Developing an Active Transportation Assessment Scorecard for Rural and Suburban Communities

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of Master of Science

Auburn, Alabama
May 5, 2023

Keywords: active transportation, walk audit, rural,
assessment, community, perception

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Abstract

In recent years, many communities have begun to focus on creating spaces for walking and bicycling throughout their localities to reduce congestion, improve public health, and promote economic growth. However, rural and suburban communities often find it difficult to select and fund active transportation, especially since many resources designed to support this effort cater to urban areas and are complex. In order to mitigate the gap in resources, this thesis creates an Active Transportation Assessment Scorecard designed specifically for rural and suburban communities. This scorecard allows communities to quantify how well local residents will feel about active transportation on that roadway segment, based on data collected from video-based user perception surveys. Twenty-five segments in Alabama were video-recorded and evaluated for analysis, each with a variety of active transportation amenities and infrastructure conditions. Additional built environment data was collected for each location as well. An ordinal probit regression was used to for analysis and resulted in the creation of five models that predict segment user perceptions. This tool will be used to support many communities in Alabama.

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List of Abbreviations

AT Active transportation

PA Physical activity

BE Built environment

LOS Level of Service

PLOS Pedestrian level of service

BLOS Bicyclist Level of Service

FHWA Federal Highway Administration

RSA Road Safety Audits

DOT Department of Transportation

AL Alabama

Chapter 1: Introduction

Active transportation (AT) is a term used to define non-motorized transportation or travel utilizing “human energy” (*1*). The infrastructure supporting AT encompasses pedestrians and bicyclist networks and occasionally public transit access as well (*2*). Often, to help visualize ideal roadways that support AT, the example of Complete Streets is used. Complete Streets is a policy that supports creating roadways that are safe for all users (*3*). Types of Complete Street treatments that support AT include bicycle lanes, sidewalks, crosswalks, and buffers, though these specific treatments may not apply to every roadway. Many studies have shown that AT participation can be influenced by factors other than roadway condition and infrastructure, including social behavior, and human perception (*4–15*). Additionally, AT is commonly connected to walkability and placemaking (i.e. theories that highlight user interaction through people-place relationships, planning techniques, mixed use facilities, and spatial aesthetics) (*16–19*).

Over the past decade, AT has seen a dramatic increase in federal, academic, and local attention. The Surgeon General’s Call to Action on promoting walkable communities (*20*) is just one example of AT support on the federal level. Guidelines, initiatives, and other educational tools have been introduced by federal entities and other organizations to support pedestrians and bicyclists. Notable examples include: Roadway Safety Audits (RSA), a program that supports AT through safety guidelines for road users (*21*); Vision Zero, a campaign aiming to eliminate traffic deaths and injuries for all road users (*22*); Rails to Trails, an organization aims to create and connect trail networks using the rail-trail movement (*23*); and, as mentioned previously, Complete Streets. Many communities have adopted these initiatives and campaigns to better their localities (*24*, *25*). The Infrastructure Investment and Jobs Act (IIJA) provides competitive funding for planning and constructing projects that create or connect AT infrastructure (*26*). On the academic level, AT was shown to be an emerging trend of research in the transportation sciences (*27*, *28*). Research of AT spans topics of health, safety, and demographics including different age groups, from analyzing safe routes to school, youth perception, impact on health of working adults, to elderly access of health resources (*29–34*).

This awareness and appreciation for AT stems from its many benefits, beginning with its potential to systemically impact community health. The rise of chronic diseases, including obesity rates (*8*, *35*), has increased attention on community health and large-scale measures of well-being. In response to the concerns brought by this epidemic, increasing opportunities for physical activity (PA) through active travel has been a major goal for communities nationwide. Physical activity is defined as bodily movement that causes metabolic need or physical effort (*36*). Many health impact assessments have noted that active transportation has substantial benefits for communities through increasing physical activity levels (*12*, *37–39*). Studies have also shown that increased weekly participation in AT showed a decrease in risk for cardiovascular diseases including hypertension, diabetes, and obesity (*40*). Establishing routine physical activity is known to have immediate benefits for cognitive health and long-term benefits like weight management and decreasing the risk of disease (*41–43*). Additionally, inactivity has been tied to contribute to health care costs (*44*).

Pedestrian and bicyclist safety is another benefit of AT (*45*, *46*). Safety is a concern for many communities as pedestrian and bicyclist yearly fatalities have been increasing over the past decade (*47*). According to the National Highway Traffic Safety Administration, pedestrian, bicyclist, and nonoccupant fatalities made up 20% of the overall traffic fatalities in 2020, the third-highest percentage (*48*). The national pedestrian fatality ratio per 100,000 population is

1.98 though the state of Alabama has a ratio of 2.05, ranking at 18 for the states with the highest fatality to 1000,00 population ratios in the United States (*49*). Data analyzed by FARS and NASS show that the age group 50-59 have the highest fatality rates for pedestrian and bicyclist (*50*). Improving safety for AT users has been suggested to increase the likelihood of choosing AT modes (*51*). Utilizing AT practices may not only decrease traffic related fatalities and injuries but also encourage more individuals to choose AT as a way of travel.

Additionally, AT can potentially create equitable opportunities in many communities (*52*), and especially in rural areas (*53*). Since active transportation is commonly perceived as an urban characteristic, rural areas are often overlooked when it comes to research and implementation, although rural areas typically have higher obesity rates than urban areas (*54*). Additionally, though only 20% of the US population lives in rural areas (*55*), 18% of AT fatalities happened in rural areas (*56*). Rural areas have different challenges than urban areas due to lower population density, longer distance between destinations, and demand of AT differences (*53*, *57–59*).

Implementation and improvement of AT facilities in all communities usually requires an assessment of the existing environment in order to determine factors that inhibit safety and dictate where the most need is (*60*). As a result, the past decade has seen the development of many assessment tools documenting conditions of roadway characteristics, AT behavior, land uses, and user perceptions of these factors. These assessment tools often describe specific segments/streets or a large neighborhood/network. Assessment tools vary to suit different stakeholders (e.g., user friendly community tools to highly technical professional guidelines), and will be discussed in greater detail in the following chapter.

Though numerous assessment tools exist, the majority focus on urban characteristics and miss nuances specific to rural communities (*53*, *57*, *61*). Because there are such differences between rural and urban areas, it has been noted that tools that specifically target rural areas are needed (*62*). Practitioners seek more research to better characterize AT in rural communities, specifically the built environment (BE) variables that influence AT use in nonurban areas (*61*). BE is defined as the man-made spaces and structures of the environment (*63*). Culture and existing institutions in rural communities have to be considered as they are an integral part of policy and change in small communities (*53*, *62*, *64*). Public support and resource limitations are common challenges for rural areas. This includes safety concerns, municipal inclination, limited staff, and funding (*64*, *65*). Another challenge is the complexity of assessment tools. This complexity often arises from the amount documentation needed, along with the time and manpower to collect the data, and complicated scoring processes. Combined, these challenges make it difficult for rural communities to accurately assess their localities and implement AT infrastructure.

In response to the challenges presented, the purpose of this research was to create a user-friendly active transportation assessment tool focused on rural perceptions of the built environment. The objectives of research are as follows:

1. Develop and collect a video-based environment assessment survey.
2. Estimate 5 ordinal probit regression models to determine the most significant factors that influence rural resident perspectives on (a) pedestrian safety from vehicle traffic, (b) bicyclist safety from vehicle traffic, (c) segment support of physical activity, (d) segment support for children and strollers, and (e) segment support for older pedestrians.

3. Create the user-friendly active transportation assessment scorecard.

This research highlighted the unique characteristics of rural communities by documenting perception of built environment and roadway elements. The estimated models linking built environment and user perspectives hope to simplify the assessment process by only including significant factors. Ultimately, the assessment tool hopes to instruct, educate, and simplify the assessment process to support rural communities.

The rest of this thesis is organized as follows: Chapter 2 comprises of a literature review of factors affecting AT, techniques used to measure AT, and existing AT assessment tools with analyses of complexity and community context. Chapter 3 shows the steps taken to complete objective 1 including segment location selection, data collection, survey creation, survey collection, and data collection summaries. Chapter 4 follows the steps taken to complete objective 2, including the data analysis process, results of analysis, and discussion of findings. Chapter 5 summarizes the assessment scorecard and how individuals may use it. Chapter 6 includes the conclusion, and further research recommendations. Additionally, this section presents objective 3, the creation of an AT assessment scorecard to support the application of the five estimated models in small communities.

Chapter 2: Literature Review

In developing an AT assessment tool specific to small and medium-sized communities, it is important to consider the wealth of knowledge already available on the topic. This literature review included an extensive review of the state of the practice on assessments from across the world. This chapter is organized in two parts. First, 53 different assessments are cataloged and summarized. Trends are identified and the need for easy-to-implement small and medium-sized community assessments is identified. Second, trends in the most important built environment factors influencing AT are summarized from the 53 different assessments.

2.1 Cataloging the State of the Practice

Singh and Jain 2011 characterize assessment indicators into two classes: (1) characteristic-based methods (i.e. questionnaire-type assessments describing perception and environmental factors) and (2) capacity-based methods (i.e. level of service (LOS)-type assessments using highway capacity models calibrated for active transportation infrastructure) (*66*). LOS stands for level of service and is defined as the capacity of a roadway to support quality of service through qualitative measures like maneuverability, travel time, safety, and comfort (*67*). The goal for both assessment methods is to call attention to areas with AT needs in order to implement change. However, questionnaires tend to be catered towards involving community members and enhancing the educational experience.

The in-person segment questionnaire is a common tool used in the planning profession and is often called a walking audit. This type of AT measurement method consists of a group of stakeholders walking the route or segment and documenting segment characteristics and user perceptions. While there is no formal format for questionnaires, they generally consist of two parts: (a) an educational and instructional support section and (b) a data collection section. The first part sets up the scope of the tool, the capability, the factors included, and the outcome of the questionnaire. This section is usually supported by definitions of general terminology and descriptions of each factor. Segment questionnaires may contain facilitator's guides and other preparatory materials. The second part is commonly structured as a checklist and describes factors that document the existing condition of the area. Questionnaires may also give ratings of the segment or area assessed, although this is not a requirement. The existing questionnaire tools measure AT by highlighting areas of need. These tools are often only documentation activities to bring light to BE characteristics that cause harm or discomfort.

Alternatively, LOS assessments are equations designed to use the data from a questionnaire to quantitatively show the perceived functionality of traffic flow by assessing amenities and utilities, often based on the principles of the Highway Capacity Manual (*67–69*). LOS calculations include BE characteristics and behaviors (i.e., user flow, daily traffic values) and estimate quantitative ratings. These calculations are often highly technical and require concepts commonly used in transportation engineering to describe vehicle behavior. Some of the most common LOS assessments include the pedestrian level of service (PLOS) and bicycling level of service (BLOS) as well (95). LOS is determined with thresholds A to F which are specific to each equation. With LOS A being the best, roadways with low average delays and low encounters, and LOS F being the worst. To determine PLOS, a PLOS score is calculated, and the value is either immediately linked to a PLOS (i.e., A-F) or the score is cross-referenced with average pedestrian space to determine PLOS. BLOS is determined by calculating a LOS score with the equations and liking the value to a BLOS through given thresholds.

Additionally, it is important to acknowledge that many assessments also act as guidelines, or a document describing best practices for implementation. For example, Pedestrian Road

Safety Audit Guidelines and Prompt Lists (*70*) and Bicycle Road Safety Audit Guidelines and Prompt Lists (*71*) are extensive documents that define each factor included in the assessment. These tools, created by RSA, highlight the safety aspects of the physical environment. Though these tools have similar factors to LOS tools, these guides do not have a scoring capability.

Table 2.1 presents the state of the practice for current questionnaire and LOS assessment tools. This table includes 53 assessment tools: 34 questionnaires and 19 LOS. Each assessment was characterized by a series of attributes including: 'technical rating', ease of implementation; 'assessment type', questionnaire or LOS; 'issued location', where the tool was first published (33 are from the US); 'source', whether the tool was developed through a public agency or through peer-reviewed research; 'media type', how the tool is accessed through an online application or in print; 'community type', the location for which the tool was developed; 'assessment level', the intended geographic scale of the assessment; and 'built environment factors', all the types of factors included in the assessment.

First, each assessment was given a subjective score based on technical rating, or how easy it was for a community member to implement the assessment, compared to the rest of the catalog. Scores ranged from 1 to 3, with 1 indicating the tool was reasonably easy for someone with no technical knowledge to implement (uncomplicated), 2 indicating that some technical knowledge was needed to implement (manageable), and 3 indicating extensive technical knowledge was needed to implement (complex). These designations were assigned based on years of experience working with and training coalitions on AT in rural communities.

The questionnaire-type tools represent a wide range of technical rating scores. For example, the Aspen Hills Vision Zero Walk Audit Checklist (*72*) is a 2-page tool that aims to document characteristics of all AT networks on the neighborhood level. The length and straight forward questions classified this tool with a rating of 1 or uncomplicated. The Pedestrians First tool (*73*) and Walk Audit Tool Kit (*74*) were ranked as complex due to the multipage assessment system. The Pedestrian First tool could be found both as a printout document and an application. The factors included could be hard to find for the average individual. The Active Neighborhood Checklist (*75*) however, was classified as manageable due to the types of questions and length of the tool. Tool length is important as it directly impacts the time needed to complete the assessment process. This in turn impacts tool completion and use.

Many LOS-type tools represent the higher end of the technical rating scores, which is not surprising due to the mathematical nature of these assessments. However, the Pedestrian Level of Service Tool (*76*) and the Australasian Pedestrian Crossing Facility tool (*77*) were rated manageable for two reasons. First, the application style of both tools made it so the user did not need to do the calculation (a benefit) but the data required for the factors was more involved and would require time to learn if one was unfamiliar (a negative).

Interestingly, AT assessment tools come from around the world: The Street Walkability Audit Tool for route CHoice analysis (SWATCH) (*78*), Walking Route Audit Tool (WRAT) (*79*), and Built Environment & Active Transportation (BEAT) (*80*) were published in Australia, Wales, and British Colombia respectively. Others come from India (*81–84*), Bangladesh (*85*), Malaysia (*86*), Greece (*87*), Belgium (*88*), Portugal (*89*), Japan (*90*), and Scotland (*91*).

There is a large disparity when it comes to the coverage of community type. Overall, the majority of assessment tools were catered towards urban infrastructure and urban communities, with 33 tools specifically designed to assess urban areas. Rural and suburban tool coverage were both less than half of the tools catering to urban areas. Most of the tools that contained rural and suburban assessments also contained urban factors. Only 2 tools catered specifically to rural areas; Rural Active Living Assessment Tools (*92*) and Community Health Quick Audit (*93*). This disparity, along with ease of use was analyzed to show the imbalance of tool coverage for rural areas and can be seen in Figure 2.1.

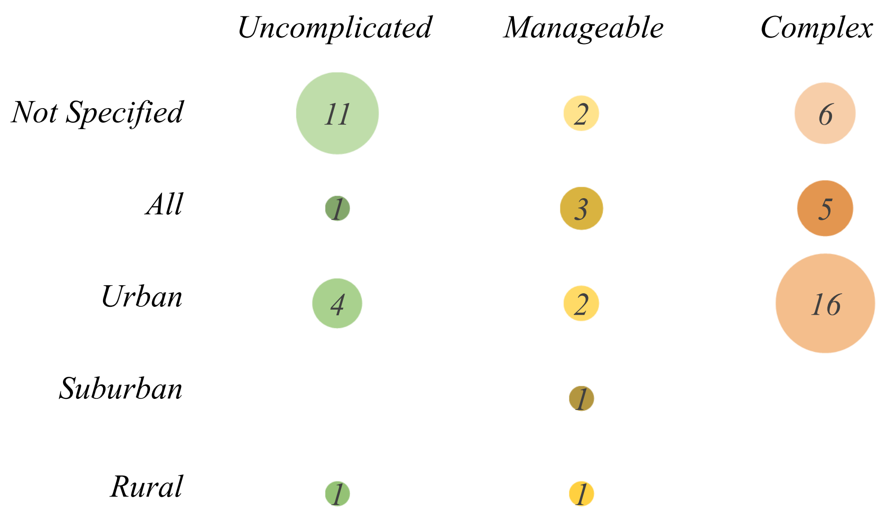


Figure 2.1 AT assessment tools based on community context and ease of use

Figure 2.1 shows a visualization of crosstabulation between community type (y-axis) and ease of use (x-axis). As seen from the table, tools that are urban and complex make up the majority of the tools collected with unspecified, uncomplicated tools following. The data presented above shows the need for more tools that cater to rural areas and are uncomplicated to a member of the general public. It is important to develop tools such as Rural Active Living Assessment Tools (*92*) to support communities in rural areas.

There is also meaningful variety in scale of evaluation. The scale ranged from segment to neighborhood to township or city. Some tools, "Defining a GIS-based Walkability Index" (*87*)addressed neighborhoods, while Pedestrian and Bicyclist Safety Guides (*94*, *95*) evaluate areas on a bigger scale, township or city. The LOS-type tools commonly focused on segment assessment with the idea to connect segment assessments to create an assessment of full networks. LOS tools also had fewer BE characteristics included in the assessment.

2.2 Factors Affecting Walkability and AT

The BE characteristics included in the table were based on the previous findings of influences on walkability and AT. Pedestrian, Bicyclist, and Transit columns identify the assessment tools that include each network. Healthy Streets Design Check (*117*) is a questionnaire tool that assesses all three networks, though not uncommon for questionnaires. LOS tools usually focus on one or two networks (i.e., PLOS, BLOS). However, two LOS tools are specifically designed to address multimodality, Multimodal Level of Service Analysis for Urban Streets: User Guide (*114*)and MultiModal Quality/ Level of Service Handbook (*115*). Additionally, Low-Stress Bicycling and Network Connectivity (*113*) also use influences from all three networks. Shared-Use Path Level of Service and PLOS and BLOS calculation Using HCM (*112*)includes both pedestrian and bicyclist networks in its analysis.

Table 2. 1 Existing AT Assessment Tools

Assessment Tools		Workplace Walkability Audit Tool	Rural Active Living Assessment Tools	Aspen Hills Vision Zero Study: Walk Audit Checklist	Pedestrians First: tools for a Walkable City	Walk Audit Tool Kit	Active Neighborhoods Checklist	Healthy and Complete Communities in Delaware: The Walkability Assessment Tool	Pedestrian Road Safety Audit Guidelines and Prompt Lists	Bicycle Road Safety Audit Guidelines And Prompt Lists
Reference		*(96)*	*(92)*	*(72)*	*(73)*	*(74)*	*(75)*	*(97)*	*(70)*	*(71)*
Technical Rating		1	1	1	3	3	2	3	3	3
Assessment Type	Questionnaire	✓	✓	✓	✓	✓	✓	✓	✓	✓
	LOS									
	Guideline								✓	✓
Issued	U. S	✓	✓	✓		✓	✓	✓	✓	✓
	International				✓					
Source	Public	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Research Paper	✓	✓							
Media Type	Printout	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Application				✓					
Community Type	Rural		✓							✓
	Urban	✓			✓			✓	✓	✓
	Suburban									✓
Assessment Level	Segment	✓	✓		✓	✓		✓	✓	✓
	Neighborhood		✓	✓	✓		✓	✓	✓	✓
	Town or City		✓		✓					
Built Environment Factors	Pedestrian Infrastructure	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Bicyclist Infrastructure		✓	✓	✓	✓			✓	✓
	Transit Infrastructure		✓	✓	✓	✓	✓	✓	✓	✓
	Road and Traffic Characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Connectivity	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Landscaping and Aesthetics	✓		✓	✓	✓	✓	✓	✓	✓
	Public Amenities and Furniture	✓		✓	✓	✓	✓	✓	✓	✓
	Accessibility and Disadvantage	✓		✓	✓	✓	✓	✓	✓	✓
	Comfort and Safety	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Destination and Land Use		✓		✓	✓	✓			

Table 2.1 (cont.) Existing AT Assessment Tools

Assessment Tools		Community Assessment Tool	Pedestrian Level of Service Assessment tool	M-NCPPC Pedestrian Audit Toolkit	Inclusive Walk Audit Facilitator's Guide	Active Transportation Planning Tool for Small- and Mid-Sized Communities	Pedestrian Safety Guide and Countermeasure Selection System	Bicycle Safety Guide and Countermeasure Selection System	Transportation Equity Audit Tool	Walkability Workbook
Reference		*(98)*	*(76)*	*(99)*	*(100)*	*(101)*	*(94)*	*(95)*	*(102)*	*(103)*
Technical Rating		1	2	1	1	2	2	2	2	2
Assessment Type	Questionnaire	✓	✓	✓	✓	✓	✓	✓	✓	✓
	LOS		✓							
	Guideline				✓	✓	✓	✓	✓	✓
Issued	U. S	✓		✓	✓	✓	✓	✓		✓
	International		✓							
Source	Public	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Research Paper									
Media Type	Printout	✓		✓	✓	✓	✓		✓	✓
	Application		✓			✓	✓	✓	✓	
Community Type	Rural					✓	✓	✓		✓
	Urban	✓					✓	✓	✓	✓
	Suburban	✓				✓	✓	✓		✓
Assessment Level	Segment	✓	✓		✓				✓	✓
	Neighborhood	✓		✓	✓	✓			✓	✓
	Town or City					✓	✓	✓	✓	
Built Environment Factors	Pedestrian Infrastructure	✓	✓	✓	✓	✓	✓		✓	✓
	Bicyclist Infrastructure	✓	✓			✓	✓	✓	✓	✓
	Transit Infrastructure	✓		✓		✓	✓	✓	✓	
	Road and Traffic Characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Connectivity	✓				✓	✓	✓		
	Landscaping and Aesthetics		✓	✓		✓	✓	✓		✓
	Public Amenities and Furniture		✓	✓		✓	✓	✓	✓	✓
	Accessibility and Disadvantage	✓		✓	✓	✓	✓	✓	✓	✓
	Comfort and Safety		✓	✓	✓	✓	✓	✓	✓	✓
	Destination and Land Use	✓	✓			✓	✓		✓	✓

