9.4 Health

Carolina Thread Trail, NC

Introducing Health and Transportation

Many people associate health with illness, doctors' offices and hospitals. Yet health is as much about how and where we live, work, learn and play. The World Health Organization (WHO) does not define health simply as the lack of illness. In 1946, it declared that "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO). Likewise, the Centers for Disease Control and Prevention (CDC) defines a healthy community as one "that is continuously creating and improving those physical and social environments and expanding those community resources that enable people to mutually support each other in performing all the functions of life and in developing to their maximum potential" (CDC).

Chronic Conditions

The leading causes of death in North Carolina are from chronic diseases, including cancer, heart disease, respiratory disease and stroke (NC SCHS). Seven out of ten deaths result from chronic diseases (Kung, 2005). The most common medical conditions that contribute to mortality are high blood pressure, diabetes and overweight/obesity. While some of the burden from these diseases can be attributed to genetics and lack of access to quality health care, lifestyle behaviors are most significant. In fact, three key preventable behaviors are responsible for the greatest amount of disease and mortality: physical inactivity, poor nutrition and tobacco use.

Disparities in Health

It is critical that public officials consider and address the disparities between communities and vulnerable populations that are most at risk for poor health. These largely preventable conditions are more common in communities of color and in low-income neighborhoods. In addition, older adults and people with disabilities are more likely to live with chronic diseases. Finally, children are perhaps our most vulnerable and yet hold the greatest potential to learn and adopt healthy lifestyles.

In this Appendix

The Financial Cost of Physical Inactivity in North Carolina

Most of us have lost loved ones to chronic disease and/or we live with these conditions within our families. The human burden of pain and suffering is clear. What is increasingly obvious is the financial burden from chronic diseases that are forced on families and society. Recent reports have estimated the annual direct medical cost of physical inactivity in North Carolina at $3.67 billion, plus an additional $4.71 billion in lost productivity (Chenoweth, NCMJ, 2012 and Be Active, "Tipping the Scales" 2012). While these financial figures are bleak, researchers have also found that every dollar invested in accessible pedestrian and bicycle trails can result in a savings of nearly $3 in direct medical expenses (Chenoweth 2012; Wang, et al 2006).

The Benefits of More Physical Activity

Physical activity is a key indicator of health. Increasing one's level of physical activity reduces the risk and impact of cardiovascular disease, diabetes, and some types of cancer. It also helps to control weight, improve mood and reduce the risk of premature death. The Surgeon General recommends the following levels of activities by age group (for more detail on these guidelines, see the 2008 Physical Activity Guidelines for Americans):

- **Children and adolescents should do 60 minutes or more of physical activity daily.**
- **Adults should do at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination**
- **When older adults cannot do 150 minutes of moderate-intensity aerobic activity a week because of chronic conditions, they should be as physically active as their abilities and conditions allow.**

▲ Durham, NC ca. 1900

These recommendations allow individuals to combine 10-minute bouts of activity to achieve the goal of 30 minutes each day (1996 US Surgeon General's Report, and 2008 Physical Activity Guidelines for Americans). In 2012, the National Cancer Institute determined that regular leisure-time physical activity can extend our lives more than three years for meeting the recommended guideline (NCI, 2012, PLOS).

North Carolina and the nation are in the midst of an epidemic of overweight and obesity (F as in Fat, 2012).

Regular physical activity plays a crucial role in weight control and quality of life, along with a healthy diet. Yet the health potential of routine physical activity extends beyond overweight and obesity. Physical inactivity is established as an independent risk factor for chronic diseases. This means that, regardless of one's weight, regular physical activity delays the onset and reduces the likelihood of developing chronic diseases (Telford, 2007).

When the US Surgeon General declared the disease-preventing potential of regular moderate physical activities, particularly walking and bicycling, it created a health promotion prescription within reach of all North Carolinians.

Rather than having to exercise rigorously or join a fitness center, children and adults can lead measurably healthier lives by incorporating 30 or more minutes of activity each day. Using "active transportation" to and from school, work, parks, restaurants, stores and other routine destinations, is one of the best things we can do to prevent chronic diseases. Active transportation typically includes walking, bicycling and transit use (Rodriguez, 2009).

