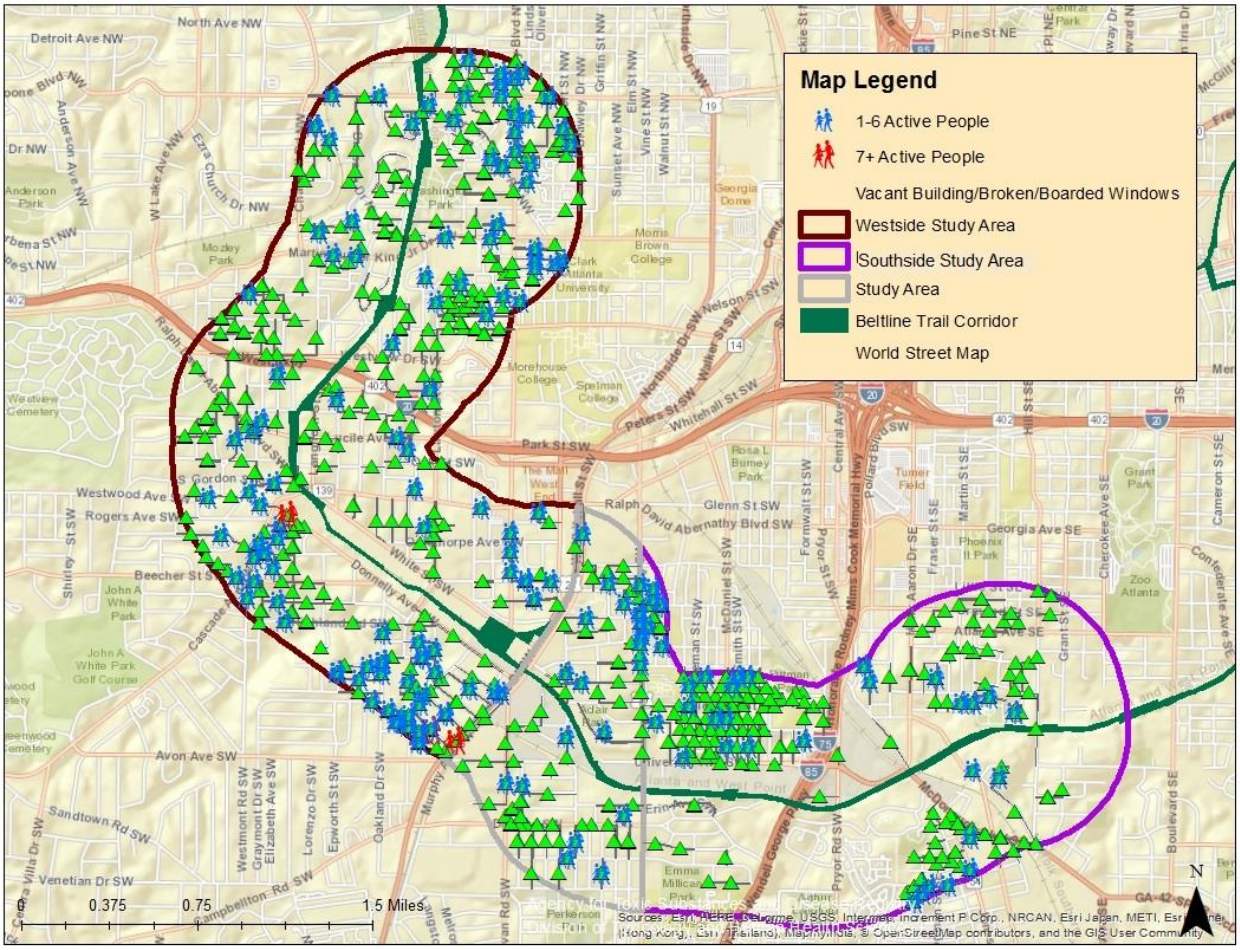
Figure 3: Distribution of Active People along Atlanta Beltline Segments Equipped with a Bus Stop



Comparing the distribution of active people along bus-stop equipped segments between the Southside and Westside study area communities revealed interesting differences in distributions. In the Southside community, the prevalence of active people using bus-stop equipped segments only constituted 14.94 percent (n=81). Along the Westside community, the prevalence of active people using segments equipped with a bus-stop was much higher, accounting for 29.7 percent (n=188).

The mapping scheme shown in Figure 4 displays the distribution of broken/boarded windows and vacant buildings that were observed along all surveyed Beltline segments. Overall, a total of 807 segments were found to contain a vacant property or a building with broken/boarded windows. From the 807 segments with visibly vacant properties, 21.2 percent or 171 of street segments were found to have people engaged in physical activity.