Table 2.1 (cont.) Existing AT Assessment Tools

Assessment Tools		Community Assessment Tool	Bikeability Checklist	Walking Audit	8 80 City Walk Audit	Walking Route Audit Tool (WRAT)	Building A Bicycle Friendly America	Built Environment & Active Transportation (BEAT)	Place Standard Tool	Healthy Active by Design Master Checklist	Community Health Quick Audit	Walkability Checklist	PLOS and BLOS Calculation Using HCM
Reference		(*104*)	(*105*)	(*106*)	(*107*)	(*79*)	(*108*)	(*80*)	(*91*)	(*109*)	(*93*)	(*110*)	(*68*)
Technical Rating		3	1	1	1	1	1	1	1	1	2	1	3
Assessment Type	Questionnaire	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	LOS												✓
	Guideline								✓	✓			✓
Issued	U. S	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	International				✓								
Source	Public	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Research Paper	✓	✓										
Media Type	Printout	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Application				✓								
Community Type	Rural		✓							✓	✓		
	Urban	✓			✓			✓	✓	✓			
	Suburban									✓			
Assessment Level	Segment	✓	✓		✓	✓		✓	✓	✓		✓	✓
	Neighborhood		✓	✓	✓		✓	✓	✓	✓		✓	
	Town or City		✓		✓						✓		
Built Environment Factors	Pedestrian Infrastructure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Bicyclist Infrastructure		✓	✓	✓	✓			✓	✓	✓		✓
	Transit Infrastructure		✓	✓	✓	✓	✓	✓	✓	✓			
	Road and Traffic Characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Connectivity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Landscaping and Aesthetics	✓		✓	✓	✓	✓	✓	✓	✓		✓	
	Public Amenities and Furniture	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Accessibility and Disadvantage	✓		✓	✓	✓	✓	✓	✓	✓		✓	
	Comfort and Safety	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
	Destination and Land Use		✓		✓	✓	✓				✓		

Table 2.1 (cont.) Existing AT Assessment Tools

Assessment Tools		Australasian Pedestrian Crossing Facility	National Walkability Index	Shared-Use Path Level of Service	Low-Stress Bicycling and Network Connectivity	Multimodal Level of Service Analysis for Urban Streets: User Guide	MultiModal Quality/ Level of Service Handbook	Development of the Bicycle Compatability Index (BCI): A Level of Service Concept Final Report	Healthy Streets Design Check	Street Walkability Audit Tool for route CHoice analysis' (SWATCH)
Reference		*(77)*	*(111)*	*(112)*	*(113)*	*(114)*	*(115)*	*(116)*	*(117)*	*(78)*
Technical Rating		1	3	3	3	3	3	3	2	3
Assessment Type	Questionnaire									✓
	LOS	✓	✓	✓	✓	✓	✓	✓	✓	
	Guideline		✓			✓	✓			
Issued	U.S		✓	✓	✓	✓	✓	✓		
	International	✓							✓	✓
Source	Public	✓	✓	✓	✓	✓	✓	✓	✓	
	Research Paper									✓
Media Type	Printout		✓	✓	✓	✓	✓			✓
	Application	✓							✓	
Community Type	Rural		✓				✓			
	Urban		✓		✓	✓	✓	✓	✓	✓
	Suburban		✓				✓	✓		
Assessment Level	Segment	✓		✓	✓	✓	✓	✓	✓	✓
	Neighborhood		✓	✓	✓		✓			
	Town or City		✓		✓					
Built Environment Factors	Pedestrian Infrastructure	✓		✓	✓	✓	✓		✓	✓
	Bicyclist Infrastructure			✓	✓	✓	✓	✓	✓	
	Transit Infrastructure		✓		✓	✓	✓		✓	✓
	Road and Traffic Characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Connectivity				✓	✓	✓			✓
	Landscaping and Aesthetics						✓		✓	✓
	Public Amenities and Furniture								✓	✓
	Accessibility and Disadvantage					✓			✓	
	Comfort and Safety				✓	✓	✓			✓
	Destination and Land Use			✓	✓		✓	✓		✓

Table 2.1 (cont.) Existing AT Assessment Tools

Assessment Tools		Pedestrian Environmental Data Scan (PEDS)	A New Method for Evaluation of Level of Service in Pedestrian Facilities	Development and validation of automated microscale walkability audit method	What matters when it comes to "Walk and the city"? Defining a weighted GIS-based walkability index	Indicators of Accessibility and Attractiveness of Pedestrian Environments (IAAPE)	Global Walkability Index	A behavioral modeling approach to bicycle level of service
Reference		*(118)*	*(90)*	*(119)*	*(87)*	*(89)*	*(120)*	*(121)*
Technical Rating		1	3	3	3	3	3	3
Assessment Type	Questionnaire	✓		✓	✓	✓	✓	
	LOS		✓					✓
	Guideline							
Issued	U. S	✓		✓			✓	✓
	International		✓		✓	✓		
Source	Public							
	Research Paper	✓	✓	✓	✓	✓	✓	✓
Media Type	Printout	✓		✓	✓	✓		✓
	Application							
Community Type	Rural	✓						✓
	Urban	✓	✓	✓		✓	✓	✓
	Suburban	✓						✓
Assessment Level	Segment	✓	✓	✓		✓		✓
	Neighborhood				✓	✓	✓	
	Town or City					✓	✓	
Built Environment Factors	Pedestrian Infrastructure	✓	✓	✓	✓	✓	✓	
	Bicyclist Infrastructure	✓		✓			✓	✓
	Transit Infrastructure	✓		✓				
	Road and Traffic Characteristics	✓		✓			✓	✓
	Connectivity	✓			✓	✓		
	Landscaping and Aesthetics	✓	✓	✓			✓	
	Public Amenities and Furniture	✓		✓		✓	✓	
	Accessibility and Disadvantage			✓		✓	✓	
	Comfort and Safety		✓	✓		✓	✓	✓
	Destination and Land Use				✓	✓	✓	

Table 2.1 (cont.) Existing AT Assessment Tools

Assessment Tools		Development of a bicycle level of service model for urban street segments in mid-sized cities carrying heterogeneous traffic: A functional networks approach	Pedestrian Facilities and Perceived Pedestrian Level of Service (PLOS): A Case Study of Chittagong Metropolitan Area, Bangladesh	A pedestrian level of service method for evaluating and promoting walking facilities on campus streets	Modelling Perceived Pedestrian Level of Service of Sidewalks: A Structural Equation Approach
Reference		(*81*)	(*85*)	(*86*)	(*82*)
Technical Rating		3	3	3	3
Assessment Type	Questionnaire				
	LOS	✓	✓	✓	✓
	Guideline				
Issued	U.S				
	International	✓	✓	✓	✓
Source	Public				
	Research Paper	✓	✓	✓	✓
Media Type	Printout	✓			
	Application				
Community Type	Rural				
	Urban	✓		✓	
	Suburban				
Assessment Level	Segment		✓	✓	✓
	Neighborhood				
	Town or City				
Built Environment Factors	Pedestrian Infrastructure		✓	✓	✓
	Bicyclist Infrastructure	✓			
	Transit Infrastructure	✓	✓		✓
	Road and Traffic Characteristics	✓	✓	✓	✓
	Connectivity				
	Landscaping and Aesthetics			✓	
	Public Amenities and Furniture		✓	✓	✓
	Accessibility and Disadvantage		✓	✓	✓
	Comfort and Safety		✓		
	Destination and Land Use	✓			

Table 2.1 (cont.) Existing AT Assessment Tools

Assessment Tools		A New Pedestrian Crossing Level of Service (PCLOS) Method for Promoting Safe Pedestrian Crossing in Urban Areas	Development of Pedestrian Level of Service Assessment Guidelines for Mixed Land Use Areas Considering Quality of Service Parameters	Evaluation of pedestrian crosswalk level of service (LOS) in perspective of type of land-use
Reference		(*88*)	(*83*)	(*84*)
Technical Rating		3	3	3
Assessment Type	Questionnaire			
	LOS	✓	✓	✓
	Guideline			
Issued	U.S			
	International	✓	✓	✓
Access	Public			
	Research Paper	✓	✓	✓
Media Type	Printout	✓	✓	✓
	Application			
Community Type	Rural			
	Urban	✓	✓	✓
	Suburban			
Assessment Level	Segment	✓	✓	✓
	Neighborhood			
	Town or City			
Built Environment Factors	Pedestrian Infrastructure	✓	✓	✓
	Bicyclist Infrastructure			
	Transit Infrastructure			
	Road and Traffic Characteristics	✓	✓	✓
	Connectivity			
	Landscaping and Aesthetics		✓	
	Public Amenities and Furniture	✓	✓	
	Accessibility and Disadvantage		✓	
	Comfort and Safety	✓		✓
	Destination and Land Use			✓

‘Road and Traffic’ is an attribute that identifies the use of factors that include roadway characteristics, vehicle behavior, and perception of the road and vehicles. This attribute was identified in tools 49 times, the most identifications of any attribute. The connectivity attribute identified tools that included continuity, driveway interruptions, and multimodal interconnectedness. Landscaping and Aesthetics identified tools that utilized factors that documented trees, shrubbery, visual permeability, and any factor describing aesthetics. Public amenities identified assessment tools that contained questions on lighting, roadway furniture, trashcan availability, the presence of public bathrooms, and so on. Accessibility highlighted the tools that specifically addressed ADA infrastructure design, the presence of ramps, infrastructure supporting the visually impaired, and disadvantaged groups. Comfort identified the tools that use factors about safety, perceived safety, and weather. Lastly, Destination highlights the tools that use land use, density, distance, and destinations.

AT is a complex system of different networks often sharing limited space with other modes of transportation. Within the AT system are many networks including pedestrian, bicyclist, and occasionally transit. Along with AT networks, other modes of transportation, like vehicle and rail, interact and intersect, all impacting one another. The combination of many networks can often feel overwhelming to any road user especially if there is not a space specifically allocated to your mode choice. This situation is commonly seen for AT users (*122*). Built environment, vehicle behavior, crossing the road, and many other factors impact AT and influence pedestrians and bicyclists (*8–12*, *51*)

One major concept that describes how successful AT is in a segment or area is walkability. Though walkability does not have a standard definition and has many interpretations

(*19*, *123*), it can be summarized as the many factors, that enhance not only walking but all forms of physical activity (*124*). Specifically, walkability is defined by factors such as BE characteristics (e.g., AT infrastructure, roadway characteristics, vehicle behavior), social demographics (*125*), and user perceptions(e.g., safety, comfort) (*19*, *123*, *124*, *126–128*). Some researchers have categorized walkability into a number of comprehensive factors, as seen in Table 2.1 (*123*, *126–128*).

Table 2. 2 Categorized walkability factors

Source	Walkability Factor Categories
Forsyth, 2015 (*123*)	(1) transversable, (2) compact/close, (3) safe, (4) physical/enticing, (5) lively and sociable, (6) sustainable option, (7) exercise-inducing, (8) multidimensional, and (9) holistic solution
Speck, 2012 (*126*)	(1) useful, (2) safe, (3) comfortable, and (4) interesting
Alfonzo, 2005 (*127*)	(1) pleasurability, (2) comfort, (3) safety, (4) accessibility, (5) feasibility
Southworth, 2005 (*128*)	(1) connectivity of path network, (2) linkage with other modes, (3) varied land use, (4) safety, (5) quality of path, and (6) path context

Forsyth, 2015, categorized walkability with the nine factors shown in Table 2.1. The categories impact condition or means, outcomes, and proxy definitions of walkability. Tranverseable, compact/close, safe, and physical/enticing are factors that make up the means of walkability. The author relates walkability to the word transverable, a segments capability of being walked or traveled on. Forsyth also describes walkability as having destinations nearby, safety from the environment, including vehicles, and enticing through the availability of pedestrian-oriented features. This author contributes the next three factors as outcomes of walkable areas. Walkability impacts areas by creating spaces that are sociable, more sustainable, and encourage physical activity which supports the previous findings (*37*). Forsyth also defines walkable as measurable and holistic, representative of how the term is used in research and debate.

Speck, 2012 categorizes walkability with four factors, Table 2.1. Similar to the previous study, interest, or enticement, was used to define walkability. Safety was also a repeated factor used in each study. Speck also uses comfort and useful as factors where comfort is perceived safety and useful describes concepts similar to compact/close. Alfonzo, 2005 uses comfort as well, along with pleasurability, accessibility, and feasibility. Comfort and pleasurability are defined similarly by the factors in the previous studies. Accessibility describes walkability as supporting inclusivity by making sure that areas accommodate individuals with disabilities. Walkable projects and implantation feasibility was considered in this study as well. Smithworth, 2005 describes walkability similarly to the previous studies with land use, quality of path, and path context. These factors are similar to transferable, useful, comfort, enticing, and accessibility. However, this author includes connectivity in the study as well to describe walkability as a continuous network of AT pathways and interconnect modes.

Walkability categories showed how comprehensive AT networks can be and the complex influences on AT. The factors used to define walkability are very similar to factors that affect the AT network. (*8–12*). These factors, along with walkability factors, are both subjective and objective (*5*). Studies have shown that compact destinations, mixed-use, safety, and the presence of AT infrastructure are al factors that influence AT (*9*, *11*, *43*). Physical environment and user perception along with the sociocultural environment and economic factors have been seen to impact AT users such as societal norms, gender, and ethnicity (*5*, *10*, *13–15*, *38*). Grabow et al., 2019 estimated that demographics (i.e., age, gender, education, marital status, income, race, community type), subjective factors (i.e., travel time, distance, community characteristics, traffic safety), and objective characteristics (i.e., AT facilities and public amenities) predicted AT use.

Chapter 3: Data Collection

This chapter covers the methods used to complete the first research objective, develop and collect video-based built environment assessment surveys. Completing the first objective was done by fulfilling the steps seen in Figure 3.1. This section begins by discussing the segment location selection process. With the segments selected, technical data, specifically, BE characteristics and perception factors, were collected for each location. Additionally, video-based assessment surveys were created and collected to obtain rural perceptions of the same segments. This chapter will also cover the summary of responses from both the technical data collection and the surveys. Completion of the first objective allows for data analysis and leads to the second objective as seen in Figure 3.2.

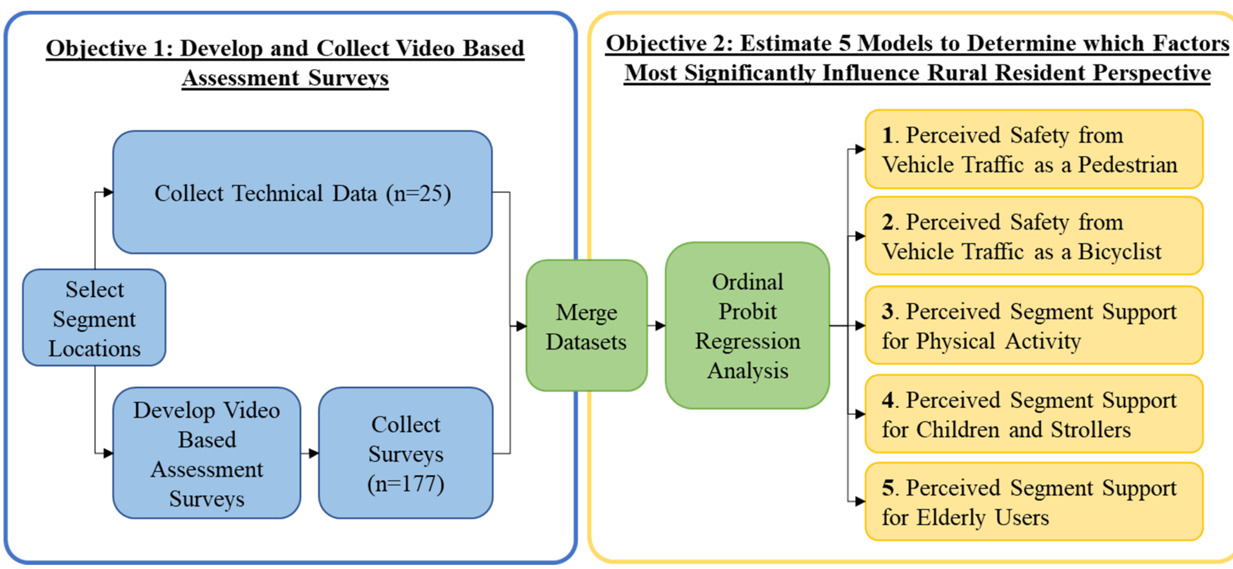


Figure 3. 1 Research process and objectives

3.1 Selecting Representative Segments

To begin, 25 segments were selected for assessments. Each selected segment location varied in place, land use, and condition. The segments were located in different Alabama counties, as seen in Figure 3.2. The number segments chosen in each county can be seen in Figure 3.2.a. The segments are located in the following counties, as seen in Figure 3.2.b: Baldwin, Macon, Mobile, Monroe, Montgomery, Pike, and Lee. The majority of the segments were located in the Auburn-Opelika area, Figure 3.2.c. The segments in Lee County totaled to 16 locations including the segments in Waverly, Alabama, Figure 3.2.d. Multiple segments were located in Troy, Alabama and Fairhope, Alabama, and can be seen in Figure 3.2.e and 3.2.f respectively.

Selecting segments from different areas allowed for a wider range of road types, conditions, and situations. This also allowed for selecting segments that serviced different land uses. Segments in residential, and commercial areas were chosen along with segments servicing downtown areas and segments of county roads. Segments were also intentionally selected to show a range of conditions (i.e., good, fair, poor) and can be seen in Figure 3.2 as well. However, no formal ranking system was created, the research team hypothesized conditions for each segment. The hypothesized condition of each segment was classified using criteria based on the findings from the literature review. Infrastructure present, maintenance, overall walkability, and perception of safety were some factors used for condition classification.

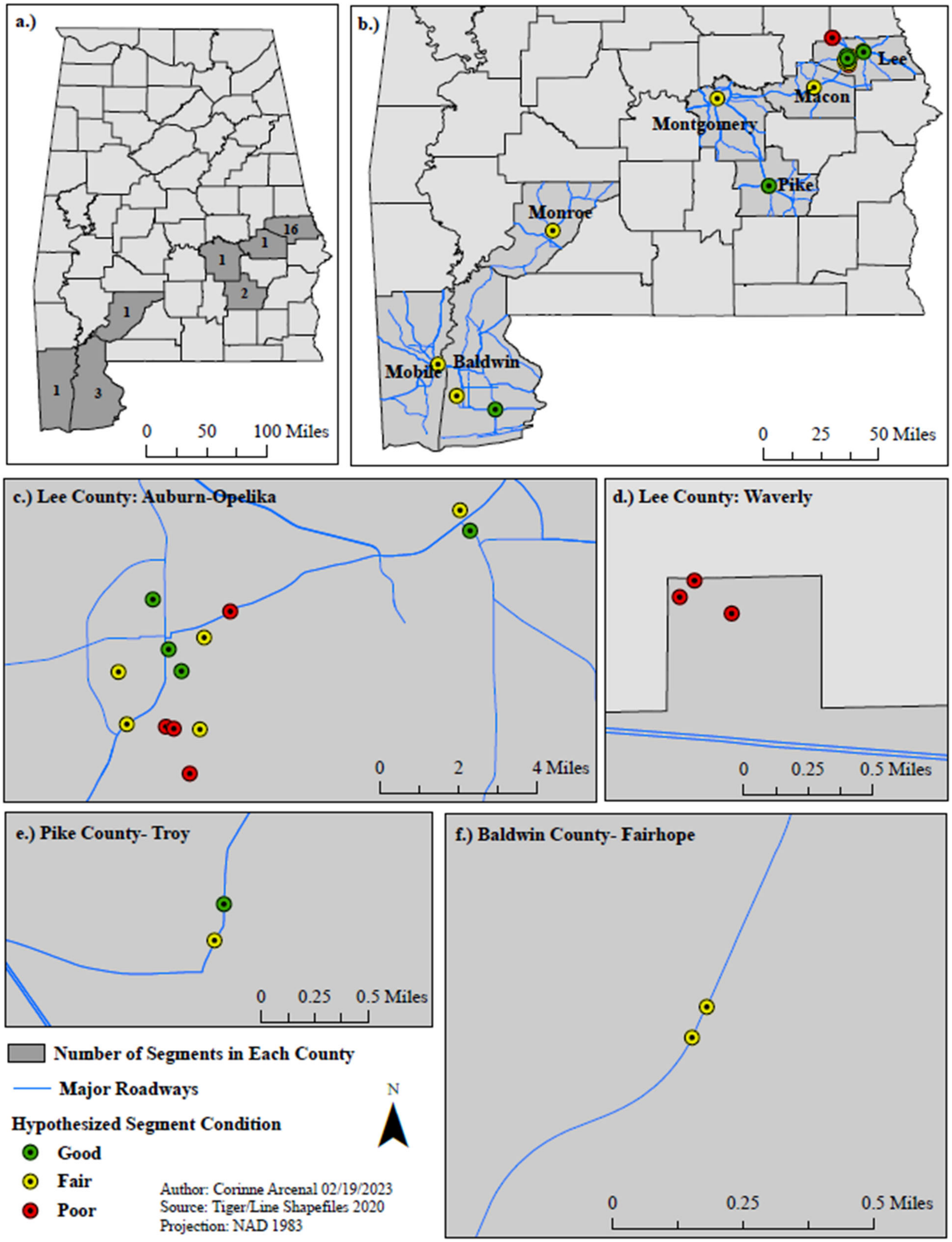


Figure 3. 2 Locations and hypothesized condition of each segment

Out of the 25 segments, 6 were classified as being in “good” condition, 12 being in “fair” condition, and 7 segments being in “poor” condition. The segments classified as being in “good” condition had significant support of AT infrastructure, walkability, and user perception. The segments classified in this condition often had wide sidewalks and were located in downtown or residential areas. The segments hypothesized as being in “fair” condition supported AT but lacked infrastructure or caused user discomfort. The segments classified under “poor” hypothesized conditions lacked AT characteristics and caused user discomfort. The segments under both ‘fair” and “poor” conditions serviced all the areas (i.e., downtown areas, county roads, commercial areas, and residential areas).