Active Transportation as a Public Health Priority

Both federal and state health officials have prioritized physical activity as a key health objective and one that can be advanced through a transportation system that supports safe walking and bicycling. After carefully considering the best science and converging evidence, public health authorities, including the CDC and the Institute of Medicine, have recommended road improvements, connectivity, land use policies, active transportation to schools and programs to advance walking and bicycling. (CDC, 2009; IOM, 2009)

Broader Approach, Greater Collaboration

The roots of collaboration between urban planning and public health professionals date back more than a century. Housing and sanitation systems and standards moved the nation's health forward by reducing the burden of waterborne and communicable diseases (Silver, 2012). City planners helped enact important land use and zoning restrictions to protect people from industrial pollutants. But as chronic diseases replaced infectious diseases as the leading causes of death throughout the 20th century, the public health profession did not actively focus on policies and built environments that impact these conditions. In recent years, public health officials and researchers have come to recognize and better understand the important role that the built environment plays in chronic disease prevention and quality of life. In particular, our transportation system and design of communities directly impacts our choices to lead healthy lives. For this reason, health professionals and advocates have become new partners in promoting and planning for pedestrian and bicycle transportation.

Co-Benefits of an Active Transportation System

The public health impacts of the transportation system extend beyond physical inactivity and obesity. By shifting more North Carolinians to walking and bicycling for

Active Transportation: Pathway to Health

transportation, even for small trips, the state will reduce automobile emissions and improve air quality. Cleaner air leads to fewer symptoms and illnesses for those suffering from asthma and other chronic respiratory conditions. Similarly, a well-developed system that supports pedestrian and bicycle transportation not only improves options for new users, but it improves safety for North Carolinians who already utilize active transportation.

Momentum at Home

Outside the state, North Carolina's departments of transportation and health are highly regarded. For years, the NC Department of Health and Human Services (NC DHHS) has helped lead the way in encouraging local health departments to work collaboratively and implement policy and environmental strategies to create healthier communities. At the state level, NC DHHS convened the Healthy Environments Collaborative (HEC), which includes the departments of Transportation (NCDOT), Commerce and Environment and Natural Resources. The HEC's purpose is to consider the health impacts of each department's work and collaborate in improving health in North Carolina. In 2012, NCDOT's Board of Transportation adapted its mission statement to include "health and well-being" and passed a "Public Health Policy," which declares the importance of a transportation system that supports positive health outcomes.

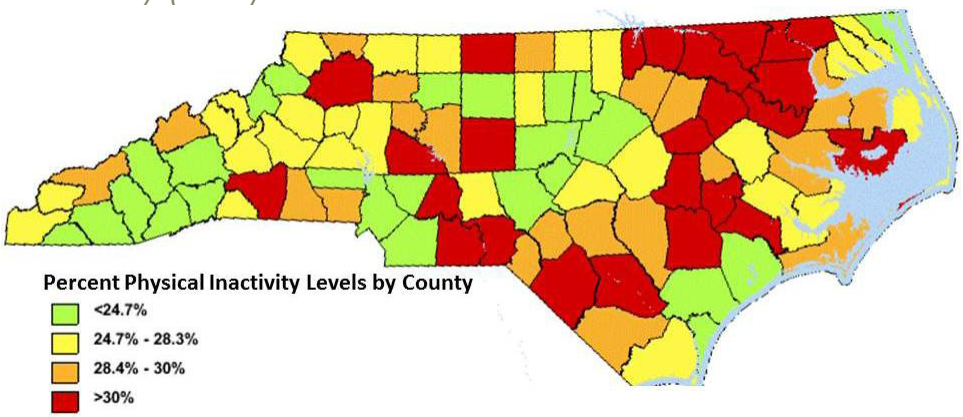
The Health Appendix provides an overview of health as it relates to pedestrian and bicycle transportation and how North Carolina can improve the health of its citizens, in part, through its transportation system. The sections that follow address the health conditions in the state and the current science on how the transportation system impacts health. This appendix also presents best and promising practices from within North Carolina. Finally, recommendations are offered to help our state move forward to create a model pedestrian and bicycle transportation system – one that accommodates and prioritizes active transportation for better health.