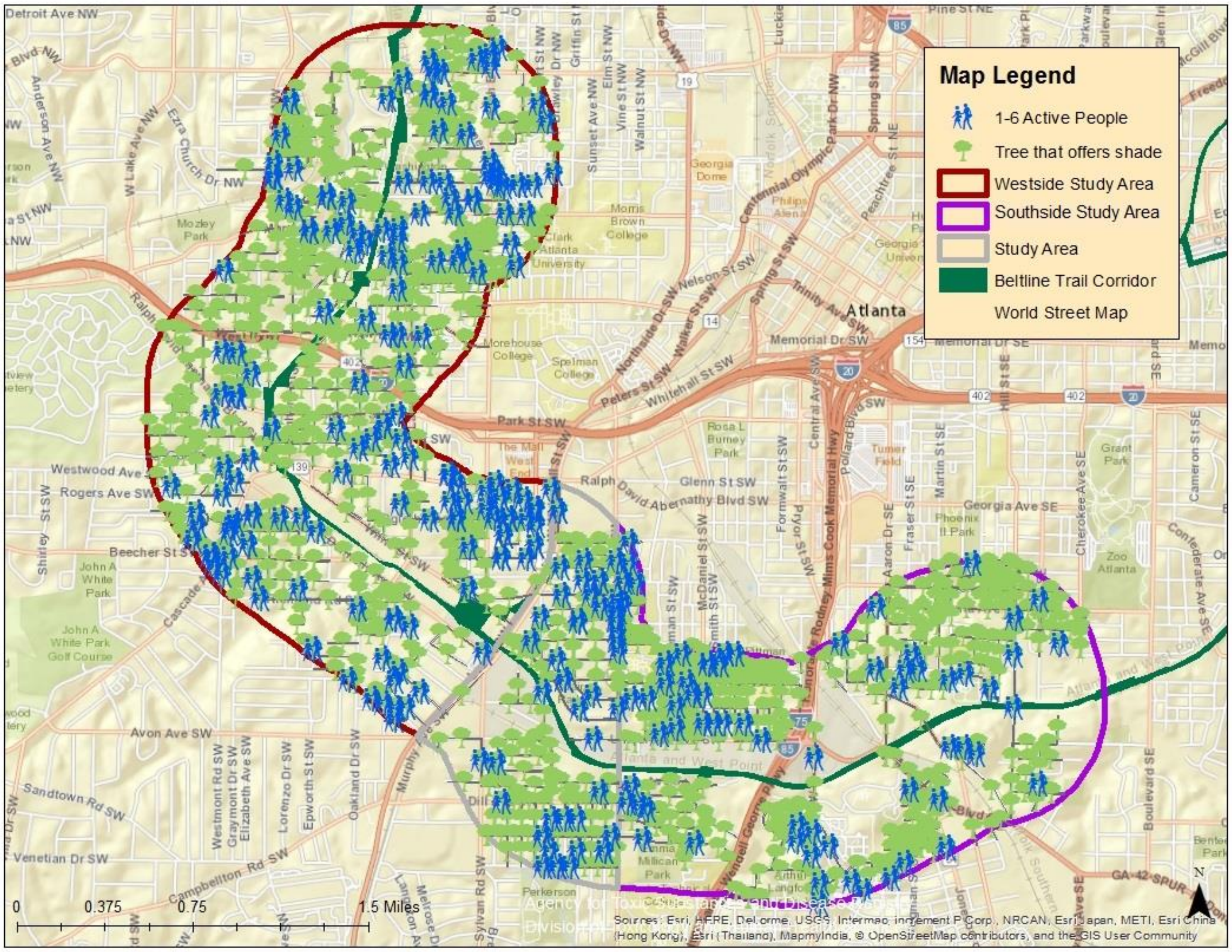
Figure 4: Distribution of Physically Active People along Beltline Segments with a Vacant Building or Present Broken/Boarded Windows



The prevalence rates were then calculated for each individual community. In the Westside community, the prevalence of physical activity along segments that contained a broken/vacant property was 24.7 percent (n=481). Prevalence rates were much lower in the Southside community, with 14.5 percent of segments with a broken/boarded home showing to also support physical activity (n=234).

The mapping results for the distribution of trees that could offer shade to Beltline segment users is displayed in Figure 5. This map also shows the distribution of active people that were present along the tree-shaded segments during the time of data collection. Out of the possible 3144 segments surveyed for the Atlanta Beltline Project, 1584 segments were equipped with trees big enough to offer the segment' users shade. Only 18 percent of the 1584 shaded segments, amounting to 285 segments, were deemed to contain active people.

Figure 5: Distribution of Active People along Trees Shaded Atlanta Beltline Segments



The distribution of trees that could offer shade in relation to physical activity levels were then separately compared for the control and the experimental communities. In the Westside community, the prevalence of physical activity along tree-shaded segments was 21.5 percent (n=802). The prevalence of physical activity along tree-shaded segments was 12.2 percent across the Southside community (n=565).

CHAPTER 5: DISCUSSION

In a quality city, a person should be able to live their entire life without a car, and not feel deprived.
– Paul Bedford

This chapter focuses on the implications of the study's findings, especially as the analysis results are related to the original research question that initially guided this capstone. The author discusses the impact of the GIS maps, and what significance the findings of this capstone may have for municipalities and policymakers when attempting to address walkability concerns in their respective cities and towns. This chapter also includes the strengths and limitations of the research, and ways to potentially address limitation concerns in future projects.

Discussion of the Results

The author of this project wanted to evaluate street design characteristics that correlate most strongly with impacting decisions for physical activity. As a result, this capstone's research approach was guided by the following question: How do various features of the built environment influence and relate to physical activity? While this capstone is certainly limited in its ability to answer such a question conclusively, the findings presented here should be treated as a foundational platform upon which future walkability research can be further built.

It is important to perform an analysis of the descriptive statistics that were presented for each GIS map included under Chapter 4: Results. First, it is important to examine the descriptive statistics calculated in Table 2 showing the walkability environment for the overall Beltline study area. Looking at the prevalence rates calculated for each environmental feature for the overall study area revealed interesting findings concerning physical activity.