Video recordings of each segment were taken to be used later for data collection. The videos were reviewed to ensure that each video was around 1-2 minutes long to mitigate survey fatigue and recorded at a walking pace for unhurried observations. The video recordings of each segment allowed the research team to create virtual data collection opportunities. This allowed for virtual walking audits and allowed segments to be easily “revisited” for data collection.

3.2 Selecting Built Environment Factors and Collecting Supporting Segment Data

Data was collected virtually through the use of the segment recordings, Alabama Department of Transportation Traffic Data Manager (*129*), and Google Maps. The characteristics of each segment were documented using factors from existing literature. The factors collected contained both qualitative and quantitative data and were documented through Likert scales, binary options (i.e., yes/no, present/not present), and measurements of physical features. Factors were selected based on the literature reviewed and organized by the four characteristics of walkability, usefulness, safety, comfort, and interest (*126*). This was done to ensure thorough documentation of each segment (e.g., confirm different aspects of AT). The factors selected were categorized into four sections, each representing a factor of walkability.

The questions placed into the "Useful" section collected factors on the importance of the segment. Not only the ability to connect individuals to destinations but the value of the segment and its surroundings as well, whether it be historical or commercial. The 13 factors included in this section are as follows: land use (i.e., commercial, residential, educational, etc.), area significance (i.e., located downtown, historical significance, community gathering areas), traffic perceptions, vehicle types, AT users, and trail access. This section ensured that segment importance was documented.

Questions organized into the "Safety" section documented many technical elements of roadway assessment. This section highlights the factors that ensure segment safety for all users, including the presence of AT infrastructure, roadway characteristics, and accessibility. This section included 48 factors that document physical measurements of roadway components and the presence of safety features. The factors included in this section are as follows: vehicle behavior (i.e. speed limit, traffic, parking), lane characteristics (i.e., marking visibility, turning lane, number of lanes, width), presence of traffic calming devices, segment slope, and curvature, signage, bicyclist network characteristics (i.e., bicycle lane, bicycle buffer, visible markings), pedestrian network characteristics (i.e., sidewalk characteristics, crosswalk characteristics, accessibility, continuity), presence of roadway shoulders, and intersection characteristics.

Factors placed in the "Comfortable" section focused on characteristics that support AT users. Another aspect of AT safety is the perceived safety of segments commonly termed comfort. The 12 factors in this section focus on documenting the presence of amenities and user perception of safety. The questions included in this section are as follows: segment is free of trash, debris, and standing water, the segment has lighting for all users, the segment has rest areas for pedestrians (i.e., benches, bus stops, patio areas, parks), the segment has shaded areas (i.e., bus stops, patio areas, trees), the segment has sheltered areas (i.e., restaurants, public bathrooms, bus stops), the segment has public amenities (i.e., bathrooms, water fountains, dog stations, trashcans), segment users feel seen (i.e., presence of big windows, patio areas, other pedestrians, and frequent vehicles), pedestrian and bicyclist discomfort due to vehicle speed, pedestrian and bicyclist discomfort due to physical aspects of the segment, and discomfort crossing the segment.

The last section hosted questions that documented segment characteristics that appeal to users, features that draw residents and tourists to the segment. The "Interesting' section contained 7 factors intended to report on characteristics that wholistically describe the segment. Factors include perception of segment representation of the community, community support, segment support on community collaboration, support for all ages, encouragement of physical activity, and encouragement of more visits. While these factors are best answered by local and long-time residents, the perception from individuals outside of the community is also valuable. The factors were collected through technical data collection and survey collection. Technical data collection focused on documenting quantitative data (i.e., measurements, presence of infrastructure) while the survey was designed to obtain the more qualitative factors (i.e., user perceptions, comfort, interest)

3.3 Comparing Segment Built Environment Factors with Hypothesized Segment AT Performance

The technical data collected through the questionnaire can be categorized as built environment characteristics or segment user perception. Tables 3.1.a through Table.3.1.c show the hypothesized condition and a select amount of technical data collected on each segment. The table shows both BE characteristics present at the segment and hypothesized user perception of the segment. The address of each segment can also be seen in the following tables.

Tables 3.1.a, b, and c visualize the factors most present in each segment by hypothesized condition. The factors most present regardless of hypothesized condition were shaded areas, and visible lanes, these two BE characteristics were present in over 75 % of all segments. The BE characteristics present in at least 50% of all segments were sidewalks, crosswalks, curbs, buffers, rest areas and light fixtures. BE characteristics that represented at least 25% of all segments were bicycle lanes, speed signage, cars parked in roadway, on street parking, sheltered areas, public amenities, downtown location, and access to trials. Traffic calming devices, pedestrian signage, steep roadway, and curved roadway were represented in less than 25% of the segment sample. The tables also show that the BE characteristics most present in all segments are commonly well represented in "good" segments but not in "poor" segments. The table also shows which factors are not represented in the segments classified as "good" and "poor", all factors were represented in "fair" segments. The "good" segments were not represented by access to trails showing that no segment classified as "good" provided access to trails. There was no documentation of sidewalks and traffic calming devices in all segments with hypothesized poor conditions.

Table 3. 1. a Select BE characteristics of segments characterized with hypothesized good condition

	Location	S 9th St, Opelika, AL	W Laurel Ave, Foley, AL	Cary Dr, Auburn, AL	S 3 Notch St, Troy, AL	Payne St, Auburn, AL	W Magnolia Ave, Auburn, AL
	BE Characteristics	Hypothesized Good					
Segment Characteristics	Sidewalks	✓	✓	✓	✓	✓	✓
	Sidewalk Width (ft)	10.5	9.0	5.0	9.5	3.5	12.0
	Bicycle Lanes			✓			
	Bicycle Lane With (ft)	0.0	0.0	4.0	0.0	0.0	0.0
	Crosswalks	✓	✓	✓	✓		✓
	Crosswalk Width (ft)	6.0	8.0	8.0	6.5	0.0	8.5
	Visible Lanes	✓	✓	✓	✓	✓	✓
	Number of Lanes	2.0	3.0	2.0	2.0	2.0	3.0
	Lane Width (ft)	10.0	11.0	13.0	13.5	10.0	9.5
	Traffic Calming Devices				✓		✓
	Curbs	✓	✓	✓	✓	✓	✓
	Buffers	✓	✓	✓	✓	✓	
	Buffer Width (ft)	6.0	0.0	3.0	6.0	4.5	13.5
	Speed Signage		✓	✓		✓	
	Speed Limit (mph)	35.0	25.0	25.0	30.0	25.0	20.0
	Pedestrian Signage	✓					✓
	Cars Parked in Roadway	✓	✓	✓	✓	✓	✓
	On Street Parking	✓	✓		✓		✓
	Parking Space Width (ft)	6.0	11.0	0.0	8.0	0.0	10.5
	Shaded Areas	✓	✓	✓	✓	✓	✓
	Sheltered Areas		✓		✓		✓
	Public Amenities	✓	✓		✓		✓
	Rest Areas	✓	✓		✓		✓
	Light Fixtures	✓	✓	✓	✓		✓
	Steep Slope			✓			
	Curved Roadway			✓			
	Located Downtown	✓	✓		✓		✓
	Provides Access to Trails						
	Number of Vehicles per Minute	109.0	627.0	34.0	579.0	183.0	480.0

Table 3. 1. b Select BE characteristics of segments characterized with hypothesized fair condition

	Location	Government St, Mobile, AL	N Mnt Peasant Ave , Monroeville, AL	7th St, Opelika AL	Fred Gray St, Tuskegee, AL	Harper Avenue, Auburn, AL	S College St, Auburn AL	Wrights Mill Rd, Auburn, AL	AL-15, Troy AL	Cloverdale Rd, Montgomery, AL	US 98 ALT, Fairhope, AL	US 98 ALT, Fairhope, AL	Wire Rd, Auburn, AL
	BE Characteristics	Hypothesized Fair											
Segment Characteristics	Sidewalks	✓	✓		✓		✓		✓		✓	✓	
	Sidewalk Width (ft)	12.0	13.5	0.0	9.0	0.0	5.0	0.0	8.0	0.0	8.0	6.0	0.0
	Bicycle Lanes							✓		✓			✓
	Bicycle Lane With (ft)	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	7.0	0.0	0.0	6.0
	Crosswalks	✓	✓		✓				✓		✓	✓	✓
	Crosswalk Width (ft)	7.0	7.0	0.0	7.0	0.0	0.0	0.0	7.0	0.0	7.0	6.0	7.5
	Visible Lanes	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓
	Number of Lanes	5.0	2.0	2.0	1.0	2.0	6.0	2.0	2.0	2.0	2.0	2.0	5.0
	Lane Width (ft)	10.0	16.0	14.0	18.0	17.0	12.5	10.5	17.5	19.5	11.5	11.5	14.0
	Traffic Calming Devices		✓										
	Curbs	✓	✓	✓	✓	✓	✓		✓	✓			
	Buffers	✓	✓	✓		✓	✓		✓		✓	✓	
	Buffer Width (ft)	12.0	16.5	0.0	0.0	0.0	3.0	0.0	4.5	0.0	0.0	2.5	0.0
	Speed Signage					✓		✓		✓	✓	✓	✓
	Speed Limit (mph)	35.0	25.0	30.0	25.0	30.0	45.0	35.0	30.0	25.0	35.0	35.0	40.0
	Pedestrian Signage		✓								✓		
	Cars Parked in Roadway	✓	✓		✓	✓							
	On Street Parking		✓		✓				✓				
	Parking Space Width (ft)	9.0	10.0	0.0	11.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0
	Shaded Areas	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	
	Sheltered Areas	✓					✓				✓	✓	
	Public Amenities	✓	✓		✓								
	Rest Areas	✓	✓		✓		✓				✓	✓	
	Light Fixtures	✓	✓		✓	✓	✓		✓				✓
	Steep Slope												✓
	Curved Roadway						✓	✓		✓		✓	
	Located Downtown	✓	✓		✓				✓				
	Provides Access to Trails	✓	✓					✓		✓	✓	✓	✓
	Number of Vehicles per Minute	1,554.0	415.0	32.0	232.0	64.0	1,433.0	547.0	579.0	127.0	306.0	306.0	645.0

Table 3. 1. c Select BE characteristics of segments characterized with hypothesized poor condition

	Location	Ogletree Rd, Auburn, AL	E University Blvd, Auburn, AL	E University Blvd, Auburn, AL	Patrick St, Waverly, AL	Patrick St, Waverly, AL	Bernard Ave, Waverly, AL	Opelika Rd, Auburn, AL
	BE Characteristics	Hypothesized Poor						
Segment Characteristics	Sidewalks							
	Sidewalk Width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bicycle Lanes	✓	✓	✓				
	Bicycle Lane With (ft)	3.0	5.0	5.0	0.0	0.0	0.0	0.0
	Crosswalks		✓					
	Crosswalk Width (ft)	0.0	7.0	7.0	0.0	0.0	0.0	0.0
	Visible Lanes	✓	✓	✓		✓	✓	✓
	Number of Lanes	2.0	3.0	3.0	2.0	2.0	2.0	5.0
	Lane Width (ft)	11.0	11.0	11.0	10.0	10.0	9.5	11.5
	Traffic Calming Devices							
	Curbs		✓	✓				✓
	Buffers	✓	✓	✓				✓
	Buffer Width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Speed Signage	✓		✓				
	Speed Limit (mph)	45.0	30.0	30.0	25.0	25.0	35.0	45.0
	Pedestrian Signage		✓					
	Cars Parked in Roadway				✓			
	On Street Parking				✓			
	Parking Space Width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Shaded Areas	✓	✓	✓	✓	✓	✓	✓
	Sheltered Areas				✓			✓
	Public Amenities							
	Rest Areas				✓	✓		✓
	Light Fixtures	✓	✓	✓				✓
	Steep Slope		✓	✓				
	Curved Roadway						✓	
	Located Downtown				✓	✓		
	Provides Access to Trails	✓	✓	✓				
	Number of Vehicles per Minute	525.0	995.0	995.0	47.0	47.0	26.0	1,270.0

The BE characteristics were further studied by determining the factor presence for each hypothesized condition, Table 3.2. This table shows how much percent each BE characteristic is seen in segments of a certain condition. The percentages are based on the number of times each BE characteristic is present within segments of the same condition out of the total number of segments of the same condition. Among the segments classified as being in “good” condition, the BE characteristics of shaded areas, visible lanes, curbs, sidewalks, and cars parked in the roadway were seen in all 6 of these segments. The BE characteristics of buffers, crosswalks, and light fixtures are seen in 83.3% of the "good" segments, which amounts to 5 of the 6 segments. The presence of rest areas, on-street parking, trashcans, and located in the downtown area are characteristics seen in 66.7% of the segments characterized as 'good". Sheltered areas, speed signage, traffic calming devices, pedestrian signage, bicycle lanes, steep slopes, curved roadways, and access to trails are seen in these segments 50% or less.

Table 3. 1 Percentage of BE characteristics present in each segment condition

	Hypothesized Condition (%)		
Built Environment Characteristics	Good	Fair	Poor
Shaded Areas	100.0	83.3	100.0
Visible Lanes	100.0	83.3	85.7
Curbs	100.0	66.7	42.9
Sidewalks	100.0	58.3	0.0
Cars Parked in Roadway	100.0	33.3	14.3
Buffers	83.3	66.7	57.1
Crosswalks	83.3	58.3	14.3
Light Fixtures	83.3	58.3	57.1
Rest Areas	66.7	50.0	42.9
On Street Parking	66.7	25.0	14.3
Located Downtown	66.7	33.3	28.6
Trashcans	66.7	16.7	14.3
Sheltered Areas	50.0	33.3	28.6
Speed Signage	50.0	50.0	28.6
Traffic Calming Devices	33.3	8.3	0.0
Pedestrian Signage	33.3	16.7	14.3
Bicycle Lanes	16.7	25.0	42.9
Steep Roadway	16.7	8.3	28.6
Curved Roadway	16.7	33.3	14.3
Provides Access to Trails	0.0	58.3	42.9

The segments categorized as “fair” usually had the following characteristics (e.g., more than a 50% documentation percentage): shaded areas, visible lanes, and trails along with the presence of curbs, sidewalks, buffers, crosswalks, and light fixtures. The characteristics shaded areas and visible lanes are documented the most in these segments (83.3%), with curbs and buffers following (66.7%), then sidewalks, crosswalks, light fixtures, and access to trails (58.3%). The characteristics with low percentages include rest areas, speed signage, cars parked in the roadway, located downtown, sheltered areas, curved roadways, on-street parking, bicycle lanes, trashcans, pedestrian signage, traffic calming devices, and steep roadway.

Compared to BE characteristic percentages for segments classified as “good”, “fair” segments had lower percentages for each characteristic except speed signage, which remained at 50% across the two conditions, and bicycle lanes, curved roadway, and access to trails, which saw increases in percentages from “good” to “fair”. The top two characteristics for both conditions stayed the same: shaded areas and visible lanes. Some percentages of BE characteristics changed drastically between segments considered ‘good” and segments considered ‘fair”. The greatest decreases in BE characteristics between the two conditions were cars parked in roadway percentage at 66.7% followed by the presence of trashcans at 50%. Another significant change was the BE characteristics sidewalk presence and on-street parking (41.7%).

The segments classified as having “poor” conditions had high percentages for shaded areas (100%) and visible lanes (85.7%); this was similarly seen for the other two conditions as well. The other high percentages were the presence of buffers and light fixtures, both at 57.1%. Moving from “fair” to “poor” segment conditions show many percentage differences. The biggest percent decreases between the segments with “fair” conditions and segments with “poor” conditions were the presence of sidewalks (58.3%) and the presence of crosswalks (44%). Other notable decreases are seen for the presence of curbs (23.8%), speed signage (21.4), cars parked in the roadway (19.0%), curved roadways (19.0%), and access to trails (15.5%). Percentages also increased for some BE characteristics. Including steep roadways (20.2%), the presence of bicycle lanes (17.9%), shaded areas (16.7%), and visible lanes (2.40%).

As mentioned before, shaded areas and the presence of visible lanes remained relatively high in percentage across each segment condition. The biggest change in BE characteristics was the presence of sidewalks from "good" segments at 100% to "poor" segments at 0%. Other BE characteristics following the same majority-to-minority percentage trend from "good" to "fair" to "poor" conditions include the presence of curbs, cars parked in the roadway, crosswalks, rest areas, on-street parking, downtown located, and presence of trashcans. This shows that as segment conditions hypothetically decreased, the BE characteristics listed above were less present. Other notable decreases in percentages from 'good" to "poor" were buffers and light fixtures, though both characteristics, regardless of condition, were present the majority of the time (i.e., percentages stayed above 50%). BE characteristics that decreased from "good" to "poor" conditions but started with minority percentages (i.e., less than 50% regardless of condition) are as follows: the presence of sheltered areas, traffic calming devices, and pedestrian signage.

BE characteristics that increased from "good" to "poor" condition were the presence of bicycle lanes. This shows that while sidewalk presence decreased, the presence of bicycle lanes increased, though not at the same rates. Some BE characteristics did not follow linear trends. The presence of shaded areas, visible lanes, and steep roadway characteristics decreases from "good" to "fair" but then increases from "fair" to "poor". Segments that provided access to trails increased as conditions went from “good” to “poor”. Although, the presence of trail access was seen more in “fair” segments.

3.4 Developing and Collecting Surveys on User Perceptions of Segment AT Performance

Although technical data collection addressed many active transportation characteristics, rural and AT user perceptions were needed. To collect additional perspectives, shorter video-based built environment assessment surveys were created, an example can be seen in Appendix A. The survey was created and collected through Qualtrics.xm. The survey was structured into two sections, a section collecting demographic-type data and a section that hosted the virtual walk audit. The first section consisted of 6 questions all relating to the respondent’s individual data/personal data. The data collected included community type (i.e., urban, suburban, and rural), respondent's recruitment affiliation, age, race, and gender. The second section was comprised of one video recording and 18 questions about the recorded segment.

There were two types of questions included in this section of the survey. The first type documented the presence of certain characteristics with check all that apply answer choices including types of development along the segment (i.e., residential, agricultural, educational, etc.) and types of amenities along the segment (i.e., lighting, benches, bus stops, restaurant patios, etc.). The second type of question documented answers through Likert scales. These questions included the perception of sidewalk maintenance, safety from vehicle traffic, and perception of how sustainable, accessible, livable, attractive, and interesting the segment was. Additionally, questions on the perception of segment support for physical activity, more visits, older pedestrians, children and strollers, pedestrians with mobility impairments, and pedestrians with visual impairments were included as well.

The surveys were collected over a period of four months from March 2022 to July 2022, ending with a total of 177 usable responses. Respondents were invited to take surveys initially through online recruitment and then through event recruitment. The online recruitment happened by emailing the surveys out to different organizations and groups in order to get responses from individuals with differing levels of AT knowledge and experience. These organizations included the Centers for Disease Control (CDC) and Alabama Extension and Cooperative System. The surveys were also sent to community coalition leaders throughout Alabama to obtain local rural responses. Figure 3.3 shows the response percentages of each group (i.e., CDC, Alabama Extension, Coalition, Community Member) out of the total number of responses. The responses from CDC members were mainly recruited online. Online recruitment responses were also from Alabama Extension members as well as relatively low percentage of community member responses.

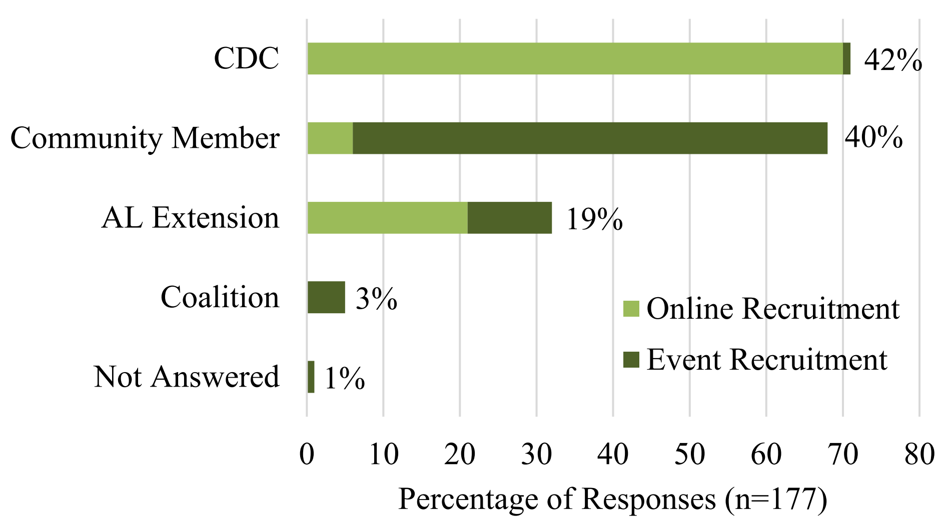


Figure 3. 3 Total recruitment response percentages

Since the responses from online recruiting showed low numbers of community coalitions and individuals within these communities, the research team attended and recruited at events in small-sized communities. Event recruitment, also seen in Figure 3.3 shows that there were many responses from local individuals (i.e., Community Member). In total, CDC members comprised the largest respondent group at 42% followed by local individuals at 40%. Members of Alabama Extension made up 19% of the responses while responses from community coalition leaders made up 3% of total responses.