Source: Robert Wood Johnson Foundation
http://www.rwjf.org/en/blogs/new-public-health.html

THE STATE OF HEALTH AND PHYSICAL ACTIVITY IN NORTH CAROLINA

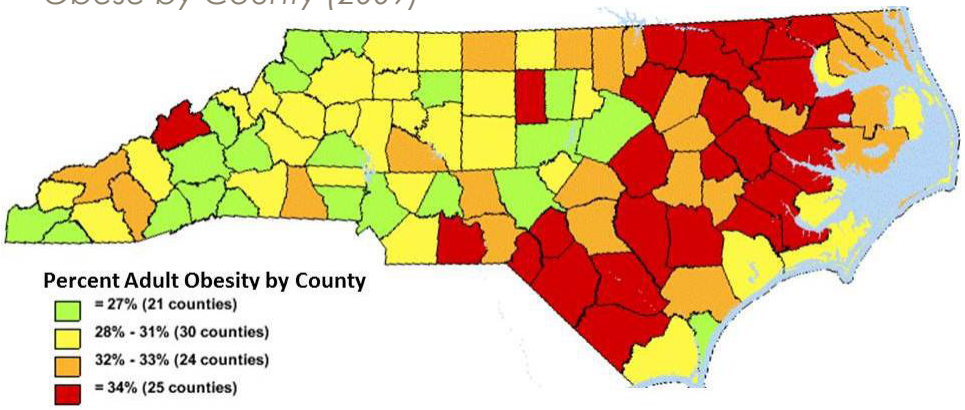
According to America's Health Rankings, North Carolina is the 32nd healthiest state and 36th in premature death. Many factors influence these rankings, including those that have implications for walking and bicycling, like air pollution, injuries and obesity. As of 2011, only 46.8% of North Carolina adults were performing the minimum recommended amount of weekly physical activity (NC BRFSS, SCHS). Lack of physical activity increases the likelihood of overweight and obesity and increases the risk of Type II diabetes, heart disease, hypertension, colon and breast cancers and depression (WHO). The instance of obesity in the United States has greatly increased over the past 20 years and was declared a national epidemic by the US Surgeon

Percentage of NC Adults Who are Physically Inactive by County (2009)



▲ *Source: Centers for Disease Control and Prevention, Diabetes Data and Trends*

Percentage of NC Adults Who are Obese by County (2009)



▲ *Source: County Health Rankings*, 2012*

** In some cases, County Health Rankings aggregates data from many years for counties with lower sample sizes.*

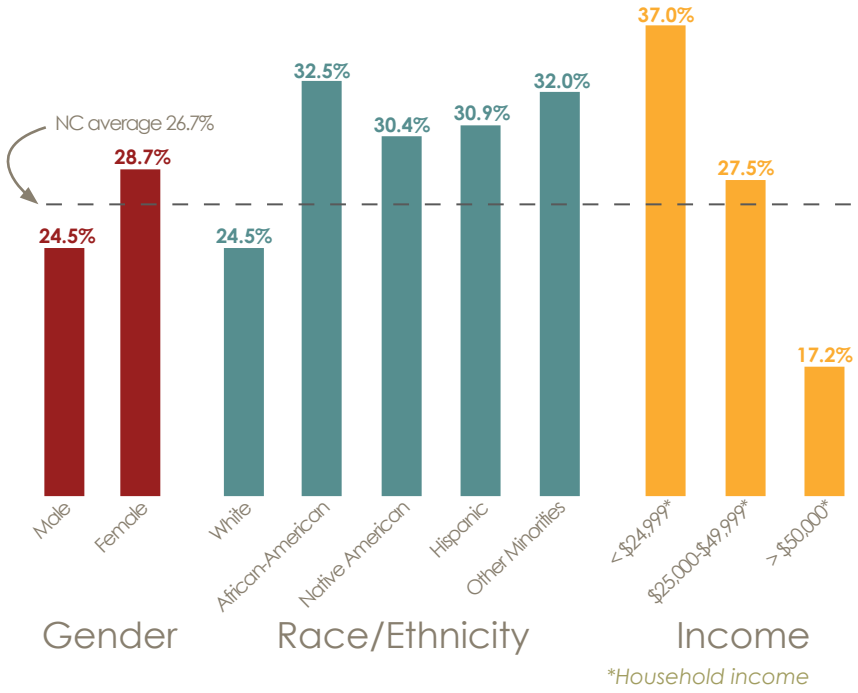
General in 2001. The rate of obesity in North Carolina adults has more than doubled in the past twenty years, from 13% in 1990 to 29.1% in 2011 (NC BRFSS, SCHS).