Overall, segments with a bus stop present had the highest prevalence of active people (26.3 percent). This is consistent with findings from the scientific literature, indicating that users of public transportation increased their daily physical activity by an additional 8 to 33 minutes (Rissel, C., et al., 2012). From among the features assessed for walkability, it seems that bus-stops have the strongest influence on active people in the Beltline study area. Interestingly, Beltline segments with broken/boarded windows/vacant buildings/homes had the second highest prevalence rates for active people (21.21 percent). The author of this capstone did not anticipate segments with broken/boarded houses to have the second highest frequency of activity events, mainly because past studies found this environmental feature to be negatively correlated with physical activity (Kelly, C.M., et al. 2007).

The findings of this analysis show Beltline segments equipped with sidewalks were substantially more walkable than segments in which sidewalks were not present. This study also revealed some key findings related to the distribution of physically active people across Atlanta Beltline segments furnished with at least one light fixture. Wanting to assess whether spatiopsychosocial aspects of the physical environment may potentially influence decisions to physical activity, the author selected street light fixtures to represent each segment's 'perception of safety' measure. Out of the 468 physically active segments recorded, only 273, or approximately 58.3 percent of segments were equipped with streetlights. In comparison, data analysis showed that 84.4 percent of all visibly active individuals were active on streets that were equipped with a sidewalk. Besides, out of those 273 segments containing active people and light fixtures segments, 236 streets or nearly 86.4 percent of those segments also had access to sidewalks. Meaning, sidewalk presence can serve as a depicter of the walkability environment for the Atlanta Beltline communities.

Interestingly, having both sidewalks and light fixture characteristics present along a streetscape did not produce a substantial difference in determining physical activity. This is evident by study findings showing that only 50.4 percent of all segments with physically active people were equipped with both lights and sidewalks. Also, out of all 1389 segments recorded to have light fixtures, only 19.65 percent of segments supported physical activity at the time of surveying. As a result, it 's hard to infer a conclusive determination regarding the relationship between light fixtures and walkability patterns. Based on these outcomes alone, the evidence might suggest that Beltline communities equipped with sidewalks should expect to see far more active people than streets equipped with light fixtures alone or with both light fixtures and sidewalks. This will vary widely during the time of the day and whether the presence of lighting from light fixtures is necessary during nighttime. Such a conclusion remains inadequate, namely because additional factors and variables must also be taken into consideration. For example, because the Atlanta Beltline Project data collection only occurred during the daytime, any light fixtures present along surveyed segments would have been turned off. Such a limitation makes it difficult to conclusively state how important light fixtures were to promoting physical activity during the daytime. Additional limiting factors are discussed in greater depth in the following section.

Segments with trees that could offer participants shade appeared to have a surprisingly weak relationship between physical activity in the Beltline study area, with an overall prevalence rate of 17.9 percent. While segment trees that offer shade had a weak, positive association with physical activity, the low incidence rate is mostly negligible. From among all the environmental features analyzed for walkability, 'trees that could offer shade' was the environmental variable with the lowest prevalence of physical activity for segments along both the Westside and the Southside communities, with a prevalence rate of 21.5 percent and 12.2 percent, respectively. These findings conflict with past studies, which show a positive association between streetscape greenery and an increase in physical activity (Pietilä, M., et al. 2015). The low prevalence of physical activity along tree-shaded segments can be attributed to some reasons. For example, active people largely used 'purposeful routes' that were best suited for their travel needs and final destination. Meaning, Beltline segments with trees that could have offered users much beneficial shade were inconveniently located and out of the way for those traveling to a particular location. While the literature indicates that trees may promote walkability, this variable does not solely control decisions to partake in activity (Pietilä, M., et al. 2015).

Looking at the prevalence rates calculated for each of the Beltline communities revealed considerable differences related to their walking environments. Overall, the segments surveyed in the Westside community appeared to have more streetscape amenities than the segments of the Southside community. The same was also true for the distribution of physical activity events captured during the time data was collected. The walkability features of the segments in the Westside community were more diverse than those in the Southside community.

Overall, activity prevalence rates were higher across the Westside segments as compared to segments of the Southside community. For example, Westside segments equipped with sidewalks were shown to be more linked with physical activity than sidewalk-equipped segments of the Southside community, with prevalence rates of 25.5 percent and 12.3 percent, respectively. This can be attributed to the overall differences in infrastructure and levels of development between the two communities. The portion of the Atlanta Beltline's West End trail most adjacent to the Westside community has been open to the public and active since June 2010. In comparison, the portion of the West End trail that neighbors the Southside community is currently still under construction and has yet to be opened to the public (www.Beltline.org). Given that the Westside community's portion of the West End Beltline trail has already been operational for nearly seven years, the neighborhood has had time to develop the walkability features of the surrounding segments and so contribute to the increased frequency of physical activity.

Also, Westside segments with accessibility to a bus-stop were also shown to be more associated to physical activity than bus-stop equipped segments of the Southside community, with prevalence rates of 29.7 percent and 14.9 percent, respectively. This can be attributed to some factors, including an overall higher frequency of physical activity events being recorded for segments of the Westside community. Also, the difference in prevalence rates can be due to increased utilization of public transportation for residents of the Westside community than the residents of the Southside community. Nevertheless, it is difficult to conclusively state why the two communities exhibit such a large difference in these prevalence rates.

As previously stated, the author was most surprised by the findings related to the frequency of physical activity along segments furnished with broken/boarded windows/buildings. The prevalence rates of physical activity for segments with boarded/vacant homes were 24.7 percent and 14.5 percent for the Westside and the Southside communities, respectively. Out of all selected built environment features analyzed for walkability along the Beltline study area, segments with boarded/vacant buildings exhibited the second highest frequency of physical activity rates. These findings somewhat contradict the scientific literature, with past studies showing that vacant buildings tend to decrease the public's perception of safety, which consequentially can lead to increasing physical disorder and reducing physical activity (Garvin, E., et al., 2013).