Event recruitment spanned from May 2022 until July 2022 in three different Alabama communities, Eufaula, Tuskegee, and Wetumpka. The research team collected surveys at seven events which can be seen in Figure 3.4. The events were each hosted by organizations within the communities. Surveys were collected by setting up a table or tent at each event along with instructional signs and bottled water. Responses were collected with iPads and the number of responses per location were kept uniform to assure a moderately even distribution of survey responses.

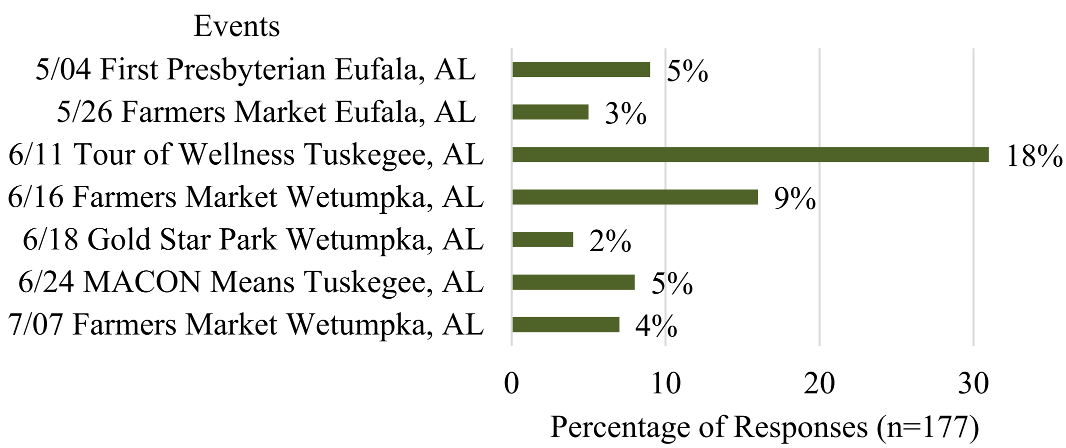


Figure 3. 4 Percentage of recruitment responses by event

As mentioned previously, certain demographic characteristics were documented during survey collection. These characteristics, gender, age, race, and community type, were self-reported. These response percentages show that there was sample bias as some response percentages did not represent the Alabama population or the U.S. population (*130*, *131*). The data shows that most of the respondents identified as female (75%), with male respondents representing only 24% of the sample, as seen in Figure 3.5. These percentages do not match the gender ratio for either the Alabama population of the U.S. population (*130*). Sampling bias can also be seen in age, Figure 3.6. The figure shows that response percentages were heavily skewed towards the age group 26 to 35 which represented 41% of responses. The other percentages were relatively more representative of the state and county populations. Compared to the population the age groups 56 to 65 and 66 to 75 were overrepresented while age groups 18 to 25, 36 to 45, 46 to 55, and 76 and up were underrepresented. Notably, while age groups 18 to 25, and 76 and up have the lowest percentages or survey responses, these age groups respectively make up 9% and about 7% of the overall population (*130*).

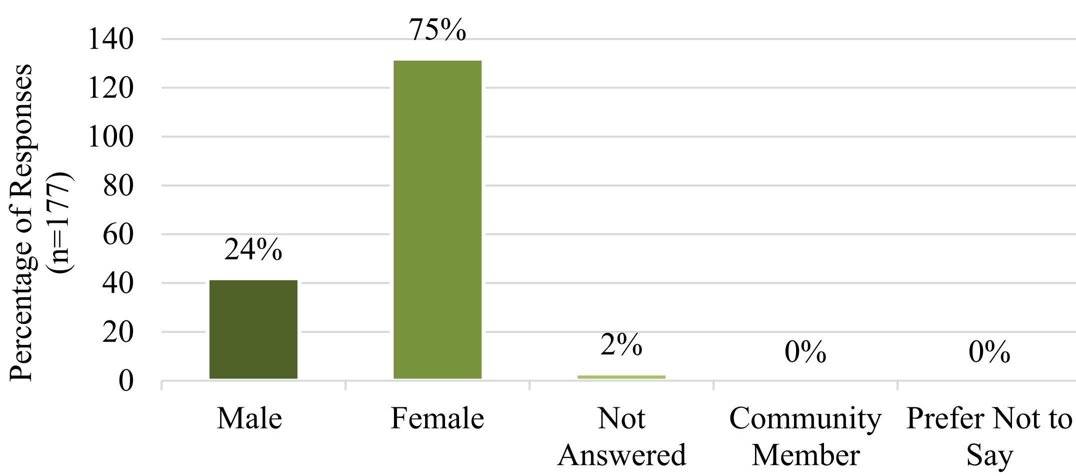


Figure 3. 5 Percentage of responses by gender

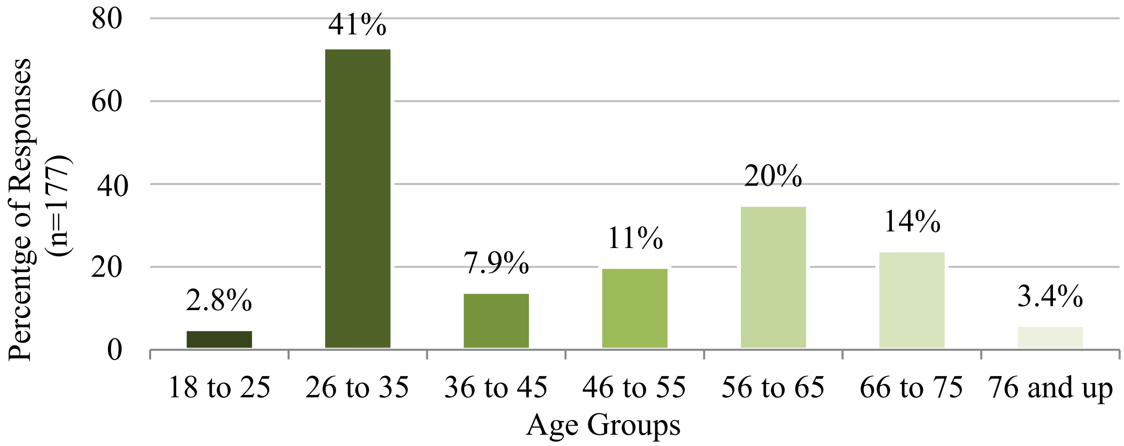


Figure 3. 6 Percentage of responses by age

The responses were also overwhelmingly from white respondents at 72% of the total response rate as seen in Figure 3.7. Individuals who identify as white had 47% more representation than the next highest population percentage. Though more diversity is needed, the response percentage closely follow the race percentages of the Alabama population (*131*). The US population also sees the same trend; where white individuals are the majority, a much lower black or African American population, and even lower percentages for other ethnic groups and races (i.e., Asian, Indigenous Americans) (*131*).

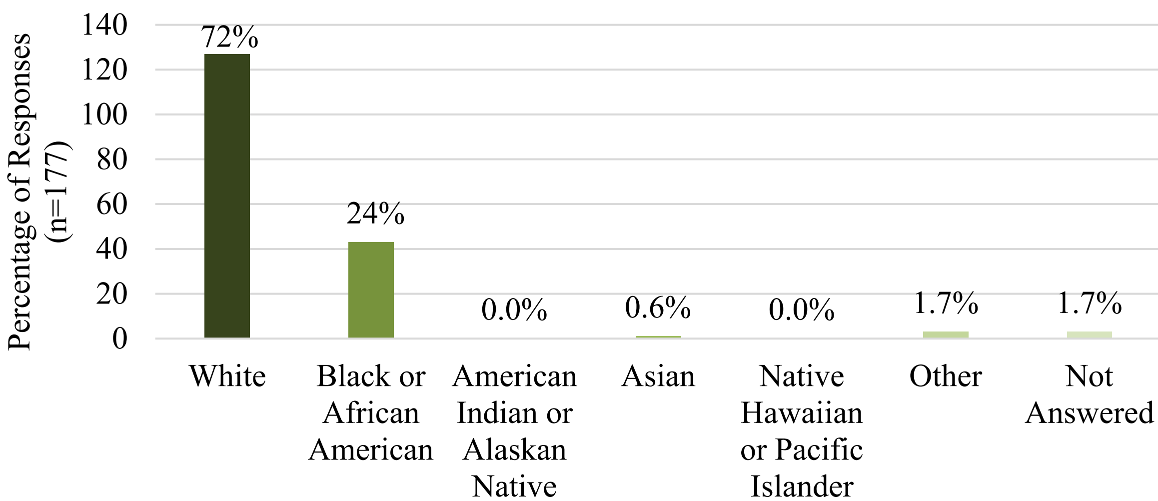


Figure 3. 7 Responses by race

The percentage of urban, suburban, and rural respondents can be seen in Figure 3.8. The percentages below can be compared to the Urban Rural Decennial Census (DEC) Survey, though the DEC characterizes housing units by only urban areas, urban clusters, and rural thresholds (*132*). Compared to the Alabama population, both urban and rural residents are underrepresented. However, compared to the US population, urban residents are underrepresented while rural residents are overrepresented.

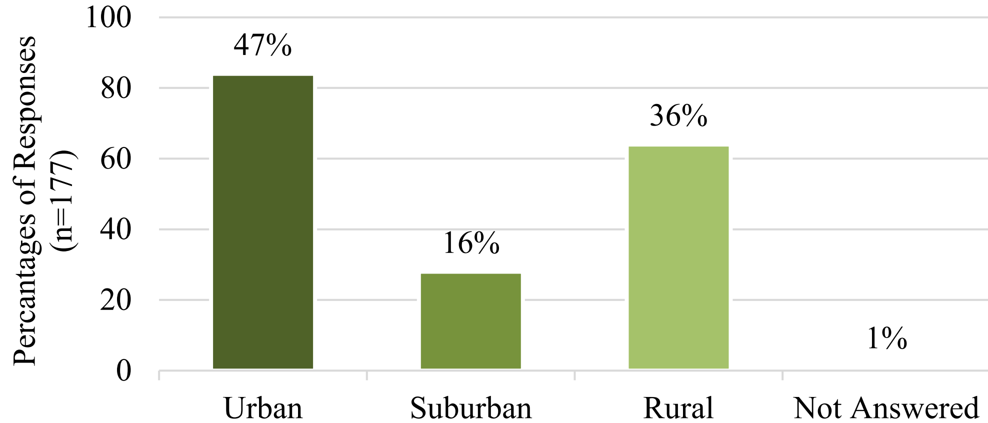


Figure 3. 8 Response by community type

3.5 Reviewing Survey Data Results

As mentioned at the beginning of this section, the survey collected user perception using virtual walk audit techniques. A Likert scale was used to document the data with 5 being the best (i.e., extremely well, extremely safe, extremely agree), 3 being neutral, and 1 being the worst (i.e., extremely poor, extremely unsafe, extremely disagree). Table 3.3 shows the 15 questions that documented respondents' perceptions and the overall mean of each perception. The average perceptions shown in Table 3.3 are between the values 3.07 and 2.03 which shows that each perception was ranked around neutral and somewhat poor (i.e., 2 on the Likert scale). The middle to low scores of each perception shows the need for increasing both support for active transportation and placemaking. Notably, while the perception of segment support on pedestrians from vehicle traffic was the highest perception average, the lowest averages were perceptions of how well segments supported pedestrians with either mobility or visual impairments. The two highest-scoring perceptions were I feel safe from traffic crossing the road (3.07) and I feel safe from traffic walking or running (3.00). The lowest scoring perceptions were this roadway segment supports pedestrians with mobility impairments (2.18), and this roadway segment supports pedestrians with visual impairments (2.03).

Table 3. 2 Average rating of user perceptions

User Perception	Mean
How well maintained is the sidewalk?	2.46
How safe from vehicle traffic do you feel if you are…	
walking or running (a)	3.00
crossing the road	3.07
riding a bicycle (b)	2.46
How well does this roadway segment…	
encourages physical activity (c)	2.81
entices you to visit again	2.49
How well does this roadway segment support…	
older pedestrians (d)	2.49
children and strollers (e)	2.38
pedestrians with mobility impairments	2.18
pedestrians with visual impairments	2.03
Do you think this roadway segment is…	
accessible	2.64
livable	2.83
attractive	2.63
sustainable	2.77
interesting	2.56

Table 3.3 also identifies the five perceptions that were chosen to determine model estimations (i.e., a-e). The perceptions are as follows: (a) how safe from vehicle traffic do you

feel if you are walking and running, (b) how safe from vehicle traffic do you feel if you are riding a bicycle, (c) how well does this roadway segment encourage physical activity, how well does this roadway segment support older pedestrians, and (e) how well does this roadway segment support children and strollers. The perceptions were selected as they represent a wide variety of AT user groups. Perceptions of walkers, runners, and bicyclists will be represented in the scorecard, along with older pedestrians and children. Additionally, the perception of how well segment features support or encourage PA was chosen since increasing PA has been linked to healthier communities, as mentioned previously. The five perceptions will be further discussed at the end of this section.

3.6 Comparing User Perceptions of Segment AT Performance with Hypothesized Segment AT Performance

Documented user perceptions were also examined for each segment, seen in Table 3.4. The 15 user perceptions, shown previously in Table 3.3, were averaged for each segment. Table 3.4 shows the hypothesized conditions juxtaposed to the average user perception along with the average user perception of each group (i.e., CDC, Alabama Extension, Coalitions, and Community Members). The table also contains the number of responses for each segment, where each segment location had at least 6 responses, the highest at 11 responses. The segments were organized by hypothesized conditions and then ranked highest to lowest perception by condition. The segment with the highest mean user perception was located on W Magnolia Ave, Auburn, Alabama at 3.98, followed by Government Street, Mobile, Alabama 3.66. The segment with the lowest user perception was located on Ogletree Rd, Auburn, Alabama with an average perception of 1.54 followed by Opelika Rd Auburn, Alabama with a mean perception of 1.55.

Table 3. 3 Average rating of segments **Updated Table**

Location	Responses	Hypothesized Condition	User Perception				
			Mean (SD)	CDC (SD)	Alabama Extension (SD)	Coalition Member (SD)	Community Member (SD)
S 9th St, Opelika, AL	11	5	3.53 (0.69)	3.36 (0.96)	3.18 (1.17)		3.86 (1.02)
W Laurel Ave, Foley, AL	7	5	3.66 (1.36)	3.93 (0.46)	3.97 (1.25)		3.19 (1.24)
Cary Dr, Auburn, AL	7	5	2.98 (0.96)	2.73 (1.15)	3.40 (0.74)		3.09 (1.33)
S 3 Notch St, Troy, AL	6	5	3.50 (0.91)	3.27 (1.01)	4.20 (0.56)		3.77 (0.60)
Payne St, Auburn, AL	6	5	3.52 (1.26)	2.87 (1.33)	4.53 (0.64)		3.63 (1.34)
W Magnolia Ave, Auburn, AL	6	5	3.98 (1.04)	4.05 (0.79)	3.73 (0.46)		3.93 (0.26)
Government St, Mobile, AL	7	3	3.83 (1.12)	4.02 (0.95)	4.33 (0.49)		3.11 (1.01)
N Mnt Peasant Ave, Monroeville, AL	8	3	3.62 (1.08)	3.35 (1.19)	4.07 (0.62)		
7th St, Opelika AL	6	3	3.13 (1.20)	1.40 (0.74)	3.08 (0.95)		3.59 (0.89)
Fred Gray St, Tuskegee, AL	9	3	2.96 (1.01)	2.90 (1.30)	3.00 (1.02)		3.00 (1.04)
Harper Avenue, Auburn, AL	7	3	1.62 (1.37)	1.23 (0.50)		1.53 (0.74)	1.86 (1.04)
S College St, Auburn AL	7	3	1.94 (1.09)	1.92 (1.18)	1.47 (0.74)		2.23 (0.97)
Wrights Mill Rd, Auburn, AL	7	3	1.93 (1.12)	1.18 (0.39)	2.37 (1.25)		2.63 (1.07)
AL-15, Troy AL	7	3	2.91 (1.12)	3.09 (1.14)	2.80 (1.42)		2.78 (0.90)
Cloverdale Rd, Montgomery, AL	7	3	3.27 (1.23)	2.50 (1.28)	4.20 (0.56)	2.20 (1.01)	3.82 (1.23)
US 98 ALT, Fairhope, AL	6	3	2.98 (1.09)	3.22 (0.93)	3.80 (0.41)		2.20 (0.76)
US 98 ALT, Fairhope, AL	6	3	2.92 (0.90)	2.77 (1.24)	3.80 (0.42)		3.43 (1.13)
Wire Rd, Auburn, AL	7	3	2.41 (0.72)	1.40 (0.81)	2.67 (0.62)		2.88 (1.02)
Ogletree Rd, Auburn, AL	8	1	1.54 (1.07)	1.27 (0.76)	2.00 (1.26)		
E University Blvd, Auburn, AL	8	1	1.58 (1.20)	1.23 (0.50)		1.53 (0.74)	1.75 (1.02)
E University Blvd, Auburn, AL	7	1	2.42 (0.99)	1.83 (0.91)	3.07 (1.16)		2.55 (1.28)
Patrick St, Waverly, AL	7	1	2.06 (1.21)	1.65 (1.15)	2.67 (0.82)		3.07 (1.44)
Patrick St, Waverly, AL	6	1	1.87 (1.09)	1.20 (0.48)	1.64 (0.93)	2.07 (1.04)	3.14 (1.10)
Bernard Ave, Waverly, AL	7	1	2.21 (1.09)		1.37 (0.67)		2.62 (1.24)
Opelika Rd, Auburn, AL	7	1	1.55 (1.23)	1.44 (0.69)			1.63 (0.74)

3.6.1 Visual Inspection of Hypothesized Condition vs. User Perception

In order to explore the differences between hypothesized conditions and user perspective, the hypothesized condition ratings were scaled to match the survey response rating to allow for visual inspection. This was done since the hypothesized conditions used a 3-point scale (i.e., good, fair, poor), and survey responses were measured on a 5-point rating, Appendix A. As seen in Table 3.4, the hypothesized conditions were simplified into values of 5 for hypothesized good, 3 for hypothesized fair and 1 for hypothesized poor. The same conditional format color scheme was used for both datasets to show the variability between hypothesized and perceived conditions. Through visual analysis, one can see that user perception mirrors the hypothesized condition to a certain extent.

The user perceptions in green or light green are most concentrated in the same grouping as the segments classified as hypothesized good. This behavior is also seen with user perception in red and the segment hypothesized to be in poor condition. The user perceptions for the segments hypothesized as fair condition have a mix of ratings, ranging from 4.33 (Alabama Extension rating of Government Street, Mobile, Alabama) to 1.18 (CDC rating of Wrights Mill Road, Auburn, Alabama. As seen in Table 3.4, many segments have differing hypothesized condition and user perceptions. For example, Cary Dr, Auburn, Alabama has a mean user perception classified as fair or yellow though it was hypothesized to be good. Some segments hypothesized as poor were perceived as between fair and poor, in orange. Visually speaking, while most of the segments were hypothesized as fair, users tended to perceive them as either good or poor. Compared to the mean user perspectives, CDC members had more responses in red and orange showing that this group rated more segments negatively than the mean. Additionally, Alabama Extension members and community members rated segments more positively compared to the mean. To summarize, the visual analysis showed the nuances of user perception and its difference from hypothesized classification. Additionally, though Table 3.3 shows that many of the user perceptions had an overall neutral score, the visual inspection, Table 3.4 demonstrated the range of user perceived conditions. The range of perceived conditions shows that the research team was successful in selecting a segment sample with a variety of conditions.

3.6.2 Value Inspection of Hypothesized Condition vs. User Perception

The data can also be interpreted using the 5-point rating (i.e., extremely well, somewhat well, neutral, somewhat poor, extremely poor). The user response rating was translated onto the hypothesized scale to define the conditions based on response perceptions. The 5-point scale was divided into three equal ranges to translate average perception values into condition classifications. The perceived condition ranges are as follows: segments with good conditions fall between the values of 5.00 and 3.67, fair conditions range between 3.66 and 2.34, and poor conditions range from 2.33 to 1.00. The values can be seen in Table 3.4 as well.

Assessing conditions using the values of perceived condition showed different condition ratings than the visual inspection. The values of the mean perceptions show that only two segments classify as having a good perceived condition (located at W Magnolia Ave, Auburn, Alabama, and Government Street, Mobile, Alabama). Using the same translation, nine segments fall into the range of values of the mean perceptions defining poor condition. The locations of the nine segments are as follows: S College St, Auburn AL, Wrights Mill Rd, Auburn, Alabama, Harper Avenue, Auburn, Alabama, Bernard Ave, Waverly, Alabama, Patrick St, Waverly, Alabama, Patrick St, Waverly, Alabama, E University Blvd, Auburn, Alabama, Opelika Rd, Auburn, Alabama, and Ogletree Rd, Auburn, Alabama. This means that 14 segments were perceived as being in fair condition, which differed from the visual inspection

Out of the 25 segments, 10 segments had differing condition classifications between hypothesized condition and the mean perceived condition. Five segments were originally hypothesized as good were perceived as fair, W Laurel Ave, Foley, Alabama, S 9th St, Opelika, Alabama, Payne St, Auburn, Alabama, S 3 Notch St, Troy, Alabama, and Cary Dr, Auburn, Alabama. One segment, Government St, Mobile, Alabama, was hypothesized as fair but perceived as good. Three segments were hypothesized as being in fair condition but were perceived as being in poor condition, S College St, Auburn AL, Wrights Mill Rd, Auburn, Alabama, and Harper Avenue, Auburn, Alabama. The segment located on E University Blvd, Auburn, Alabama was hypothesized as poor and perceived as fair.