The lack of pedestrian and bicycling infrastructure leads, in part, to physical inactivity. In recent decades, the cultural shift has moved people from walking and bicycling and into vehicles. In 1960, about 10% of all trips were taken by walking and bicycling, and that number dwindled to just above 3% by 2009 (Ogden and Carroll, 2010. CDC, NHANES, McDonald, 2007. NHTS, 2009). In that same time, the adult obesity rate has gone from 13% to over 29% and a similar trend can be observed among children (NC BRFSS, SCHS, 2011). In 2011, 26.7% of North Carolina adults were physically inactive; in other words, over a quarter of North Carolina residents do not exercise in a month's time (NC BRFSS, SCHS). Physical activity is defined broadly by the CDC as activities that cause increased breathing or heart rate (CDC). Physical activity can include walking, bicycling and other leisure time activities and recreational activities.

Excess weight due to physical inactivity and poor diet cause an estimated 300,000 premature deaths each year in the US, second only to tobacco in causes of preventable death (Ewing et. al., 2008). North Carolina, in particular, has the 17th highest rate of obesity (29.1%) in the country (NC BRFSS, SCHS, 2011). If current trends persist, an estimated 58% of North Carolina adults will be obese by 2030 (RWJF, 2012). This would increase the risk for a number of chronic physical conditions, including heart disease, arthritis and diabetes. The added human toll and economic burdens to North Carolina residents, families, insurers and governments are alarming.

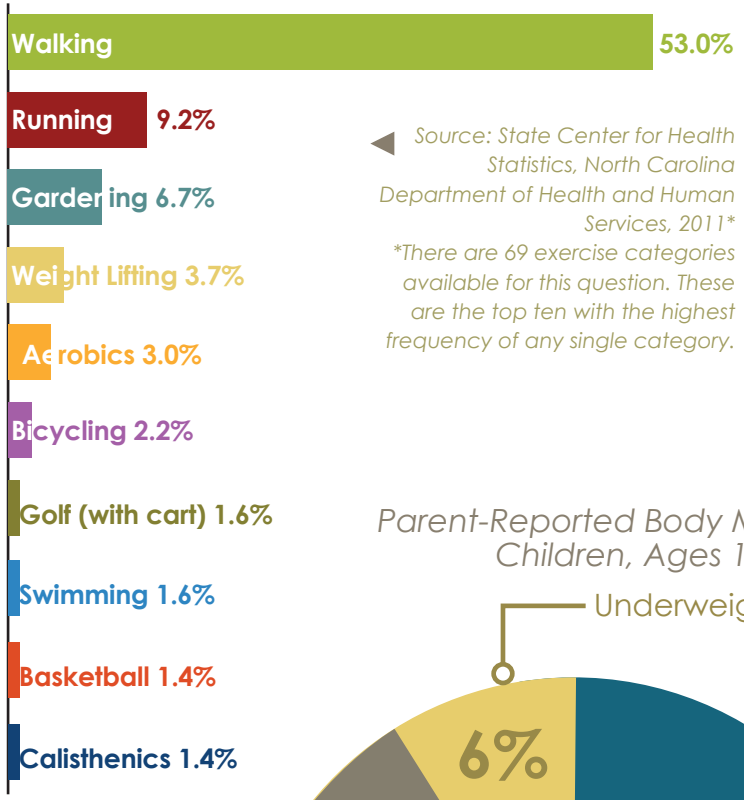
North Carolina counties with higher levels of physical inactivity and diabetes rates are predominantly in the eastern part of the state. Those with lower percentages of physical inactivity and lower diabetes rates tend to be in more urban areas. Health disparities along racial and income lines cause further concern. Among low-income people and people of color, physical inactivity rates are higher than the state average, posing even greater risk among these populations. In North Carolina, non-Hispanic blacks experience