While these results seem to indicate how important sidewalk access is to determining and promoting physical activity, this study cannot infer causality between the independent variables. Sidewalks, light fixtures, trees for shade, and bus stops can all potentially influence people's decisions to partake in physical activities, but such conclusions simply cannot be reached without further research and additional evidence. The importance of other factors and variables on the overall findings of this study are later discussed in detail in the 'Implications of Findings' section of this chapter.

Implications of Findings

The results presented in this capstone project reveal some interesting implications for the field of public health. The results presented in this paper are based on the analysis of 3144 street segments, data that was collected as part of the Atlanta Beltline Project. Each environmental feature was selected and analyzed with the number of observed active people. The walkability analysis was performed for the overall Atlanta Beltline study area and also for each of the Beltline communities individually. The spatial data was displayed utilizing the Geographic Information Systems technology.

This capstone project was able to evaluate several key descriptors of the walking environment for the overall Atlanta Beltline study area, in addition to making an important comparison between the more developed Westside community and the study area of the experimental, Southside community. Activity prevalence rates calculated for each environmental feature for the overall Beltline study area never exceeded 26.3 percent (as calculated for the presence of bus stops and active people). Most importantly, this study captured substantial differences in the walkability environments between the two communities selected by the investigators of the Atlanta Beltline Project. Study findings revealed the substantially higher prevalence of active people rates across the segments of the control community. It can be particularly useful to the members of the Atlanta Beltline Project to better understand the reasons that may attribute to more active people across the segments of the control, Westside community. Doing so could potentially influence the built environment of the Southside community, and other Beltline communities that have yet to commence forward with their redevelopment and building plans.

Findings that pertain to physical activity along segments with vacant/boarded windows/buildings could suggest a different understanding of the environmental feature, previously shown to negatively affect activity and use of street segments. This study shows that vacant/boarded homes did not negatively impact active people, but in fact, exhibited a positive relationship. Such conclusions may be encouraging, and potentially even indicate that the presence of physical disorder may not discourage activity to the extent concluded by evidence of previous studies (Garvin, E., et al., 2013). These findings may offer an avenue for future research and need to be investigated further.

As outlined earlier in the '*Discussion of Research Questions'* section of this chapter, it is important to understand that this study's results remain inconclusive for several reasons. While this capstone project revealed substantial findings, such as the role sidewalk might have on facilitating physical activity, it 's hard to measure decisions to partake in activity as solely based on the evaluation of only a handful of streetscape characteristics. An individual's decision to partake in physical activity relies on many various factors and variables, such as personal needs or weather conditions, all conditions that were just not covered in this study. Many of these variables also fall under the spatiobehavioral and policy-based categories of the Behavioral Model of Environments, groups that remained largely untouched by this study. The limitations of this capstone project can aid in guiding future studies, especially since researchers continue to seek ways to understand better how specific aspects of the physical environment may facilitate or hinder physical activity.

Also, if the presence of sidewalks or bus-stops along street segments can indeed promote people to partake in physical activity, mutual collaborations between public health experts, urban planners, and policymakers need to occur to ensure that sidewalks are developed as part of all future building projects. This conclusion also has implications for future research, as additional findings on the relationship between sidewalks, connectivity, and pedestrian patterns may shed light on forging walkable and healthier communities.

Study Strengths and Limitations

To the author's knowledge, this was the first walkability study in which environmental features were selected and independently evaluated as related to their potential impact on physical activity outcomes. This type of analysis offers researchers a unique opportunity to assess any variable of interest and assess how it presumably can affect and predict walkability patterns. Using GIS to showcase the walkability environment of the community is also a powerful, alternative method of communicating and digesting data results. This is particularly important given the ever-growing research that continues to demonstrate a strong correlation between walkable communities and improvements to people's health-related outcomes.

This capstone project offers several successes that can guide future research projects focused on measuring walkability patterns across any geographical location. One of the project's greatest achievements includes the ability for other researchers to recreate it easily. The author's analysis approach can be easily modified to include any variable of interest, offering a convenient method to assessing walkability data from any neighborhood. The project also provides flexibility and widespread applicability that is pertinent to any community. This approach is also inexpensive, provided a community has the means to gather walkability data using any commonly used environmental audit instrument. Such audit tools can be found on the web and downloaded free of charge.

As with all research, this capstone project had several limitations that can be used as learning opportunities, particularly for any future research related to the analysis of pedestrian walkability patterns. A substantial limitation of this capstone approach was only to analyze a handful of variables about supporting active people. To establish a more comprehensive understanding of any given community's walking environment, future studies may want to select additional variables to analyze.

The author of this capstone also has some concerns about the validity and reliability of the secondary walkability data that served as the foundation of this capstone's data analysis. The author was among the surveyors that participated in the walkability data collection process for the Atlanta Beltline Project. The principal investigators of the Beltline Study took several measures towards ensuring the reliability of the environmental data. Specifically, surveyors had to go through extensive walkability audit training and establish inter-rater reliability before being allowed to commence with data collection and recordings. Also, data collectors had to cross-check data entries that were completed by other segment auditors to ensure that the digital data records matched the walkability data that was collected on the paper forms. Even with such protocols aimed at reducing data inaccuracies, an error in data collection or coding is simply unavoidable. This is largely attributed to the Atlanta Beltline Project having more than 25 data collectors and coders surveying over 3144 street segments. Several segments have missing data fields, making them simply incapable of being used in the data analysis. Moreover, because the author was not the only one responsible for collecting all the segment data for the Beltline Project, a decrease in the data's accuracy and objectivity simply cannot be ruled out. While performing an analysis of secondary data can be an immensely time-saving, convenient, and low-cost measure, the author of this capstone understands that it also comes with several limitations and risks.