User perception between the groups differed as well. Compared to the mean, CDC members rated the segments more positively and negatively meaning that there were less segments rated as being in fair condition. Alabama Extension members rated segments more positively compared to the mean which was similar to the previous finding. Community members tended to rate the segments as being in fair condition.

3.7 Comparing User Perceptions of Segment AT Performance with Segment Built Environment Factors

Next, the interaction between perception and BE characteristics was explored. To delve deeper into the five user perceptions chosen for estimation, responses from each perception are cataloged by segment and answer choice, as seen in Figures 3.9 through Figure 3.13. Each figure shows a histogram containing response percentages and a table of select BE characteristics. The segments were organized percentage by most positive to least positive response percentage, highest percentages of extremely safe, then highest percentages of somewhat safe, and so on. Along with the histogram, hypothesized conditions and BE characteristics from select factors were shown. The BE characteristics for each represented perception were selected based on knowledge from literature review findings. The BE characteristics shown are documented as a continuous number (i.e., measurement, amount) or checkmark to show the presence of infrastructure or availability of access (e.g., sidewalk, buffer, access to trails, park access). This type of data presentation allows for the identification of certain trends between user perception and BE characteristics. Since the locations are presented from positive to negative perceptions, trends can be identified by consistent characteristics. For example, in Figure 3.9, the column “Sidewalk” has consistent checkmarks in the upper half of the table. This shows that segments perceived more positively had sidewalks. This trend shows that there may be a positive impact of sidewalk presence on pedestrian safety from vehicles.

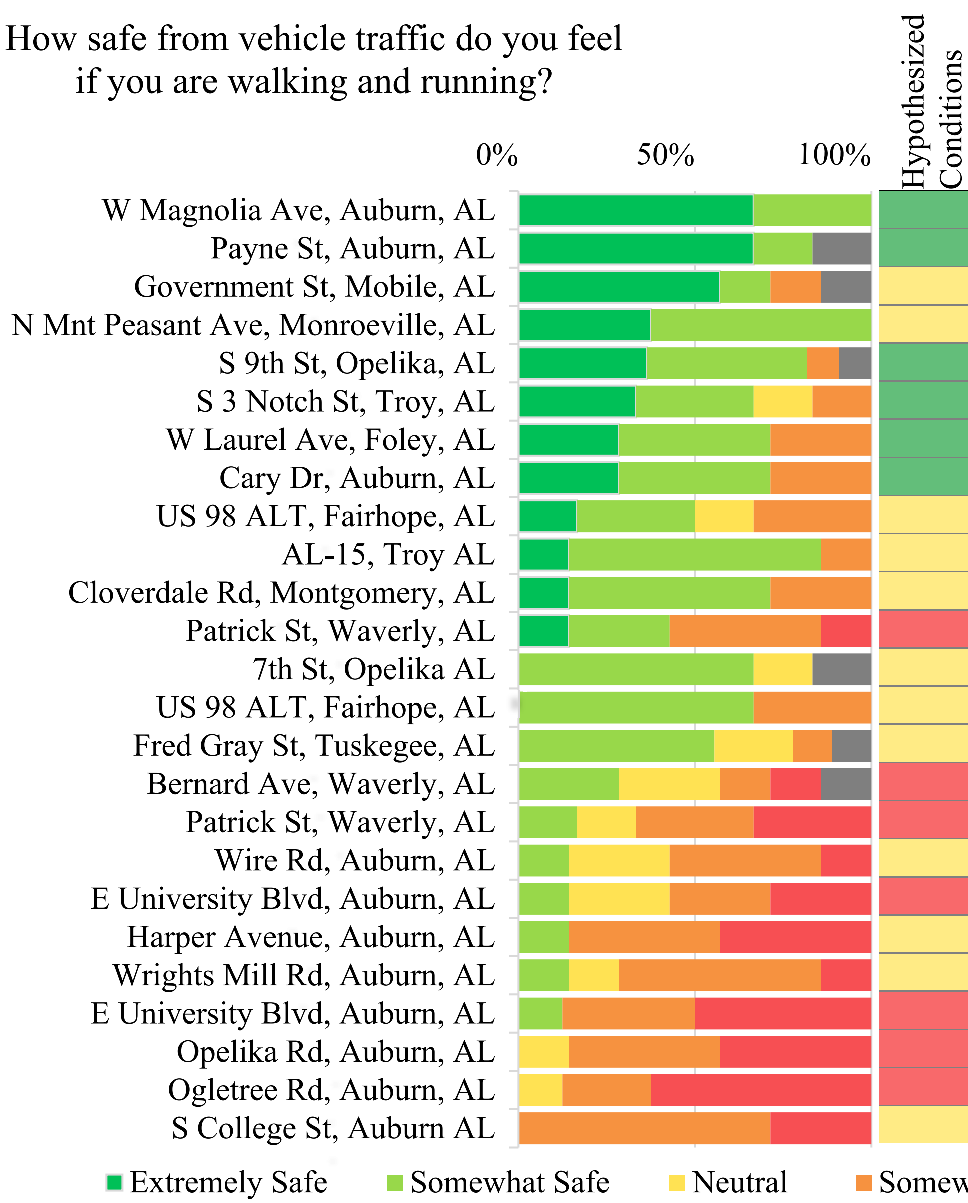
To begin, the responses documented by the question, “How safe from vehicle traffic do you feel if you are walking and running?”, can be seen in Figure 3.9. Overall, the perception of traffic as a pedestrian is evenly spread. Meaning, that the amount of positive and negative responses was relatively equal. This is supported by previous findings on pedestrian safety perception where the average perception was 3.00 (Table 3.3). The trending BE characteristics seen for the perception of pedestrian safety from vehicles are the segment is located downtown, sidewalk presence, and speed limit. These findings were determined by response concentrations and segment perception. The checkmarks for the factors located downtown and sidewalk characteristics are concentrated on the segments with more positive responses. These characteristics may show a positive impact on this perception. The speed limit factor shows higher speed limits for the segments with more negative responses. This shows that lower speed limits may have a positive impact on perception. As seen in Figure 3.9, the other characteristics are not concentrated on segments with either positive or negative segment perceptions.

Next, Figure 3.10 presents the perception, “How safe from vehicle traffic do you feel if you are riding a bicycle?”. Compared to the previous variable, perception as a bicyclist is more negative showing that individuals usually felt unsafe. This is also supported by the average of this variable which is lower than 3.00, seen in Table 3.3 with an average of 2.46. This perception also has higher speed limits concentrated in segments that are more negatively perceived. This shows that higher speed limits decrease the perception of safety as a bicyclist and thus show the possibility that lower speed limits have a positive impact on bicyclist safety perception. Along with speed limit, bicycle lanes and trail access show possible impact on this perception. This was determined by identifying the concentration of responses though in this case, since there is a more negative perception overall, there was a smaller number of segments with more positive perceptions. The concentration of responses for the two latter factors is shown to be in the negatively perceived segments. This shows that the presence of bicycle lanes and access to trails may decrease segment perception. However, this may also show the need for improving roadways that have bicyclist and trail infrastructure.

Figure 3.11 shows the responses to the question, “How well does this segment encourage physical activity?”. The response percentages for this perception have trends that follow more closely to the perception of pedestrian safety than bicyclist safety which is supported by an average of 2,81 (Table 3.3). The trending BE characteristics for this perception are lower speed limit and sidewalk presence, similar to pedestrian safety perception, along with crosswalk presence. This shows that lower speed limits, the presence of sidewalks, and the presence of crosswalks may positively impact the perception of a segment's ability to encourage physical activity.

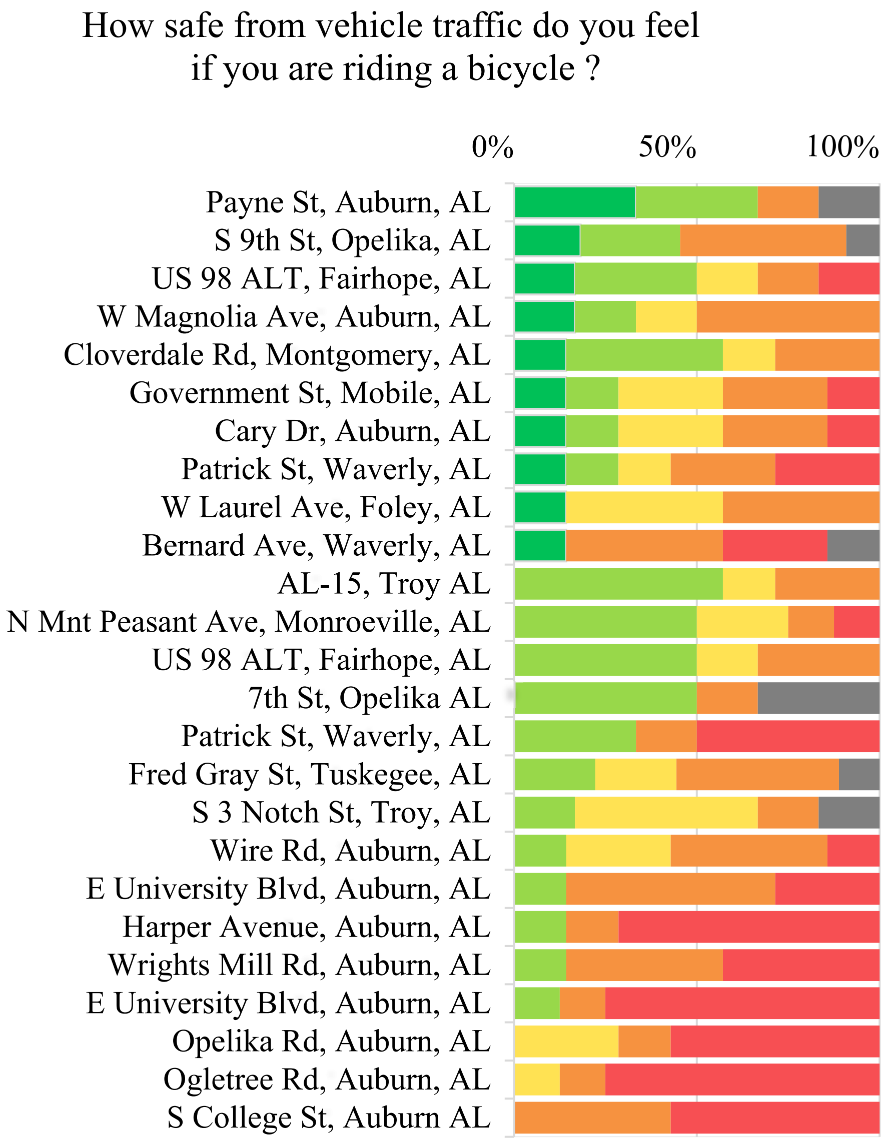
Response percentages for, “How well does this segment support older pedestrians?” can be seen in Figure 3.12. The response histogram for this perception contains more negative responses than positive responses. This is supported by the average perception seen in Table 3.3 of 2.49. The trends seen for this perception are located downtown, on-street parking spaces, sidewalk presence, crosswalk presence, and speed limit. The responses are concentrated on the segments with more positive perceptions. This shows that the perception of segment support for older pedestrians may be impacted by downtown areas, on-street parking, sidewalks, crosswalks, and lower speed limits.

Lastly, response percentages from the question “How well does this segment support children and strollers?” can be seen in Figure 3.13. This perception has more negative responses as well and is supported by the overall user perception average of 2.38 (Table 3.3). The trends seen for this perception are on-street parking spaces, sidewalk presence, crosswalk presence, and speed limit. The responses are concentrated on more positive segment perceptions. This shows that the perception of segment support for children and strollers may increase by implementing on-street parking, sidewalks, crosswalks, and lower speed limits. To summarize, each user perception had trending BE characteristics and many of them were repeatedly seen. In total, the trending characteristics are as follows: located downtown, sidewalk presence, speed limit, bicycle lane presence, trail access, on-street parking space, and crosswalk presence. This being said, the five perceptions are hypothesized to be impacted by the seven BE characteristics, or factors, stated previously.



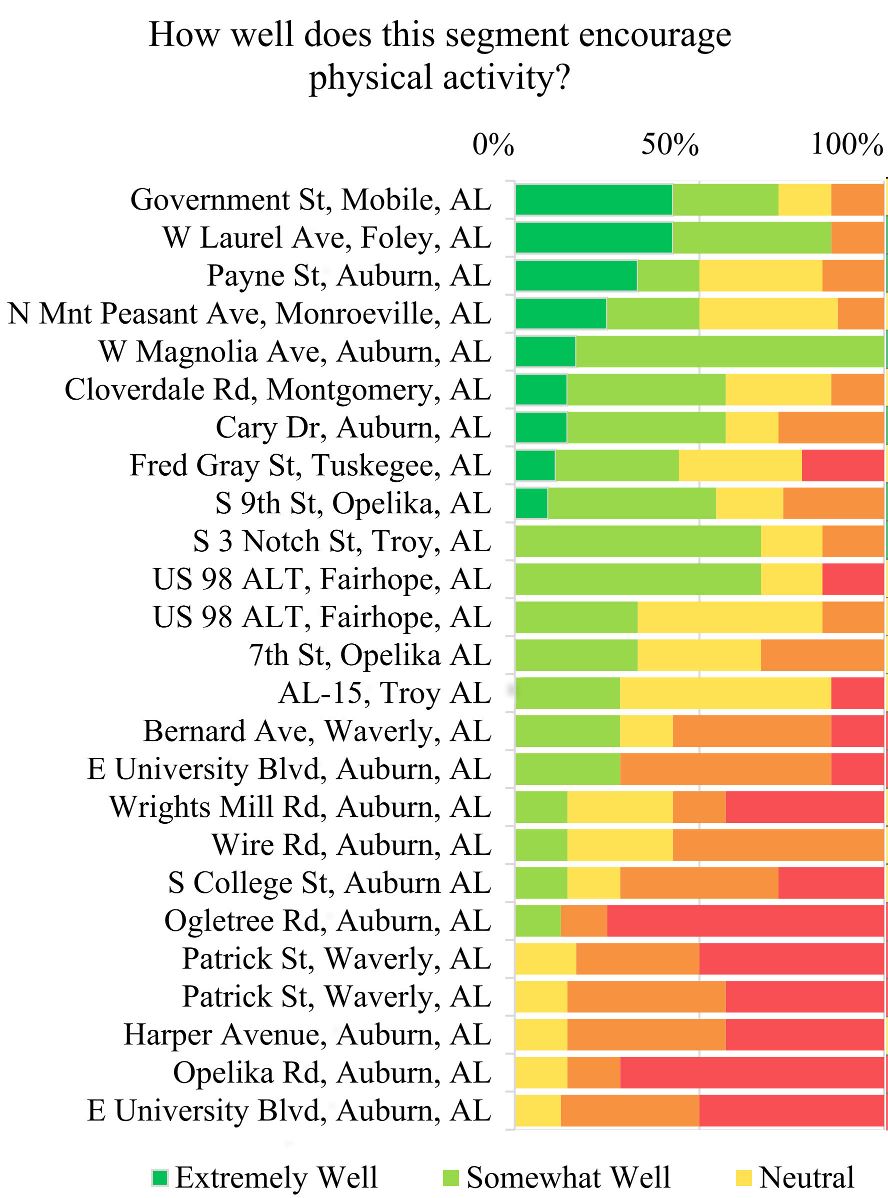
Segment	Located Downtown	Trail Access	Speed Sign	Turning Lane	Sidewalk	Buffer	Lanes	Lane Width (ft)	Vehicles per Hour	Speed Limit (mnh)
W Magnolia Ave, Auburn, AL	✓			✓	✓	✓	3	9.5	480	20
Payne St, Auburn, AL			✓		✓	✓	2	10.0	183	25
Government St, Mobile, AL	✓	✓		✓	✓	✓	5	10.0	1554	35
N Mnt Peasant Ave, Monroeville, AL	✓	✓			✓	✓	2	16.0	415	25
S 9th St, Opelika, AL	✓				✓	✓	2	10.0	109	35
S 3 Notch St, Troy, AL	✓				✓	✓	2	13.5	579	30
W Laurel Ave, Foley, AL	✓		✓	✓	✓		3	11.0	627	25
Cary Dr, Auburn, AL			✓		✓		2	13.0	34	25
US 98 ALT, Fairhope, AL		✓	✓		✓	✓	2	11.5	306	35
AL-15, Troy AL	✓			✓	✓	✓	2	17.5	579	30
Cloverdale Rd, Montgomery, AL		✓	✓				2	19.5	127	25
Patrick St, Waverly, AL	✓						2	10.0	47	25
7th St, Opelika AL						✓	2	14.0	32	30
US 98 ALT, Fairhope, AL		✓	✓		✓	✓	2	11.5	306	35
Fred Gray St, Tuskegee, AL	✓				✓		1	18.0	232	25
Bernard Ave, Waverly, AL							2	9.5	26	35
Patrick St, Waverly, AL	✓						2	10.0	47	25
Wire Rd, Auburn, AL		✓	✓	✓			5	14.0	645	40
E University Blvd, Auburn, AL		✓	✓	✓		✓	3	11.0	995	30
Harper Avenue, Auburn, AL			✓			✓	2	17.0	64	30
Wrights Mill Rd, Auburn, AL		✓	✓				2	10.5	547	35
E University Blvd, Auburn, AL		✓		✓		✓	3	11.0	995	30
Opelika Rd, Auburn, AL				✓		✓	5	11.5	1270	45
Ogletree Rd, Auburn, AL		✓	✓			✓	2	11.0	525	45
S College St, Auburn AL				✓	✓	✓	6	12.5	1433	45

Figure 3. 9 Pedestrian safety perception rates and select BE characteristics for each segment



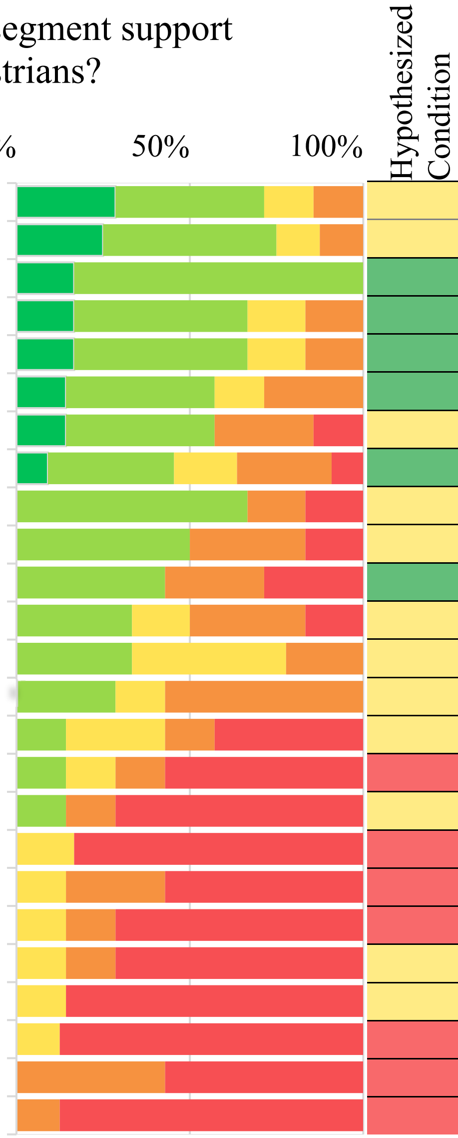
Segment	Hypothesized Condition	On Street Parking	Bicycle Lane	Trail Access	Speed Sign	Number of Lanes	Lane Width (ft)	Vehicles per Hour	Speed Limit (mph)
Payne St, Auburn, AL	Green				✓	2	10	183	25
S 9th St, Opelika, AL	Green	✓				2	10	109	35
US 98 ALT, Fairhope, AL	Yellow			✓	✓	2	12	306	35
W Magnolia Ave, Auburn, AL	Green	✓				3	10	480	20
Cloverdale Rd, Montgomery, AL	Yellow		✓	✓	✓	2	20	127	25
Government St, Mobile, AL	Yellow			✓		5	10	1554	35
Cary Dr, Auburn, AL	Green		✓		✓	2	13	34	25
Patrick St, Waverly, AL	Red	✓				2	10	47	25
W Laurel Ave, Foley, AL	Green	✓			✓	3	11	627	25
Bernard Ave, Waverly, AL	Red					2	10	26	35
AL-15, Troy AL	Yellow	✓				2	18	579	30
N Mnt Peasant Ave, Monroeville, AL	Yellow	✓		✓		2	16	415	25
US 98 ALT, Fairhope, AL	Yellow			✓	✓	2	12	306	35
7th St, Opelika AL	Yellow					2	14	32	30
Patrick St, Waverly, AL	Red					2	10	47	25
Fred Gray St, Tuskegee, AL	Yellow	✓				1	18	232	25
S 3 Notch St, Troy, AL	Green	✓				2	14	579	30
Wire Rd, Auburn, AL	Yellow		✓	✓	✓	5	14	645	40
E University Blvd, Auburn, AL	Red		✓	✓	✓	3	11	995	30
Harper Avenue, Auburn, AL	Yellow				✓	2	17	64	30
Wrights Mill Rd, Auburn, AL	Yellow		✓	✓	✓	2	11	547	35
E University Blvd, Auburn, AL	Red		✓	✓		3	11	995	30
Opelika Rd, Auburn, AL	Red					5	12	1270	45
Ogletree Rd, Auburn, AL	Red		✓	✓	✓	2	11	525	45
S College St, Auburn AL	Yellow					6	13	1433	45

Figure 3. 10 Bicyclist safety perception rates and select BE characteristics for each segment



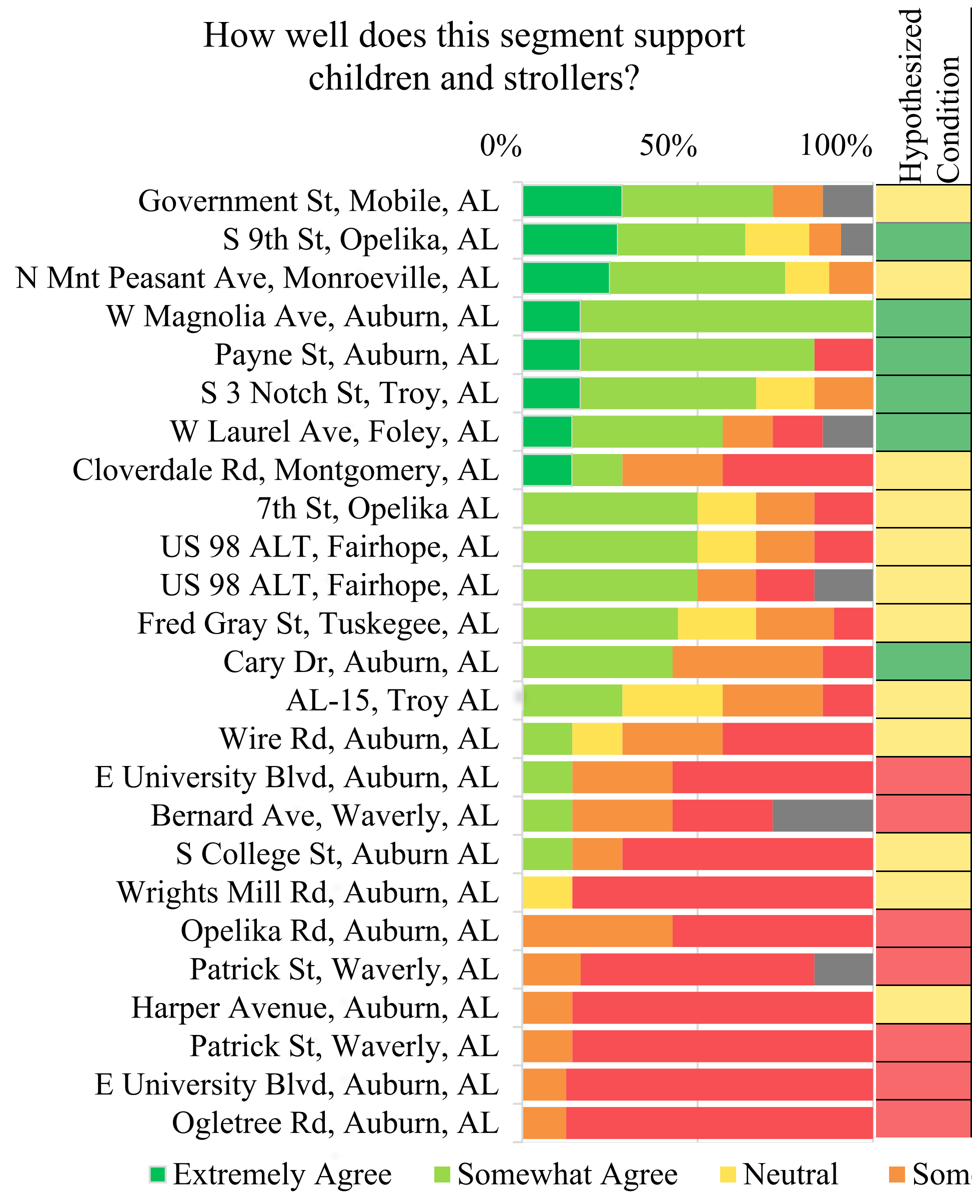
Segment	Hypothesize Condition	Park Access	Trail Access	Bicycle Lan	Sidewalk	Crosswalk	Lanes	Vehicles per Hour	Speed Limit (mph)
Government St, Mobile, AL			✓		✓	✓	5	1554	35
W Laurel Ave, Foley, AL					✓	✓	3	627	25
Payne St, Auburn, AL					✓		2	183	25
N Mnt Peasant Ave, Monroeville, AL			✓		✓	✓	2	415	25
W Magnolia Ave, Auburn, AL					✓	✓	3	480	20
Cloverdale Rd, Montgomery, AL			✓	✓			2	127	25
Cary Dr, Auburn, AL		✓		✓	✓	✓	2	34	25
Fred Gray St, Tuskegee, AL		✓			✓	✓	1	232	25
S 9th St, Opelika, AL		✓			✓	✓	2	109	35
S 3 Notch St, Troy, AL					✓	✓	2	579	30
US 98 ALT, Fairhope, AL			✓		✓	✓	2	306	35
US 98 ALT, Fairhope, AL		✓	✓		✓	✓	2	306	35
7th St, Opelika AL							2	32	30
AL-15, Troy AL					✓	✓	2	579	30
Bernard Ave, Waverly, AL							2	26	35
E University Blvd, Auburn, AL		✓	✓	✓			3	995	30
Wrights Mill Rd, Auburn, AL			✓	✓			2	547	35
Wire Rd, Auburn, AL		✓	✓	✓		✓	5	645	40
S College St, Auburn AL		✓			✓		6	1433	45
Ogletree Rd, Auburn, AL		✓	✓	✓			2	525	45
Patrick St, Waverly, AL							2	47	25
Patrick St, Waverly, AL							2	47	25
Harper Avenue, Auburn, AL							2	64	30
Opelika Rd, Auburn, AL							5	1270	45
E University Blvd, Auburn, AL		✓	✓	✓		✓	3	995	30

Figure 3. 11 Segment encouragement of PA perception rates and BE characteristics



Segment	Located Downtown	Trail Access	On Street Parking	Sidewalk	Pedestrian Signage	Crosswalk	Vehicles per Hour	Speed Limit (mph)
Government St, Mobile, AL	✓	✓		✓		✓	1554	35
N Mnt Peasant Ave, Monroeville, AL	✓	✓	✓	✓	✓	✓	415	25
W Magnolia Ave, Auburn, AL	✓		✓	✓	✓	✓	480	20
S 3 Notch St, Troy, AL	✓		✓	✓		✓	579	30
Payne St, Auburn, AL				✓			183	25
W Laurel Ave, Foley, AL	✓		✓	✓		✓	627	25
Cloverdale Rd, Montgomery, AL		✓					127	25
S 9th St, Opelika, AL	✓		✓	✓	✓	✓	109	35
US 98 ALT, Fairhope, AL		✓		✓		✓	306	35
US 98 ALT, Fairhope, AL		✓		✓	✓	✓	306	35
Cary Dr, Auburn, AL				✓		✓	34	25
7th St, Opelika AL							32	30
Fred Gray St, Tuskegee, AL	✓		✓	✓		✓	232	25
AL-15, Troy AL	✓		✓	✓		✓	579	30
Wire Rd, Auburn, AL		✓				✓	645	40
E University Blvd, Auburn, AL		✓					995	30
S College St, Auburn AL				✓			1433	45
Patrick St, Waverly, AL	✓						47	25
Bernard Ave, Waverly, AL							26	35
Patrick St, Waverly, AL	✓		✓				47	25
Wrights Mill Rd, Auburn, AL		✓					547	35
Harper Avenue, Auburn, AL							64	30
E University Blvd, Auburn, AL		✓			✓	✓	995	30
Opelika Rd, Auburn, AL							1270	45
Ogletree Rd, Auburn, AL		✓					525	45

Figure 3. 12 Segment support for older pedestrian perception rates and BE characteristics



Segment	Park Access	Trail Access	On Street Parking	Sidewalk	Pedestrian Signage	Crosswalk	Vehicles per Hour	Speed Limit (mph)
Government St, Mobile, AL		✓		✓		✓	1554	35
S 9th St, Opelika, AL	✓		✓	✓	✓	✓	109	35
N Mnt Peasant Ave, Monroeville, AL		✓	✓	✓	✓	✓	415	25
W Magnolia Ave, Auburn, AL			✓	✓	✓	✓	480	20
Payne St, Auburn, AL				✓			183	25
S 3 Notch St, Troy, AL			✓	✓		✓	579	30
W Laurel Ave, Foley, AL			✓	✓		✓	627	25
Cloverdale Rd, Montgomery, AL		✓					127	25
7th St, Opelika AL							32	30
US 98 ALT, Fairhope, AL	✓	✓		✓	✓	✓	306	35
US 98 ALT, Fairhope, AL		✓		✓		✓	306	35
Fred Gray St, Tuskegee, AL	✓		✓	✓		✓	232	25
Cary Dr, Auburn, AL	✓			✓		✓	34	25
AL-15, Troy AL			✓	✓		✓	579	30
Wire Rd, Auburn, AL	✓	✓				✓	645	40
E University Blvd, Auburn, AL	✓	✓					995	30
Bernard Ave, Waverly, AL							26	35
S College St, Auburn AL	✓			✓			1433	45
Wrights Mill Rd, Auburn, AL		✓					547	35
Opelika Rd, Auburn, AL							1270	45
Patrick St, Waverly, AL							47	25
Harper Avenue, Auburn, AL							64	30
Patrick St, Waverly, AL			✓				47	25
E University Blvd, Auburn, AL	✓	✓			✓	✓	995	30
Ogletree Rd, Auburn, AL	✓	✓					525	45

Figure 3. 13 Segment support of children perception rates and BE characteristics

Chapter 4: Roadway Perception Model Estimation

This chapter presents both the ordinal probit regression model methodology used to estimate the five perception equations as well as the results of each estimation. The five segment perceptions include (a) pedestrian safety from vehicular traffic, (b) bicyclist safety from vehicular traffic, (c) segment encouragement of physical activity, (d) segment support of children and strollers, and (e) segment support of older pedestrians.

4.1 Ordinal Probit Regression Methodology

This thesis utilized an ordinal probit regression model to determine the significant factors that impact roadway perception relating to active travel. The perception of five different activities and user groups was determined. This model is the most appropriate regression for predicting segment perceptions because ordinal values (i.e., meaning that there are more than two values that are ranked or on a scale) were used to measure each dependent variable. Specifically, respondents described their perception of different user groups in the following choices: extremely safe/well, somewhat safe/well, neutral, somewhat unsafe/poor, or extremely unsafe/poor. Additionally, the independent variables included in the analysis fit the criteria for this regression type (i.e., continuous, categorical, and ordinal).

The ordered probit regression operates by determining an underlying continuous function that relates the variables, not unlike the linear regression model. This unitless continuous function calculates a segment perception rating based on the independent variables and can be written as:

$$y^* = \beta' x_n + \varepsilon_n$$

Where

y^*= segment perception rating (continuous)

β'= matrix of estimated coefficients

x_n= matrix of independent variables impacting *n*

ε_n= error term

The ε_n term is assumed to be normally distributed and independent from x_n. Following the ordinal regression methodology, the respondent's final perception choice is then determined using y_n and can be related to the continuous function with the equations below:

y_1 = extremely unsafe/poor	if $y^* \leq \gamma_1$
y_2 = somewhat unsafe/poor	if $\gamma_1 \leq y^* \leq \gamma_2$
y_3 = neutral	if $\gamma_2 \leq y^* \leq \gamma_3$
y_4 = somewhat safe/well	if $\gamma_3 \leq y^* \leq \gamma_4$
y_5 = extremely safe/well	if $\gamma_4 \leq y^*$

where the variable γ_k represents the thresholds. These thresholds break the continuous function into the different choices of perception, Figure **. For example, a segment with a perception rating that falls in between γ_2 and γ_3 would most likely result in a prediction rating of "somewhat unsafe". The thresholds calculated are determined by the regression model and are not required to be evenly spaced. Thresholds also vary for each estimation.

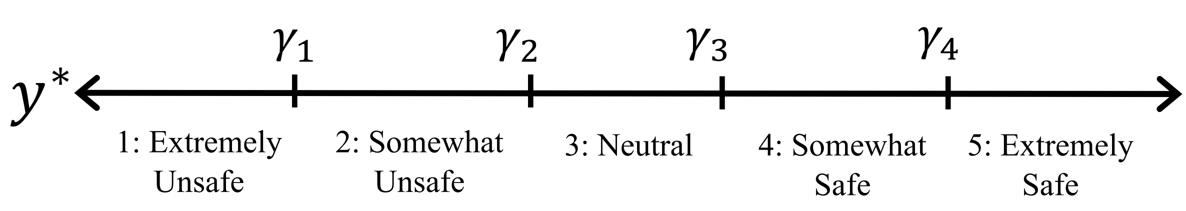


Figure 4. 1 Segment perception scale

The term "most likely" was used intentionally since this regression method uses maximum log-likelihood to determine the threshold and coefficient estimations. This estimation can be written as

$$logL = \sum_{k=1}^{K} \ln\Pr\,(y_n, x_k|\beta, \gamma_n)$$

Where

$logL$ = log-likelihood maximization

k = observed choices

Pr = probability functions

The probability functions determine the likelihood between 0 to 1 that a given event will happen. Probability functions are different for each choice and can be written as

$$\Pr\,(y_1) = \phi(\gamma_1 - \beta' x_n)$$

$$\Pr(y_2) = \phi(\gamma_2 - \beta' x_n) - \phi(\gamma_1 - \beta' x_n)$$

$$\Pr(y_3) = \phi(\gamma_3 - \beta' x_n) - \phi(\gamma_2 - \beta' x_n)$$

$$\Pr(y_4) = \phi(\gamma_4 - \beta' x_n) - \phi(\gamma_3 - \beta' x_n)$$

$$\Pr(y_5) = 1 - \phi(\gamma_4 - \beta' x_n)$$

Using this methodology, the models were iteratively estimated by removing independent variables that were redundant until a final model was determined. Notably, one variable proved redundant but was included in the final model since only two dependent variables were affected. The log-likelihood test values of the final estimations, Table 4.1, were all greater than the chisquared values which show that the final estimations seen in Table 4.2 describe the choice behavior better than the constants-only estimations.

Table 4. 1 Ordinal probit regression estimation information

	Model Fitting Information			Pseudo R-Square		Log Likelihood
Segment Perception	X^2	df	p-value	Cox and Snell	Nagelkerke	Final
Safety from traffic as a pedestrian	133.007	21	0.000	0.556	0.584	311.078
Safety from traffic as a bicyclist	87.045	21	0.000	0.414	0.435	360.002
Encourages physical activity	128.274	21	0.000	0.530	0.555	342.483
Supports children and strollers	187.376	21	0.000	0.681	0.723	233.669
Supports elderly individuals	166.459	21	0.000	0.624	0.660	286.011

4.2 Model Results

The factors mentioned in the previous sections were included in the final ordinal probit estimation including user perception, respondent community type, segment land use, roadway characteristics, and active travel characteristics, Table 4.2. Factors with 85% confidence were included in the final model This confidence level was selected due to the novelty of the study. The final estimated coefficients seen in Table 4.2, show the impact of each segment factor on the five segment perceptions (a) pedestrian safety from vehicular traffic, (b) bicyclist safety from vehicular traffic, (c) segment encouragement of physical activity, (d) segment support of children and strollers, and (e) segment support of older pedestrians. However, the increase and decrease of each coefficient imply relative influence on the variables, assuming that all other factors are held constant.

Table 4. 2 Ordered Probit Results for User Perceptions

	Pedestrian Safety		Bicyclist Safety		Physical Activity		Support for Children		Support for Elderly	
Variable	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Threshold										
1 (γ_1)	-2.69	—	-0.96	—	-1.53	—	6.62	***	1.54	—
2 (γ_2)	-0.17	—	1.10	—	0.43	—	8.58	****	3.34	—
3 (γ_3)	0.46	—	1.99	—	1.83	—	9.33	****	4.34	**
4 (γ_4)	3.23	—	4.00	**	4.43	***	13.02	****	7.55	****
User Perspective:										
Sidewalk Condition	0.76	****	0.71	****	0.99	****	1.83	****	1.36	****
Respondent Community Type										
Suburban	1.16	***	—	—	—	—	1.59	****	1.01	***
Rural	—	—	1.01	****	—	—	—	—	—	—
Segment Land Use										
Downtown Area	—	—	—	—	-1.55	*	—	—	—	—
Trail Access	—	—	1.99	**	—	—	—	—	2.66	***
Roadway Characteristics										
Vehicles per Minute	-0.13	**	—	—	—	—	-0.15	**	—	—
Posted Speed Limit	—	—	—	—	-0.07	*	0.10	**	—	—
Number of Lanes	—	—	—	—	—	—	—	—	—	—
Width of Lane	-0.20	***	—	—	—	—	-0.19	**	—	—
Vehicles Parked in Roadway	—	—	—	—	—	—	—	—	—	—
On Street Parking	—	—	—	—	—	—	—	—	—	—
Parking Space Width	—	—	—	—	0.23	*	0.28	*	—	—
Active Transportation Characteristics										
Unpaved Pathways	—	—	—	—	2.09	**	3.96	***	—	—
Visible Bicycle Lane	—	—	-1.73	***	—	—	-3.00	****	-2.78	****
Presence of Curbs	—	—	—	—	2.16	*	4.66	****	3.34	***
Sidewalk Width	—	—	-0.53	*	—	—	-0.57	*	-0.68	**
Continuous Sidewalks	—	—	—	—	—	—	—	—	—	—
Number of Driveways	—	—	—	—	—	—	—	—	-0.41	*
Buffer Width	0.23	****	—	—	—	—	0.20	***	0.15	***
Crosswalks at Intersection	3.18	**	4.75	***	3.38	**	19.75	****	20.60	****
Visible Crosswalks	—	—	-2.34	*	—	—				

* 85% significance   **90% significance   *** 95% significance   **** 99% significance

The thresholds for each estimation can be seen in Table 4.2 as well. Threshold 4 (e.g., the partition between choices somewhat safe and extremely safe) is the only consistently significant threshold throughout the five estimations. This threshold is the only significant threshold for three estimations: perceptions of segment safety as a pedestrian, safety as a bicyclist, and encouragement of physical activity. This result relates that there is no significant difference between the choices neutral, somewhat unsafe, and extremely unsafe. Along with Threshold 4, Thresholds 1, 2, and 3 were also significant for the model estimating perception of segment support for children. This shows that the differences between all choices were meaningful. The last estimation, perceived support for older pedestrians, showed that Thresholds 3, and 4 were significant. This shows that there were meaningful differences between answer choices extremely safe, somewhat safe, and neutral. These trends highlight the higher-ranking answer choices showing a meaningful difference between perceptions of neutral, somewhat safe, and extremely safe. In most of the estimations, the perception of extremely unsafe/poor and somewhat unsafe/poor are very similar.

4.2.1 Segment Perception Discussion

The coefficients were organized into five sections: user perspective, community type, land use, roadway characteristics, and active transportation characteristics, Table 4.2. Out of the 21 factors included in the final estimations, each estimation is influenced by a select number of different factors. Perception of pedestrian safety is influenced by the six factors, the lowest number of influences. Perceptions of bicyclist safety and encouragement of physical activity are influenced by seven factors. The perception of segment support for children had the highest number of influencing factors at 12 and the perception of segment support for older pedestrians followed with 9 factors. Sidewalk conditions and the presence of crosswalks at intersections positively influenced all five models. Positive influence can be interpreted as sidewalk conditions improve estimation perceptions increase as well. The presence of crosswalks at intersections shows that all perception scores increase when crosswalks are present at segment intersections. The latter factor has the biggest impact on each estimation than any other factor. Notably, the two factors had a greater effect on children and older pedestrian estimation showing that sidewalk condition and the presence of crosswalks at intersections have a greater influence on the perception of support for vulnerable age populations. Three factors included in the final estimations (i.e., parked vehicles, on-street parking, and sidewalk continuity) did not have significant differences from the other factors and thus did not affect any of the estimations. However, similar factors, the width of on-street parking and the number of driveways, significantly influenced some of the estimations.

Perception of pedestrian safety from vehicle traffic is influenced by sidewalk condition, suburban community type, number of vehicles per minute, the width of roadway lanes, the width of buffer, and the presence of crosswalks at intersections. Respondent community type has an impact on this estimation, though only for respondents from suburban communities, rural community type does not impact the perception of pedestrian safety. Number of vehicles per minute has a negative impact which can be interpreted as, for every vehicle counted the perception of pedestrian safety decreases, this result supports literature previously reviewed. The width of the lane negatively affects the perception of pedestrian safety as well, for every unit increase in lane width perception decreases. This coefficient also follows previously reviewed materials on the impact of wide roadways on pedestrian safety. As stated previously intersection crosswalks have the greatest impact on pedestrian safety perceptions showing that this factor greatly influences pedestrians.

Perception of bicyclist safety from vehicle traffics is influenced by sidewalk condition, rural community type, trail access, visible bicycle lane, the width of the sidewalk, presence of crosswalks at intersections, and visible crosswalks. Respondent community type has a positive impact on the perception of bicyclist safety, interpreted as users that live in rural communities will positively influence estimation. Access to trails, and courses also have a positive influence on this estimation. This follows literature as trails, shared-use pathways, and other similar types of infrastructure support outdoor activities such as bicycling. The other factors affecting this estimation are active transportation characteristics and do not follow common trends seen in the literature. These factors, visible bicycle lanes, the width of the sidewalk, and visible crosswalks all have negative impacts on estimation. Visible bicycle lane markings or the presence of bicycle lane is thought to have a positive influence on perception since it gives cyclists a space of their own. This particular trend may be the result of bicyclists preferring the width of car lanes to the much narrow bicycle lanes. Sidewalks having a negative impact on estimation shows that for every unit increase of sidewalk, width decreases the perception of bicyclist safety. The presence of crosswalks has a negative impact on segment perception scores unless the crosswalks service the intersection. This result does not support the literature on the importance of midblock crossings.