Also, the author encountered several issues during the data analysis. Initially planning to perform a hot and cold spot cluster analysis, the author was unable to do so after running into several data related problems. Performing a hot and cold spot analysis was not possible with this data due to lack of variation in the data. Each variable was assigned a numerical score that corresponded with a 'present' or 'not present' status along the surveyed segment. Thus, the majority of the tabular data set only contained numerical scores of 0, 1, or 2, as based on the segment presence for each categorical variable. The author quickly decided that creating a choropleth map with graduated symbols would be a great alternative to displaying the relationship between the various street characteristics of interest.

Another major limitation about the observation of physically active people along segments was the time and day during which segment data was collected. Due to safety concerns and precautions, data collectors were only allowed to audit segments in pairs and during daylight hours. As a result, the walkability data was often collected between 9:00 A.M. to 2:00 P.M. Because the majority of individuals are either at work or school during those hours, this time-slot may exhibit lower rates of visibly active people. The influence of light fixtures on activity along Beltline segments would have been mostly limited during the daylight hours of data collection. As a result, patrons wanting to partake in physical activity during the daytime would not need to gravitate towards light-emitting, streetscape light fixtures. Also, The observations collected for each segment were based on a single survey session, meaning the number of active people would vary widely over multiple observations. In addition, differences in population density clusters would also affect the prevalence of activity people. More populated communities will surely have exhibit a larger number of active people.

The limitations listed above are only a few of the possible limiting factors of this study's data and the approach used when evaluating the data. In the following chapter, the author provides advice on future recommendations.

CHAPTER 6: CONCLUSIONS

Future Recommendations

This study aimed to develop a better understanding of the walking and physical environments for the communities that surround the West End Trail of the Atlanta Beltline. While the findings of this project remain significant, the project's scope remains relatively narrow. Future studies should consider analyzing more variables and their associations to facilitating or hindering physical activity, in addition to incorporating larger geographical areas.

Future methods may want to explore different methods for data analysis. The author of this capstone mostly relied on Esri ArcGIS software tools for all data analysis. Depending on the questions that guide future studies, researchers may choose to employ alternative methods and data tools that are available via the software's ArcToolbox. Due to the nature of walkability data, the author strongly suggests that all future research continue the use of GIS software technology to enhance spatial data visually. The use of GIS technology in this project added a layer of depth to the study's overall argument and should remain a part of any future spatial analysis projects

As research in the field continues, it will be of great benefit to analyze segment data from various types of geographical locations. The data examined in this study pertained to the physical environment of neighborhoods that surround portions of the Atlanta Beltline, situated at the heart of Georgia's capital city. The walkability data collected for the Atlanta Beltline Project depicts streetscape characteristics that are common to a large metropolitan environment. Cities are no longer confined to simply being urban, suburban, or rural areas, as current American Planning Association (APA) geographical definitions also include terms such as core downtown, exurban areas that sit on the fringes of a metropolitan area, rural village, and small towns (American Planning Association, 2017). Special streetscape characteristics such as urban forests or access to alternative transportation options are elements that are primarily found in urban cities. As a result, studies that exclusively examine segment data belonging to metropolises may not necessarily produce results that accurately depict the walking environment of cities located in additional geographical settings.

This study provides valuable information on the walking environment to municipalities, policymakers, and even to urban planners. As city leaders begin looking for ways to improve the obesity rates in their local jurisdictions, they can now look to their surrounding built environment to offer potential solutions. While more research is still needed, the significance demonstrated by the conclusions of this study, mainly between specific streetscape characteristics and the reduction of sedentary, could help to guide local governments. The positive benefits of forging sustainable, walkable communities are undeniable and can be treated by municipalities as public health intervention approaches to positively impacting community health related outcomes.

Conclusions

This study analyzes several independent features of the built environment as related to physical activity, all the while utilizing GIS technology to display the walkability pattern results of the surrounding Atlanta Beltline study area. Findings from past research show that a neighborhood's density level, connectivity, and land use type are the most influential environmental features to impacting walking and cycling rates (Community Preventive Services Task Force, 2017). The conclusions of this study further support and strengthen findings of previous walkability research studies.

This capstone shows that the presence of sidewalks, bus stops, and light fixtures, may all potentially act as facilitators for physical activity, at least as it pertains to the Atlanta Beltline study area. Interestingly, this study's conclusions on vacant buildings/broken windows and ways in which they relate to physical activity, actually contradict findings of past research (Garvin, E., et al., 2.013). Segments that had buildings/broken windows present did not exhibit a lower frequency of active people as initially anticipated by the author. This can be attributed to the individual's reason for travel and consequential route choice. If a person's activity is due to purposeful travel rather than for recreation, the route utilized will most likely be out of necessity (i.e. shortest distance) rather than for leisure. Similarly, this may also explain the decreased activity prevalence that was observed along Beltline segments equipped with trees that could offer shade. Having a lower prevalence of activity along tree-segments may be due to the initial purpose of travel, making certain routes just unavoidable. Even at the depressed level of walking along tree-equipped segments, this study saw higher levels of walking along routes tied to "purposeful travel." Because segments with bus stops had the highest prevalence rates of active people, the author of this study believes that bus stops facilitate activity, particularly for people that are active due to purposeful travel.