The perception of how well a segment encourages physical activity was influenced by the following factors: sidewalk condition, downtown location, speed limit, on-street parking spaces, presence of unpaved paths, presence of curbs, and presence of crosswalks at intersections. These results show that an increase in sidewalk conditions will increase the perception that the segment encourages physical activity. However, if the segment is located in a downtown area, the perception will decrease. Increasing the speed limit by one unit decreases the estimation as well which follows the literature on negative perceptions of high speeds relating to walkability. The width of parking spaces also influences the estimation, as the width increases so does the perception score. The presence of unpaved paths and curbs also increases the perception score. These factors show that the presence of parking and active transportation characteristics is beneficial for encouraging physical activity.

The perception of how well a segment supports children and strollers is described by the following factors: sidewalk condition, suburban community type, number of vehicles, speed limit, the width of lanes, width of on-street parking spaces, presence of unpaved paths, visible bicycle lanes, presence of curbs, the width of the sidewalk, width of buffer, and presence of crosswalks at intersections. The impact of sidewalk conditions and respondents having a suburban community type follow the same behavior as the previous estimations. The roadway characteristic factors also follow the same behavior seen previously, except for the speed limit. Curiously, an increase in speed limit increases perception score as well. This result does not follow the literature previously discussed. The other roadway characteristics, increasing the number of vehicles and lane width both decrease perception scores while increasing parking space width increases perception. The factors that characterize active travel have the most impact on this estimation highlighting the importance of active transportation in child-friendly segments. The presence of unpaved paths, curbs, and crosswalks at intersections, and increasing buffer width would improve perception scores. However, the presence of bicycle lanes and increasing sidewalk width would decrease perception scores.

Finally, the factors influencing the perception of how well a segment supports older pedestrians are listed: sidewalk condition, suburban community type, trail access, number of driveways, visible bicycle lanes, the presence of curbs, the width of the sidewalk, the width of buffer, and the presence of crosswalks at intersections. This prediction is not influenced by factors characterized by roadway elements. The majority of influence is from active transportation characteristics. Each factor follows the same behaviors as in the previous estimations as well (e.g., access to trails increases perception score) except driveway interruptions, a factor only significant for this specific estimation. An increase in the number of driveways in the segment decreases this perception score, along with increasing sidewalk width and the presence of visible bicycle lanes. Support for older pedestrians can increase by suburban community type, the presence of trail access, curbs, crosswalks at intersections, and increasing sidewalk width and condition.

Chapter 5: AT Assessment Scorecard

Finally, to translate this academic work into practice, an easy-to-implement scorecard was developed (seen in Figure 5.1). This scorecard assessment tool represents a combination of the best aspects of a questionnaire (i.e. easy to understand and answer) and a LOS tool (i.e. provides a quantifiable value for comparison and ranking). Overall, the scorecard was designed to simplify data collection and the scoring process. As such, the five different models are presented on the scorecard in a way that requires no knowledge of modeling, and anyone in a rural community can assess a roadway segment on these five factors. Ideally, communities would use the assessment tool to evaluate many different roadway segments, collecting data and scoring each. These scores would be compared to determine which segments had the best and worst scores, so hopefully those with the worst relative scores would be improved.

The front of the scorecard lists the BE characteristics (i.e., questions 1 through 16) and provides the estimated coefficients for each model (which are each identified by a unique icon). This grid like structure visually shows the significant factors for each model. After users provide the required information about each segment, its value is assigned to each question and then multiplied to the coefficients in the neighboring five columns. Though the calculations may seem complex to some users, care was taken to make this process as easy as possible. Additionally, presenting the models as such supports transparency of the estimations while showing users the individual impacts of each factor.

The back of the scorecard shares a visualization of the estimated thresholds. This page connects the scores calculated on the front side to the user perspective ratings (e.g., unsafe, somewhat unsafe, neutral, somewhat safe, safe!). The last step of the scorecard summarizes each user perception rating in a final tally. This final summary is important so communities can understand how each roadway segment may be supportive of different AT user groups. Not every segment needs to support every AT user group, and this assessment tool allows engineers, planners and everyday citizens the ability to recognize which segments will support their community best.

Active Transportation Assessment Scorecard

Flip!

Segment ID:__________________ Date:___/____/________ Time:____:_____am / pm

	Step 1. Answer the questions. Circle/write the number assigned to each question below.		Step 2. Multiply the numbers with each coefficient below				
1	What community type do YOU live in?	Suburban(1)	x1.16=_____			x1.59=_____	x1.01=_____
		Rural (1)		x1.01=_____			
2	This segment is located downtown	Yes (1) No (0)			x1.55= -_____		
3	This segment provides trail access	Yes (1) No (0)		x1.99=______			x2.66=______
I spy with my little eye…							
4	Posted speed limit sign	Yes (1) No (0)			x0.07= -_____	x0.10=______	
5	Unpaved paths along the roadway	Yes (1) No (0)			x2.09=_____	x3.96=______	
6	Visible bike lane markings	Yes (1) No (0)		x1.73= -_____		x3.00= -_____	x2.78= -_____
7	Crosswalks at intersections	Yes (1) No (0)	x3.18=_____	x4.75=_____	x3.38=______	x19.8=______	x20.6=_____
8	Visible crosswalk markings	Yes (1) No (0)		x2.34= -_____			
9	Curbs	Yes (1) No (0)			x2.16=_____	x4.66=_____	x3.34=_____
Everything counts!							
10	Number of vehicles that pass by in 1 minute	________	x0.13= -________			x0.15= -_________	
11	Number of driveways	________					x0.41= -_____
Put your engineering hat on!							
12	Width of 1 lane	_______ ft	x0.20= -____			x0.19= -____	
13	Parking width	_______ ft			x0.23=_____	x0.28=_____	
14	Sidewalk width	_______ ft		x0.53= -____		x0.57= -____	x0.68= -____
15	Buffer/shoulder width	_______ ft	x0.23=_____			x0.20=______	x0.15=_____
16	Rank sidewalk maintenance Good>>Neutral>>Poor 5>>>4>>>3>>>2>>>1	Rank: _________	x0.76=_____	x0.71=_____	x0.99=_____	x1.83=_____	x1.36=_____
Step 3. Calculate your scores! Add up the values in each column and remember, mind the negatives! Or go to http://www.aupartnerprogram.com			__________	__________	___________	___________	___________
			Each column will get its own have a score!				Flip!

Figure 5. 1 Active Transportation Assessment Scorecard

Active Transportation Assessment Scorecard

Start

Segment ID:__________________ Date:___/____/________ Time:____:_____am/pm

Step 4. Fill in the calculated scores from the front page. Compare your scores to the scale bar to find out how the public feels about active transportation on your roadway segment.

Pedestrians feel safe from vehicle traffic

Score: ________

Unsafe	Somewhat Unsafe	Neutral	Somewhat Safe	Safe!

-2.69 | -0.17 | 0.46 | 3.23

Improvements: Provide crosswalks at intersections, reduce lane widths, increase buffer or shoulder widths, and maintain sidewalks.

Bicyclists feel safe from vehicle traffic

Score: ________

Unsafe	Somewhat Unsafe	Neutral	Somewhat Safe	Safe!

-0.96 | 1.10 | 1.99 | 4.00

Improvements: Provide trail access, and maintain sidewalks

This segment encourages physical activity

Score: ________

Discouraging	Somewhat Discouraging	Neutral	Somewhat Encouraging	Encouraging!

-1.53 | 0.43 | 1.83 | 4.43

Improvements: Provide crosswalks at intersections, include curbs, increase on street parking widths, and maintain sidewalks

Segment supports children and strollers

Score: ________

Unsupportive	Somewhat Unsupportive	Neutral	Somewhat Supportive	Supportive!

6.62 | 8.58 | 9.33 | 13.02

Improvements: Provide crosswalks at intersections, include curbs, reduce lane widths, increase on street parking widths, increase buffer or shoulder widths, and maintain sidewalks

Segment supports older pedestrians

Score: ________

Unsupportive	Somewhat Unsupportive	Neutral	Somewhat Supportive	Supportive!

1.54 | 3.34 | 4.34 | 7.55

Improvements: Provide trail access, provide crosswalks at intersections, include curbs, reduce, number of driveways, increase buffer or shoulder widths, and maintain sidewalks

PREDICTED SEGMENT IMPACT ON USER PERCEPTION

Pedestrians feel ____ from vehicle traffic	Bicyclists feel ____ from vehicle traffic	Segment encourages physical activity ____	Segment supports children & strollers ____	Segment supports older pedestrians ____

Figure 5. 1 (cont.) Active Transportation Assessment Scorecard

Chapter 6: Conclusion

This research paper shows the development of AT assessment models to help fill the gap in AT planning resources for rural communities. Small rural communities often struggle with improving pedestrian and bicyclist-friendly transportation infrastructure. Though many assessment tools are available to the public, most cater to more urban areas. Assessment tools are also challenging to complete due to complexity, which stem from high levels of understanding, time requirements, and lack of resources (e.g., staff, institutions, funding, education). To mitigate these disparities, AT assessment models were created to assist communities in assessing walkability. The models highlighted significant BE characteristics and their impact on user perspectives. This paper follows a unique process to create AT assessment models through an analysis of the relationship between built environment characteristics and user perceptions.

To develop the final scorecard tool, the research team collected video-based assessment surveys to identify the significant factors affecting AT perception. This process began by selecting 25 segments in 7 different counties of Alabama. The segments ranged in condition, land use, and roadway type. Data was collected for every segment, including BE characteristics and user perception User perception was documented using video-based surveys and were created based on the reviewed factors that influence walkability and AT. The two data sets were then combined and analyzed using the ordinal probit regression approach. This allowed for the estimation of five models. These models are as follows: (a) perceived safety from vehicle traffic as a pedestrian, (b) perceived safety from vehicle traffic as a bicyclist, (c) perceived segment encouragement for physical activity, (d) perceived segment support for older pedestrians, and (e) perceived segment support for children and strollers. These perceptions were chosen as they show perceived walkability for different users and commonly disadvantaged groups.

The resulting models present a range of BE factors influencing the perceptions of AT safety and adoption. The analysis determined the statistically significant factors at the 85% confidence level. User perception of sidewalk maintenance proved to influence all five models. The other factors, including community type, segment land use, roadway characteristics, and AT characteristics varied for each model. The thresholds for segment support for children and strollers were all significant, showing that there was a significant difference between levels of perceived safety.

To summarize, the research process highlighted influential BE characteristics that impact AT user perceptions. The estimates captured BE characteristics from many segments in Alabama, varying in condition, and perspectives from professionals and community members. Rural local perspectives were also included, providing rural communities a voice and representing their perception of AT and walkability.

6.1 Limitations and Further Research

This research process does come with limitations. Since many of the survey responses came from residents of a few counties of Alabama, the models are calibrated to the eastern Alabama region. This being said, larger sample sizes and samples from many other counties of Alabama would create more robust model estimates. Recommendations for future work include validation for the estimated models in terms implementation and assessment outcomes. Additionally, it is useful to explore the impact of infrastructure improvements on the scores generated by the scorecard, along with comparing scores to actual community priorities. Furthermore, it is beneficial to consider how to incorporate the scorecard outcomes into planning documents and processes, aiding in segment assessments and identification of influential BE improvements.

References

1. Conservancy, R.-T. Why Active Transportation | Rails-to-Trails Conservancy. https://www.railstotrails.org/partnership-for-active-transportation/why/. Accessed Jun. 23, 2022.
2. Ashraf, M. T., K. Dey, and D. Pyrialakou. Investigation of Pedestrian and Bicyclist Safety in Public Transportation Systems. *Journal of Transport & Health*, Vol. 27, 2022, p. 101529. https://doi.org/10.1016/j.jth.2022.101529.
3. Complete Streets. *Smart Growth America*. https://smartgrowthamerica.org/what-are-complete-streets/. Accessed Nov. 1, 2022.
4. Nasar, J. L. *Creating Places That Promote Physical Activity: Perceiving Is Believing*. Active Living Research, 2015, p. 10.
5. Grabow, M. L., M. Bernardinello, A. J. Bersch, C. D. Engelman, A. Martinez-Donate, J. A. Patz, P. E. Peppard, and K. M. C. Malecki. What Moves Us: Subjective and Objective Predictors of Active Transportation. *Journal of Transport & Health*, Vol. 15, 2019, p. 100625. https://doi.org/10.1016/j.jth.2019.100625.
6. Bigazzi, A., F. Ausri, L. Peddie, D. Fitch, and E. Puterman. Physiological Markers of Traffic-Related Stress during Active Travel. *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 84, 2022, pp. 223–238. https://doi.org/10.1016/j.trf.2021.12.003.
7. Tewahade, S., K. Li, R. B. Goldstein, D. Haynie, R. J. Iannotti, and B. Simons-Morton. Association between the Built Environment and Active Transportation among U.S. Adolescents. *Journal of Transport & Health*, Vol. 15, 2019, p. 100629. https://doi.org/10.1016/j.jth.2019.100629.
8. Smith, M., J. Hosking, A. Woodward, K. Witten, A. MacMillan, A. Field, P. Baas, and H. Mackie. Systematic Literature Review of Built Environment Effects on Physical Activity and Active Transport – an Update and New Findings on Health Equity. *International Journal of Behavioral Nutrition and Physical Activity*, Vol. 14, No. 1, 2017, p. 158. https://doi.org/10.1186/s12966-017-0613-9.
9. Gauvin, L., L. Richard, C. L. Craig, M. Spivock, M. Riva, M. Forster, S. Laforest, S. Laberge, M.-C. Fournel, H. Gagnon, S. Gagné, and L. Potvin. From Walkability to Active Living Potential: An "Ecometric" Validation Study. *American Journal of Preventive Medicine*, Vol. 28, No. 2, 2005, pp. 126–133. https://doi.org/10.1016/j.amepre.2004.10.029.
10. Casagrande, S. S., M. C. Whitt-Glover, K. J. Lancaster, A. M. Odoms-Young, and T. L. Gary. Built Environment and Health Behaviors among African Americans: A Systematic Review. *American Journal of Preventive Medicine*, Vol. 36, No. 2, 2009, pp. 174–181. https://doi.org/10.1016/j.amepre.2008.09.037.
11. Fraser, S. D. S., and K. Lock. Cycling for Transport and Public Health: A Systematic Review of the Effect of the Environment on Cycling. *European Journal of Public Health*, Vol. 21, No. 6, 2011, pp. 738–743. https://doi.org/10.1093/eurpub/ckq145.
12. Yang, L., S. Sahlqvist, A. McMinn, S. J. Griffin, and D. Ogilvie. Interventions to Promote Cycling: Systematic Review. *BMJ (Clinical research ed.)*, Vol. 341, 2010, p. c5293. https://doi.org/10.1136/bmj.c5293.
13. Ross, A., A. Rodríguez, and M. Searle. Associations between the Physical, Sociocultural, and Safety Environments and Active Transportation to School. *American Journal of Health*

Education, Vol. 48, No. 3, 2017, pp. 198–209. https://doi.org/10.1080/19325037.2017.1292877.
14. Evenson, K. R., A. S. Birnbaum, A. L. Bedimo-Rung, J. F. Sallis, C. C. Voorhees, K. Ring, and J. P. Elder. Girls' Perception of Physical Environmental Factors and Transportation: Reliability and Association with Physical Activity and Active Transport to School. *International Journal of Behavioral Nutrition and Physical Activity*, Vol. 3, No. 1, 2006, p. 28. https://doi.org/10.1186/1479-5868-3-28.
15. Annear, M., S. Keeling, T. Wilkinson, G. Cushman, B. Gidlow, and H. Hopkins. Environmental Influences on Healthy and Active Ageing: A Systematic Review. *Ageing and Society*, Vol. 34, No. 4, 2014, pp. 590–622. https://doi.org/10.1017/S0144686X1200116X.
16. Lo, R. H. Walkability: What Is It? *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, Vol. 2, No. 2, 2009, pp. 145–166. https://doi.org/10.1080/17549170903092867.
17. Dovey, K., and E. Pafka. What Is Walkability? The Urban DMA. *Journal of Urban Studies*, Vol. 57, No. 1, 2020, pp. 93–108. https://doi.org/10.1177/0042098018819727.
18. Strydom, W., K. Puren, and E. Drewes. Exploring Theoretical Trends in Placemaking: Towards New Perspectives in Spatial Planning. *Journal of Place Management and Development*, Vol. 11, No. 2, 2018, pp. 165–180. https://doi.org/10.1108/JPMD-11-2017-0113.
19. Online TDM Encyclopedia - About This Encyclopedia. https://www.vtpi.org/tdm/tdm12.htm. Accessed Mar. 2, 2023.
20. Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities.
21. RSA Resources | FHWA. https://highways.dot.gov/safety/data-analysis-tools/rsa/rsa-resources. Accessed Feb. 14, 2023.
22. Vision Zero Network. *Vision Zero Network*. https://visionzeronetwork.org/. Accessed Feb. 14, 2023.
23. Conservancy, R.-T. About RTC | Trails Connect Everyone, Everywhere. *Rails-to-Trails Conservancy*. http://www.railstotrails.org/about/. Accessed Feb. 14, 2023.
24. Moreland-Russell, S., A. Eyler, C. Barbero, J. A. Hipp, and H. Walsh. Diffusion of Complete Streets Policies Across US Communities. *Journal of Public Health Management and Practice*, Vol. 19, 2013, p. S89. https://doi.org/10.1097/PHH.0b013e3182849ec2.
25. Naumann, R. B., S. Heiny, K. R. Evenson, S. LaJeunesse, J. F. Cooper, S. Doggett, and S. W. Marshall. Organizational Networks in Road Safety: Case Studies of U.S. Vision Zero Cities. *Traffic Injury Prevention*, Vol. 20, No. 4, 2019, pp. 378–385. https://doi.org/10.1080/15389588.2019.1587752.
26. Rep. DeFazio, P. A. [D-O.-4. H.R.3684 - 117th Congress (2021-2022): Infrastructure Investment and Jobs Act. 2021.
27. Haghani, M., and M. C. J. Bliemer. Emerging Trends and Influential Outsiders of Transportation Science. *Transportation Letters*, Vol. 0, No. 0, 2022, pp. 1–37. https://doi.org/10.1080/19427867.2022.2057397.
28. Wang, H., and Y. Yang. Neighbourhood Walkability: A Review and Bibliometric Analysis. *Cities*, Vol. 93, 2019, pp. 43–61. https://doi.org/10.1016/j.cities.2019.04.015.
29. Prins, R. G., F. Pierik, A. Etman, R. P. Sterkenburg, C. B. M. Kamphuis, and F. J. van Lenthe. How Many Walking and Cycling Trips Made by Elderly Are beyond Commonly

Used Buffer Sizes: Results from a GPS Study. *Health & Place*, Vol. 27, 2014, pp. 127–133. https://doi.org/10.1016/j.healthplace.2014.01.012.

30. Park, N. S., L. L. Roff, F. Sun, M. W. Parker, D. L. Klemmack, P. Sawyer, and R. M. Allman. Transportation Difficulty of Black and White Rural Older Adults. *Journal of Applied Gerontology*, Vol. 29, No. 1, 2010, pp. 70–88. https://doi.org/10.1177/0733464809335597.
31. Roberts, J. D., S. Mandic, C. S. Fryer, M. L. Brachman, and R. Ray. Between Privilege and Oppression: An Intersectional Analysis of Active Transportation Experiences Among Washington D.C. Area Youth. *International Journal of Environmental Research and Public Health*, Vol. 16, No. 8, 2019, p. 1313. https://doi.org/10.3390/ijerph16081313.
32. Wanner, M., T. Götschi, E. Martin-Diener, S. Kahlmeier, and B. W. Martin. Active Transport, Physical Activity, and Body Weight in Adults: A Systematic Review. *American Journal of Preventive Medicine*, Vol. 42, No. 5, 2012, pp. 493–502. https://doi.org/10.1016/j.amepre.2012.01.030.
33. Rural–Urban Disparities in Obesity Prevalence Among Working Age Adults in the United States: Exploring the Mechanisms. https://journals-sagepub-com.spot.lib.auburn.edu/doi/epub/10.1177/0890117116689488. Accessed Jan. 26, 2023.
34. Ross, A., and J. M. Kurka. Predictors of Active Transportation Among Safe Routes to School Participants in Arizona: Impacts of Distance and Income. *Journal of School Health*, Vol. 92, No. 3, 2022, pp. 282–292. https://doi.org/10.1111/josh.13125.
35. Bryan, S., J. Afful, M. Carroll, C. Te-Ching, D. Orlando, S. Fink, and C. Fryar. *NHSR 158. National Health and Nutrition Examination Survey 2017–March 2020 Pre-Pandemic Data Files*. National Center for Health Statistics (U.S.), 2021.
36. Kent, M. The Oxford Dictionary of Sports Science & Medicine. Oxford University Press, , 2007.
37. Mueller, N., D. Rojas-Rueda, T. Cole-Hunter, A. de Nazelle, E. Dons, R. Gerike, T. Götschi, L. Int Panis, S. Kahlmeier, and M. Nieuwenhuijsen. Health Impact Assessment of Active Transportation: A Systematic Review. *Preventive Medicine*, Vol. 76, 2015, pp. 103–114. https://doi.org/10.1016/j.ypmed.2015.04.010.
38. Wendel-Vos, W., M. Droomers, S. Kremers, J. Brug, and F. van Lenthe. Potential Environmental Determinants of Physical Activity in Adults: A Systematic Review. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, Vol. 8, No. 5, 2007, pp. 425–440. https://doi.org/10.1111/j.1467-789X.2007.00370.x.
39. Rf, H., C. H, V. J, A.-B. T, H. Ja, and S. J. The Impact of Interventions to Promote Physical Activity in Urban Green Space: A Systematic Review and Recommendations for Future Research. *Social science & medicine (1982)*, Vol. 124, 2015. https://doi.org/10.1016/j.socscimed.2014.11.051.
40. Zwald, M. L., T. H. I. Fakhouri, C. D. Fryar, G. Whitfield, and L. J. Akinbami. Trends in Active Transportation and Associations with Cardiovascular Disease Risk Factors among U.S. Adults, 2007–2016. *Preventive Medicine*, Vol. 116, 2018, pp. 150–156. https://doi.org/10.1016/j.ypmed.2018.09.008.
41. Warburton, D. E. R., C. W. Nicol, and S. S. D. Bredin. Health Benefits of Physical Activity: The Evidence. *CMAJ*, Vol. 174, No. 6, 2006, pp. 801–809. https://doi.org/10.1503/cmaj.051351.