Optimizing walkability modeling can be especially difficult when attempting to quantify how conducive any given community's built environment is towards facilitating physical activity. This study is based on existing literature and theoretical frameworks with the intent to better understand how the associations between certain aspects of the built environment, the perception of safety, and physical activity all work in shaping human health. As researchers and policymakers continue committing to decreasing obesity and making our communities more walkable and healthier places for future generations, public health workers will be vital for ensuring additional research in this field. Today, more than ever, there is a pressing need for collective action to include the built environment in health interventions. Urban planners, public health professionals, and policymakers will need to work together to resolve the ever-growing obesity epidemic across the United States and to create the footprint for sustainable and healthy communities for future generations to come.

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APPENDICES

Appendix 1: Variables in the Spatiophysical Aspects of Walking and Bicycling (Moudon and Lee 2003)

From the table below, 'presence of sidewalk' was the roadway variable included in the walkability analysis of this capstone.

General Category	Variable Name	Data Source/Type
Roadway characteristics		
General	Condition of road; typical section attributes; intersection geometry	Composite
	Road width; roadway alignment	DOT, local GIS
	Roadway character, improvements, and environment	Composite
	Visibility	Field
Street or road segments	Length of segment under consideration for improvement	DOT, field
	Number of links in grade-separated system	Field
	Intersection; midblock	DOT, local GIS
	Midblock	DOT, local GIS
Vehicle lanes	Number of lanes; total number of through lanes; center turn lane	DOT
	Presence and width of shoulder or bike lane	Field
	Number of turn lanes; direction(s) of traffic flow	DOT
Outside lanes	Outside lane width	Field
	Usable width of outside through lane	Field
Bicycle lanes	Presence of bicycle lane/paved shoulder	DOT, local GIS
	Width of bicycle lane/paved shoulder	Field
On-street parking	Off-street parking spaces with unrestricted access per household	Field
	Parking lane; presence of on-street parking	Field
Paths	Path type	Field, local GIS
	Path width	Field
Vehicular access	Uncontrolled vehicular access, such as driveways or on-street parking spaces	Field, local GIS
Transit service	Frequent transit stop	Transit agencies
	Transit corridor	Local GIS
Bus service	Bus stops	Transit agencies, local GIS
Curbs	Curb cuts, ramp, type, and lane width (same as outside lane)	Field
	Driveways or curb cuts; driveway and side streets	Field
Slope	Sloping terrain; intersection	GIS
Barriers	Presence of barrier-free facility; obstructions	Field
	Presence of barriers within the buffer area (usually trees)	Field
Crossings	Crossing aides; opportunities, and width	Field
	Ease of street crossing (several variables within)	Composite
	Flashing crosswalk lighting; intersection markings	Field
	Marked crosswalks (signalized)	DOT, field
	Marked crosswalks (not signalized); marked midblock crosswalks	Field
	Marking/intersection markings	Field
	Types of crossings; unmarked crosswalks	Field
Median	Presence of median	DOT
Signalization	Frequency of signalization	Composite
	Signal phase; stop sign frequency; traffic control devices	Field
Pedestrian signalization	Pedestrian signal delay length	Field
	Pedestrian supportive signalization	Field
	Push button	Field
Sidewalks	Presence of sidewalk	Local GIS, field
Surface	Path condition, smoothness and material	Field
	Pavement factor	Composite
	Street surface	Field
	Surface condition, quality, and type	Field
Environment along roadway		
Buildings	Architecture (local)	Field
	Building features and frontage	Field
	Roadside development; garden maintenance	Field
Lighting	Lighting	Field
	Lighting (street)	Field
	Lighting (pedestrian scale)	Field
Litter	Maintenance; litter	Field
Bicycle parking	Parking for bicycles	Field

General Category	Variable Name	Data Source/Type
Sidewalks	Buffer between cars and pedestrians	Field
	Distance between curb and sidewalk	Field
	Path location; sidewalk width	Field
Street furniture	Benches; furniture (street)	Field
Trees	Trees (shade tree)	Field
	Trees (street tree)	Field
Network		
General characteristics	Connectivity; continuity	Composite
	Other routes available; parallel alternative facility	Composite
Sidewalk networks	Extent of sidewalk network; sidewalk continuity	Composite
Network density	Fineness of grid, distance between intersections	Composite
	Street intersection density	Composite
Access	Access to bicycle facility	Field
O/D accessibility	Actual distance/minimum distance	Local GIS
	Actual distance in time/direct distance in time	Composite
	Actual distance/direct distance	Composite
	Distance between origin and destination via alternative network	Composite
	Distance to elementary school, high school, middle school, and work	Local GIS
	Minimum distance between O/D pair along grade-separated system	Field
	Minimum distance between O/D pair at street level	Local GIS
	Total number of O/D pairs in subnetwork	Local GIS
	Travel distance range from generator or attractor	Local GIS
	Travel route distance on formal pedestrian infrastructure	Local GIS
	Travel route distance on informal pedestrian infrastructure	Field
Area		
Density/intensity	Actual development on the ground: development, streets, freeways, rivers	Local GIS
	Floor area of specific land use at destination	Local GIS
	Housing density, employment, and population density	Census, local GIS
	Intensity of adjacent land uses	Local GIS
Market area	Absolute number of residents or employees within a walkable area	Census, local GIS
Land use type	Connective tissue	Composite
	Destinations; land use types	Local GIS
	Zoning categories and related capacity	Local GIS
Land uses linked by travel	Functional complementarity of land uses	Composite
	Specific land uses that are linked by pedestrian travel	Composite
Proximity	Proximity of residential and nonresidential land uses	Composite
	Spatial complementarity of land uses	Composite
Urban form	Block size	Census, local GIS
	Average parcel size	Local GIS
Land use as travel generator	Average trip generation of attractor or generator	Standard
	Number of generators or attractors on travel distance range	Local GIS
	Number of generators or attractors per trip purpose	Local GIS
	Trip generation intensity of local land use	Standard

Source: Moudon, A., & Lee, C. (2003). Walking and bicycling: an evaluation of environmental audit instruments. American Journal Of Health Promotion, 18(1), 21-37.

Appendix 2: Variables in the Spatiopsychosocial Aspects of Walking and Bicycling (Moudon and Lee 2003)

From the table below, 'sense of security; good lighting' was the variable included in the walkability analysis of this capstone.

Variables in the Spatiopsychosocial Aspects of Walking and Bicycling

General Category	Variable Name	Data Source/Type
Perception		
Bicycling	Attractiveness for cycling	All survey type data
	Bicyclist experience level	
	Bicyclist characteristic (skill levels)	
	Difficulty for cycling	
	Driver behavior	
	Ease of biking	
	Safe places to bike	
	Roadway share with motor vehicles	
	Safety of bicycling	
	Surface quality	
	Street intersection condition	
Driving	Unrestricted sight distance	
	Visibility from nearby buildings	
Walking	Attractiveness for walking	
	Ease of walking	
	Pleasantness of walking	
	Perception of attractiveness	
	Perception of comfort	
	Perception of convenience	
	Perception of safety	
	Perception of security	
	Perception of system coherence	
	Perception of system continuity	
	Room to walk safely	
	Sense of security; good lighting; clear sight lines	
	Types of views	
	Women's rating of neighborhood safety	
Walking and bicycling	Easiness of following safety rules	
	Ease of street crossing	
	Number of neighborhood "places of significance" named by average respondent	

Source: Moudon, A., & Lee, C. (2003). Walking and bicycling: an evaluation of environmental audit instruments. American Journal Of Health Promotion, 18(1), 21-37.

Appendix 3: Atlanta Beltline Neighborhood Audit Tool

BELTLINE NEIGHBORHOOD AUDIT TOOL	Date:	Start Time:
	Street Name:	
	Segment ID:	

1. Ramps, curb cuts or mountable curbs at the start of the segment? _____ **No** _____ **Yes**

SIGNAGE/LANDMARKS

2. What **types of signs** are visible in this segment?
   - _____ Social/entertainment activities
   - _____ "Share the road"/pedestrian/bicyclist friendly signs?
   - _____ Stop or yield sign?
   - _____ No parking signs?
   - _____ Neighborhood/crime watch/ Security warning sign /No trespassing/beware of dog
   - _____ Unhealthy: Tobacco or alcohol/Fast Food sign
   - _____ Healthy: Physical activity billboard/sign/athletic event
   - _____ Beltline signage
   - _____ For sale/rent signs
   - _____ Signs in other languages?
   - _____ Directional aid marker/Advance street sign
   - _____ Neighborhood flag or sign
   - _____ Landmark (statute, fountain)
   - _____ Kiosk: Information/board with map/you are here

15. This segment has a posted **speed limit** of: _____ Enter "99" for "None posted."

SOCIAL ENVIRONMENT

3. How many **people** are visible in this segment?	None	Few/Some (1-6)	A Lot (>7)
A. People visible?	_____	_____	_____
B. Active people [e.g., playing a sport, running, climbing, walking, biking]?	_____	_____	_____
C. People stopping to talk or greet one another?	_____	_____	_____
D. People fighting, acting hostile or threatening?	_____	_____	_____
E. Stray dogs or animals in the segment (i.e., not squirrels or rabbits)?	_____	_____	_____

4. What **types of destinations** are visible in this segment? (select all that apply)
   - _____ A. Parking lot or parking garage (i.e., any size not including on-street parking)?
   - _____ B. Building or property under construction?
   - _____ C. Railroad, bridge, tunnel, highway, or overpass?

TRANSPORTATION ENVIRONMENT

5. Presence of Sidewalk? _____ **No** _____ **Yes** If **YES**: _____ Presence of Buffer _____ Continuous

6. Sidewalk Width: **0 – 3 ft** _____ **> 3 - > 6 ft** _____ **> 6 ft** _____

7.	None	Few/Some	A lot
A. **Levelness and condition of sidewalk** (heaves, cracks, broken sections, weeds)?	_____	_____	_____
B. **Obstructions** (i.e., artificial – cars, trash cans; natural – trees, bushes, rocks)?	_____	_____	_____

8. How would you rate the **bikability** of this **segment**? (select all that apply)
   - _____ A. Presence of marked bike lane, protected bike lane, or marked shoulder? If **YES**: _____ Continuous
   - _____ B. Presence of "sharrows"?

9. Presence of Bike Racks? _____ **No** _____ **Yes**

10.	None	Few/Some	A lot
A. **Levelness and condition of bike lane** (heaves, cracks, broken sections, weeds)?	_____	_____	_____
B. **Obstructions** (i.e., artificial – cars, trash cans; natural – trees, bushes, rocks)?	_____	_____	_____

11. **Availability of transit** for this segment:
    - _____ Presence of Bus Stop — If **YES**: _____ Bench or Covered Shelter
    - _____ Presence of Other Transit — _____ Handicap accessible

12. Presence of path or trail (i.e., non-concrete multi-use, biking, walking route)? _____ **No** _____ **Yes**

13. Path or Trail Width: **0 – 3 ft** _____ **> 3 - > 6 ft** _____ **> 6 ft** _____ If **YES**: _____ Marked for Multi Use?