42. Reiner, M., C. Niermann, D. Jekauc, and A. Woll. Long-Term Health Benefits of Physical Activity – a Systematic Review of Longitudinal Studies. *BMC Public Health*, Vol. 13, No. 1, 2013, p. 813. https://doi.org/10.1186/1471-2458-13-813.
43. Mahmoudi, J. Health Impacts of Nonmotorized Travel Behavior and the Built Environment: Evidence from the 2017 National Household Travel Survey. *Journal of Transport & Health*, Vol. 26, 2022, p. 101404. https://doi.org/10.1016/j.jth.2022.101404.
44. D, D., L. Kd, K.-A. Tl, F. Ea, K. Pt, van M. W, and P. M. The Economic Burden of Physical Inactivity: A Global Analysis of Major Non-Communicable Diseases. *Lancet (London, England)*, Vol. 388, No. 10051, 2016. https://doi.org/10.1016/S0140-6736(16)30383-X.
45. Litman, T. Active Transportation Policy Issues. *Victoria Transport Policy Institute*, 2003, pp. 1–2.
46. Lyons, W., H. Peckett, L. Morse, M. Khurana, L. Nash, and John A. Volpe National Transportation Systems Center (U.S.). *Metropolitan Area Transportation Planning for Healthy Communities*. Publication DOT-VNTSC-FHWA-13-01;FHWA-HEP-13-006. 2012.
47. Pedestrian & Bicycle Information Center. https://www.pedbikeinfo.org/resources/resources_details.cfm?id=5085. Accessed Jun. 23, 2022.
48. Stewart, T. Overview of Motor Vehicle Crashes in 2020. p. 43.
49. National Center for Statistics and Analysis. *Traffic Safety Facts 2020: A Compilation of Motor Vehicle Crash Data*. Publication DOT HS 813 375. National Highway Traffic Sfaety Administration, 2022, p. 242.
50. Coleman, H., and K. Mizenko. Pedestrian and Bicyclist Data Analysis. p. 26.
51. Aziz, H. M. A., N. N. Nagle, A. M. Morton, M. R. Hilliard, D. A. White, and R. N. Stewart. Exploring the Impact of Walk–Bike Infrastructure, Safety Perception, and Built-Environment on Active Transportation Mode Choice: A Random Parameter Model Using New York City Commuter Data. *Transportation*, Vol. 45, No. 5, 2018, pp. 1207–1229. https://doi.org/10.1007/s11116-017-9760-8.
52. Lee, R. J., I. N. Sener, and S. N. Jones. Understanding the Role of Equity in Active Transportation Planning in the United States. *Transport Reviews*, Vol. 37, No. 2, 2017, pp. 211–226. https://doi.org/10.1080/01441647.2016.1239660.
53. Henning-Smith, C., A. Evenson, A. Corbett, K. Kozhimannil, and I. Moscovice. Rural Transportation: Challenges and Opportunities. 2017.
54. Christopher, G., D. Fleming, R. T. Harris, T. Spencer, S. M. Gibson, C. M. Harris, D. Lakey, and O. M. Jr. *The State of Obesity: Better Polocies for a Healthier America*. Trust for Americas Health, 2022, p. 92.
55. Bureau, U. C. 2020 Census Urban Areas Facts. *Census.gov*. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2020-ua-facts.html. Accessed Feb. 13, 2023.
56. Fatality Facts 2020: Urban/Rural Comparison. *IIHS-HLDI crash testing and highway safety*. https://www.iihs.org/topics/fatality-statistics/detail/urban-rural-comparison. Accessed Feb. 13, 2023.
57. Hansen, A. Y., M. R. Umstattd Meyer, J. D. Lenardson, and D. Hartley. Built Environments and Active Living in Rural and Remote Areas: A Review of the Literature. *Current Obesity Reports*, Vol. 4, No. 4, 2015, pp. 484–493. https://doi.org/10.1007/s13679-015-0180-9.

58. Carlson, S. A., G. P. Whitfield, E. L. Peterson, E. N. Ussery, K. B. Watson, D. Berrigan, and J. E. Fulton. Geographic and Urban–Rural Differences in Walking for Leisure and Transportation. *American Journal of Preventive Medicine*, Vol. 55, No. 6, 2018, pp. 887–895. https://doi.org/10.1016/j.amepre.2018.07.008.
59. Yousefian, A., E. Ziller, J. Swartz, and D. Hartley. Active Living for Rural Youth: Addressing Physical Inactivity in Rural Communities. *Journal of Public Health Management and Practice*, Vol. 15, No. 3, 2009, pp. 223–231.
60. Schlossberg, M. From TIGER to Audit Instruments: Measuring Neighborhood Walkability with Street Data Based on Geographic Information Systems. *Transportation Research Record*, Vol. 1982, No. 1, 2006, pp. 48–56. https://doi.org/10.1177/0361198106198200107.
61. Meyer, M. R. U., J. B. Moore, C. Abildso, M. B. Edwards, A. Gamble, and M. L. Baskin. Rural Active Living: A Call to Action. *Journal of public health management and practice : JPHMP*, Vol. 22, No. 5, 2016, p. E11. https://doi.org/10.1097/PHH.0000000000000333.
62. Fan, J. X., M. Wen, and N. Wan. Built Environment and Active Commuting: Rural-Urban Differences in the U.S. *SSM - Population Health*, Vol. 3, 2017, pp. 435–441. https://doi.org/10.1016/j.ssmph.2017.05.007.
63. Gorse, C., D. Johnston, and M. Pritchard. A Dictionary of Construction. Oxford University Press, , 2020.
64. Blanchette, S., J. Lemoyne, M.-C. Rivard, and F. Trudeau. Municipal Officials' Propensity toward Active Transportation: A Rural-Urban Comparison. *Journal of Transport & Health*, Vol. 12, 2019, pp. 349–358. https://doi.org/10.1016/j.jth.2018.12.005.
65. Howse, T., and D. Libby. Greenway (Trails) For All: Voie Verte (Sentiers) Pour Tous. *Journal of Rural & Community Development*, Vol. 17, No. 4, 2022, pp. 140–163.
66. Singh, K., and P. K. Jain. Methods of Assessing Pedestrian Level of Service. *Journal of Engineering Research and Studies*, Vol. II, No. I, 2011, pp. 116–124.
67. Roess, R. P., Ed. Level of Service Concepts: Development, Philosophies, and Implications. In *Traffic Capacity and Characteristics*, Transportation Research Board, National Research Council, Washington, D.C, pp. 1–6.
68. Huff, H., and R. Liggett. The Highway Capacity Manual's Method for Calculating Bicycle and Pedestrian Levels of Service: The Ultimate White Paper. 2014, p. 62.
69. Pritchard, R., Y. Frøyen, and B. Snizek. Bicycle Level of Service for Route Choice—A GIS Evaluation of Four Existing Indicators with Empirical Data. *ISPRS International Journal of Geo-Information*, Vol. 8, No. 5, 2019, p. 214. https://doi.org/10.3390/ijgi8050214.
70. Pedestrian Road Safety Audit Guidelines and Prompt Lists. https://www.pedbikeinfo.org/resources/resources_details.cfm?id=3955. Accessed Mar. 3, 2023.
71. Bicycle Road Safety Audit Guidelines and Prompt Lists - Safety | Federal Highway Administration. https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa12018/. Accessed Mar. 3, 2023.
72. Aspen Hill Vision Zero Study. *Montgomery Planning*. https://montgomeryplanning.org/planning/communities/midcounty/aspen-hill/aspen-hill-vision-zero-study/. Accessed Jul. 17, 2022.
73. Pedestrians First: Tools for a Walkable City. *Institute for Transportation and Development Policy*. https://www.itdp.org/publication/walkability-tool/. Accessed Jun. 23, 2022.
74. Free Download: The AARP Walk Audit Tool Kit. https://www.aarp.org/livable-communities/getting-around/aarp-walk-audit-tool-kit-download/. Accessed Jun. 23, 2022.

75. Active Neighborhood Checklist. *Prevention Research Center*. https://prcstl.wustl.edu/active-neighborhood-checklist/. Accessed Jul. 17, 2022.
76. Waka Kotahi. Pedestrian Level of Service Tool. *Waka Kotahi NZ Transport Agency*. http://maps.abley.com/nzta/pedestrian-los-tool/#/step1. Accessed Mar. 23, 2023.
77. Australasian Pedestrian Crossing Facility Selection Tool. https://austroads.com.au/pedestrian-tool/_nocache. Accessed Mar. 3, 2023.
78. Shatu, F., and T. Yigitcanlar. Development and Validity of a Virtual Street Walkability Audit Tool for Pedestrian Route Choice Analysis—SWATCH. *Journal of Transport Geography*, Vol. 70, 2018, pp. 148–160. https://doi.org/10.1016/j.jtrangeo.2018.06.004.
79. Active Travel Wales Guidance. Walking Route Audit Tool (WRAT). https://www.staffordshire.gov.uk/Transport/transportplanning/documents/Appendix-D-Tamworth-Walking-Audit.pdf. Accessed Mar. 3, 2023.
80. BC Healthy Living. Built Environment & Active Transportation (BEAT) Neighborhood Assessment. https://www.bcrpa.bc.ca/media/54428/beat_neighbourhood_assessment_final.pdf. Accessed Mar. 3, 2023.
81. Beura, S. K., and P. K. Bhuyan. Development of a Bicycle Level of Service Model for Urban Street Segments in Mid-Sized Cities Carrying Heterogeneous Traffic: A Functional Networks Approach. *Journal of Traffic and Transportation Engineering (English Edition)*, Vol. 4, No. 6, 2017, pp. 503–521. https://doi.org/10.1016/j.jtte.2017.02.003.
82. Bivina, G. R., and M. Parida. Modeling Percieved Pedestrian Level of Service Od Sidewalks: A Structural Equation Approach. *Transport*, Vol. 34, No. 3, 2019, pp. 339–350. https://doi.org/10.3846/transport.2019.9819.
83. Ujjwal, J., and R. Bandyopadhyaya. Development of Pedestrian Level of Service Assessment Guidelines for Mixed Land Use Areas Considering Quality of Service Parameters. *Transportation in Developing Economies*, Vol. 7, No. 1, 2021, p. 7. https://doi.org/10.1007/s40890-021-00113-8.
84. Kadali, B. R., and P. Vedagiri. Evaluation of Pedestrian Crosswalk Level of Service (LOS) in Perspective of Type of Land-Use. *Transportation Research Part A: Policy and Practice*, Vol. 73, 2015, pp. 113–124. https://doi.org/10.1016/j.tra.2015.01.009.
85. Zannat, K. E., D. R. Raja, and M. S. G. Adnan. Pedestrian Facilities and Perceived Pedestrian Level of Service (PLOS): A Case Study of Chittagong Metropolitan Area, Bangladesh. *Transportation in Developing Economies*, Vol. 5, No. 2, 2019, p. 16. https://doi.org/10.1007/s40890-019-0078-4.
86. Asadi-Shekari, Z., M. Moeinaddini, and M. Zaly Shah. A Pedestrian Level of Service Method for Evaluating and Promoting Walking Facilities on Campus Streets. *Land Use Policy*, Vol. 38, 2014, pp. 175–193. https://doi.org/10.1016/j.landusepol.2013.11.007.
87. Tsiompras, A. B., and Y. N. Photis. What Matters When It Comes to "Walk and the City"? Defining a Weighted GIS-Based Walkability Index. *Transportation Research Procedia*, Vol. 24, 2017, pp. 523–530. https://doi.org/10.1016/j.trpro.2017.06.001.
88. Ahmed, T., M. Moeinaddini, M. Almoshaogeh, A. Jamal, I. Nawaz, and F. Alharbi. A New Pedestrian Crossing Level of Service (PCLOS) Method for Promoting Safe Pedestrian Crossing in Urban Areas. *International Journal of Environmental Research and Public Health*, Vol. 18, No. 16, 2021. https://doi.org/10.3390/ijerph18168813.
89. Moura, F., P. Cambra, and A. B. Gonçalves. Measuring Walkability for Distinct Pedestrian Groups with a Participatory Assessment Method: A Case Study in Lisbon. *Landscape and*

Urban Planning, Vol. 157, 2017, pp. 282–296. https://doi.org/10.1016/j.landurbplan.2016.07.002.
90. Mōri, M., and H. Tsukaguchi. A New Method for Evaluation of Level of Service in Pedestrian Facilities. *Transportation Research Part A: General*, Vol. 21, No. 3, 1987, pp. 223–234. https://doi.org/10.1016/0191-2607(87)90016-1.
91. Place Standard Tool. https://www.ourplace.scot/sites/default/files/2022-11/Our%20Place%20Place%20Standard%20Tool%20final%20version%20-%20Print%2C%20Interactive%20and%20booklet%20details%20-%20Oct%2022.pdf. Accessed Mar. 3, 2023.
92. Yousefian, A., E. Hennessy, M. R. Umstattd, C. D. Economos, J. S. Hallam, R. R. Hyatt, and D. Hartley. Development of the Rural Active Living Assessment Tools: Measuring Rural Environments. *Preventive Medicine*, Vol. 50, 2010, pp. S86–S92. https://doi.org/10.1016/j.ypmed.2009.08.018.
93. Plan4Health. Community Health Quick Audit. .
94. FHWA. Pedestrian Safety Guide and Countermeasure Selection System. *PEDSAFE*. http://www.pedbikesafe.org/PEDSAFE/resources.cfm. Accessed Mar. 23, 2023.
95. FHWA. Bicycle Safety Guide and Countermeasure Selection System. *BIKESAFE*. http://www.pedbikesafe.org/BIKESAFE/index.cfm. Accessed Mar. 23, 2023.
96. Dannenberg, A. L., T. W. Cramer, and C. J. Gibson. Assessing the Walkability of the Workplace: A New Audit Tool. *American Journal of Health Promotion*, Vol. 20, No. 1, 2005, pp. 39–44. https://doi.org/10.4278/0890-1171-20.1.39.
97. O'Hanlon, J., and A. P. Scientist. Healthy and Complete Communities in Delaware: The Walkability Assessment Tool.
98. National Center for and Bicycling & Walking. Community Assessment Tool.
99. Montgomery Planning. M-NCPPC Pedestrian Audit Toolkit. *Montgomery Planning*. https://montgomeryplanning.org/documents/m-ncppc-pedestrian-audit-toolkit/. Accessed Mar. 23, 2023.
100. Inclusive Walk Audit Facilitator's Guide. Dec, 2020.
101. Kansas DOT. Active Transportation Planning Tool for Small- and Mid-Sized Communities. *Kansas Active Transportation*. https://www.ksdot.gov/bureaus/burRail/bike/ATPlanningToolKit.asp. Accessed Mar. 23, 2023.
102. CUTR. Transportation Equity Toolkit. *CUTR - Center for Urban Transportation Research | University of South Florida*. https://www.cutr.usf.edu/2021/09/transportation-equity-toolkit/. Accessed Mar. 23, 2023.
103. Walkable and Livable Communities Institute. Walkability Workbook from WALC and EPA. *Walkability Workbook from WALC and EPA*. https://www.hudexchange.info/resource/4628/walkability-workbook-from-walc-and-epa. Accessed Mar. 23, 2023.
104. Walk Friendly Communities. Community Assessment Tool. .
105. Bikeability Checklist, How Bikeable Is Your Community? - Checklist. *U.S. Department of Transportation - NHTSA - Pedestrian and Bicycle Information Center -*. https://icsw.nhtsa.gov/people/injury/pedbimot/bike/bikeability/index.htm. Accessed Mar. 23, 2023.
106. Victoria Walks. *Walking Audits*. https://www.victoriawalks.org.au/Walking_audit/. Accessed Mar. 3, 2023.

107. English and Spanish 8 80 Walk Audits. *8 80 Cities*. https://www.880cities.org/8-80-walk-audits/. Accessed Mar. 23, 2023.
108. Bicycle Friendly America. *League of American Bicyclists*. https://bikeleague.org/bfa/. Accessed Mar. 24, 2023.
109. Heart Foundation. Healthy Active by Design Checklists. *Heart Foundation*. https://www.healthyactivebydesign.com.au/resources/healthy-active-by-design-master-checklists. Accessed Mar. 24, 2023.
110. Walkability Checklist | NHTSA. *United State Department of Transportation*. https://www.nhtsa.gov/document/walkability-checklist. Accessed Mar. 24, 2023.
111. US EPA, O. National Walkability Index User Guide and Methodology. https://www.epa.gov/smartgrowth/national-walkability-index-user-guide-and-methodology. Accessed Mar. 24, 2023.
112. Patten, R., R. J. Schneider, J. L. Toole, J. E. Hummer, and N. M. Rouphail. *Shared Use Path Level of Service Calculator*. Publication FHWA-HRT-05-138. 2006, p. 67.
113. Mekuria, M. C., P. G. Furth, and H. Nixon. *LOW-STRESS BICYCLING AND NETWORK CONNECTIVITY*. Publication MTI Report 11-19. 2012.
114. Dowling, R. G., D. Reinke, A. Flannery, P. Ryus, M. Vandehey, T. Petritsch, Landis, N. Rouphail, J. Bonneson, National Research Council (U.S.), and National Cooperative Highway Research Program, Eds. *Multimodal Level of Service Analysis for Urban Streets*. Transportation Research Board, Washington, D.C, 2008.
115. FDOT. Multimodal Quality/Level of Service Handbook. Jan, 2023.
116. Ross, A., T. Huber, M. Dornfeld, R. Waring, D. Bishop, G. Grigg, L. Dixon, and M. Stenmark. *Development of the Bicycle Compatibility Index*. Publication FHWA-RD-98-072. FHWA, 1998.
117. Resources — Healthy Streets. https://www.healthystreets.com/resources. Accessed Mar. 24, 2023.
118. Clifton, K. J., A. D. Livi Smith, and D. Rodriguez. The Development and Testing of an Audit for the Pedestrian Environment. *Landscape and Urban Planning*, Vol. 80, No. 1, 2007, pp. 95–110. https://doi.org/10.1016/j.landurbplan.2006.06.008.
119. Koo, B. W., S. Guhathakurta, and N. Botchwey. Development and Validation of Automated Microscale Walkability Audit Method. *Health & Place*, Vol. 73, 2022, p. 102733. https://doi.org/10.1016/j.healthplace.2021.102733.
120. Krambeck, H. V. *The Global Walkability Index*. Thesis. Massachusetts Institute of Technology, 2006.
121. Griswold, J. B., M. Yu, V. Filingeri, O. Grembek, and J. L. Walker. A Behavioral Modeling Approach to Bicycle Level of Service. *Transportation Research Part A: Policy and Practice*, Vol. 116, 2018, pp. 166–177. https://doi.org/10.1016/j.tra.2018.06.006.
122. Kelly, C. E., M. R. Tight, F. C. Hodgson, and M. W. Page. A Comparison of Three Methods for Assessing the Walkability of the Pedestrian Environment. *Journal of Transport Geography*, Vol. 19, No. 6, 2011, pp. 1500–1508. https://doi.org/10.1016/j.jtrangeo.2010.08.001.
123. Forsyth, A. What Is a Walkable Place? The Walkability Debate in Urban Design. *URBAN DESIGN International*, Vol. 20, No. 4, 2015, pp. 274–292. https://doi.org/10.1057/udi.2015.22.

124. Hajna, S., N. A. Ross, S. J. Griffin, and K. Dasgupta. Lexical Neutrality in Environmental Health Research: Reflections on the Term Walkability. *BMC Public Health*, Vol. 17, No. 1, 2017, p. 940. https://doi.org/10.1186/s12889-017-4943-y.
125. Conderino, S. E., J. M. Feldman, B. Spoer, M. N. Gourevitch, and L. E. Thorpe. Social and Economic Differences in Neighborhood Walkability Across 500 U.S. Cities. *American Journal of Preventive Medicine*, Vol. 61, No. 3, 2021, pp. 394–401. https://doi.org/10.1016/j.amepre.2021.03.014.
126. Speck, J. *Walkable City: How Downtown Can Save America, One Step at a Time*. Farrar, Straus and Giroux, New York, 2012.
127. Alfonzo, M. A. To Walk or Not to Walk? The Hierarchy of Walking Needs. *Environment and Behavior*, Vol. 37, No. 6, 2005, pp. 808–836. https://doi.org/10.1177/0013916504274016.
128. Southworth, M. Designing the Walkable City. *Journal of Urban Planning and Development*, Vol. 131, No. 4, 2005, p. 246.
129. ALDOT. Alabama Traffic Data Manager. *Alabama Traffic Data*. https://aldotgis.dot.state.al.us/TDMPublic/. Accessed Jul. 29, 2022.
130. U.S. Census Bureau. *Age and Sex American Community Survey 5-Year Estimate*. 2021.
131. U.S. Census Bureau. *Race American Community Survey 5-Year Estimate*. 2021.
132. U.S. Census Bureau. *Urban and Rural Decennial Census*. 2010.