14.	None	Few/Some	A lot
A. **Levelness and condition of trail** (i.e., alignment, cracks, broken sections, weeds)	_____	_____	_____
B. **Obstructions** (i.e., artificial – cars, trash cans – or natural – trees, bushes, rocks)	_____	_____	_____

STREET CHARACTERISTICS

16. Street Type:	Divided ≥ 4 lanes	Undivided ≥ 4 lanes	2 marked lanes	No marked lanes	One way	Other
	_____	_____	_____	_____	_____	_____

- _____ A. **Street design characteristics or traffic calming devices** to reduce volume or speed (e.g., roundabouts, narrow lanes, street closures, speed humps, traffic signals, diverter, street trees)?
- _____ B. **Crossing aids** for pedestrians and bicyclists to cross the street safely. (e.g., crosswalks, stop light, overpass, traffic island, curb extension)
- _____ C. **Street lighting fixtures** on your side of the segment?

FACILITIES

17. What **types of recreational equipment** are visible in this segment?
    - _____ A. Playground equipment (e.g., swings, slide)
    - _____ B. Sports equipment (i.e., all necessary elements are visible – posts, nets, etc.)

18. **Other Amenities (Check all that apply)**
    - _____ Bench/street furniture (non-bus stop)
    - _____ Trees that could offer shade
    - _____ Call boxes
    - _____ Handrails on stairs and ramps
    - _____ Covered shelter (non-bus stop)
    - _____ Drinking fountains
    - _____ Public Restrooms
    - _____ Trash bins

19. People can be seen when walking (windows/places for sitting facing street): _____ **No** _____ **Yes**

AESTHETICS

20. Are at least 75% of the buildings well maintained? _____ **No** _____ **Yes** _____ **No Buildings**

21. **Which of the following items are present?**
    - _____ Abandoned cars
    - _____ Broken/boarded windows/vacant buildings/houses
    - _____ **Incivilities**: Drug paraphernalia/broken glass, liquor bottles, cans, litter in yards/on sidewalk, Graffiti (not murals)

22. Noise pollution audible in this segment (e.g., loud traffic, trains, construction, factories)? _____ **No** _____ **Yes**

23. Ramps, curb cuts or mountable curbs at the end of the segment? _____ **No** _____ **Yes**

GENERAL COMMENTS:

Source: Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. Walkability Data of Communities around the Atlanta Beltline (2016).

Appendix 4: GIS Key for the Atlanta Beltline Study's Shapefiles

Shapefile	Source
Study Area	GRASP
Outside50per	GRASP
StreetSegments_v2	TomTom/GRASP
BeltlineCorridor	Beltline

QuarterMileGrild	GRASP

Source: Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. Walkability Data of Communities around the Atlanta Beltline (2016).

Appendix 5: The 'Select by Attribute' Command Scripts used for GIS Analysis

Segment Indicators	Select by Attribute Script/Conditions
Active Segments	"Q9_2" = 1 OR "Q9_2" = 2
Sidewalk Along Segment	"Q11" = 1
Light Fixtures Along Segments	"Q27_4" = 1
Active Segments with Sidewalks	"Q9_2" = 1 OR "Q9_2" = 2 AND "Q11" = 1
Active Segments with Light Fixtures	"Q9_2" = 1 OR "Q9_2" = 2 AND "Q27_4" = 1
Segments with "broken/boarded windows/vacant buildings/houses"	"Q32_2" = 1
Active Segments with "broken/boarded windows/vacant buildings/houses"	"Q9_2" = 1 OR "Q9_2" = 2 AND "Q32_2" = 1
Segments with trees that could offer shade	"Q29_8" = 1
Active segments with trees that could offer shade	"Q9_2" = 1 OR "Q9_2" = 2 AND "Q29_8" = 1
Segments with Bus-Stops Present	"Q19" = 1
Active Segments with Bus-Stops	"Q9_2" = 1 OR "Q9_2" = 2 AND "Q19" = 1

Appendix 6: Descriptive Analysis Results for Beltline Segment Attributes

Variable Name	Number of Segments	Percent of Segments
Active segments	**468**	---
Active with sidewalks	395	84.40%
Active with light fixture	273	58.33%
Active with broken/boarded windows/homes	171	36.53%
Segments with sidewalks	**1889**	---
Active Sidewalks	395	20.91%
Sidewalks with lights	1031	54.57%
Sidewalks with broken/boarded windows/homes	594	31.44%
Segments with a light fixture	**1389**	---
Active and lights	273	19.78%
Lights and sidewalk	1031	74.22%
Lights and broken/boarded windows/homes	393	28.29%
Segments with broken/boarded windows/homes	**806**	---
Active segments with broken/boarded windows/homes	171	21.21%
Broken and with a light fixture	393	48.75%
broken/boarded windows/homes and a sidewalk	594	73.69%
Segments with trees	**1584**	---
Trees and active	285	17.99%
Trees and light fixture	737	46.52%
Trees and broken/boarded windows/homes	470	29.67%
Segments with Bus-Stop	**307**	---

Bus-stop and active	81	26.38%
Bus-stop and sidewalk segments	288	93.81%
Bus-stop and broken/boarded windows/homes	84	27.36%
Bus-stop and light fixture	188	61.12%