Percentage of NC Adults Who are Physically Inactive by Gender, Race/Ethnicity and Income (2011)



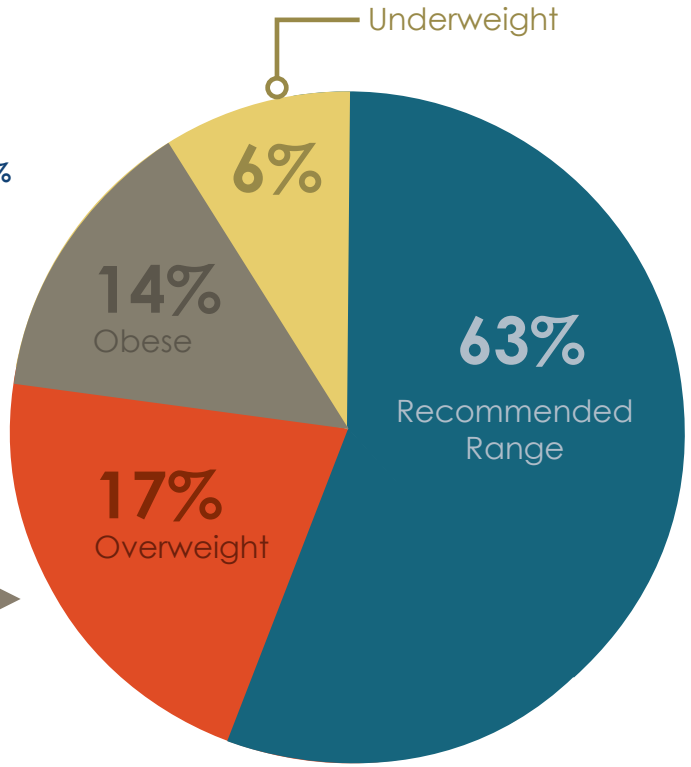
Source: State Center for Health Statistics, North Carolina Department of Health and Human Services, 2011

Top Leisure Physical Activities in the Past Month, NC Adults



Source: State Center for Health Statistics, North Carolina Department of Health and Human Services, 2011*
*There are 69 exercise categories available for this question. These are the top ten with the highest frequency of any single category.

Parent-Reported Body Mass for NC Children, Ages 10-17 (2011)



Source: NC BRFSS CHAMP, SCHS, 2011

almost double the rate of obesity to their non-Hispanic white counterparts at 42.4% and 26.7%, respectively. Racial and ethnic differences also exist in diabetes rates; 15.3% of non-Hispanic blacks in North Carolina have diabetes compared to 8.7% of non-Hispanic whites (America's Health Rankings, 2011).

Along with unhealthy diet, physical inactivity is attributed to the leading causes of premature or preventable death in North Carolina. Fifty-three percent of all deaths in North Carolina are preventable by changing health behaviors (NC DHHS). Sixty-five percent of adult North Carolinians are currently overweight or obese, which is just below the

North Carolina and United States Rates for Health Indicators

Chronic Diseases, Conditions and Health Risk Factors	North Carolina (%)	United States (%)	NC National Ranking
Obesity (2010)	29.1	28.3	32nd
Meet physical activity recommendations (2009)	46.5	49.6	43rd
Diabetes (2010)	9.4	8.7	41st
History of cardiovascular disease (2010)	8.7	7.9	40th
High blood pressure (2009)	30.5	28.2	42nd
Disability (2010)	22.9	22.0	31st

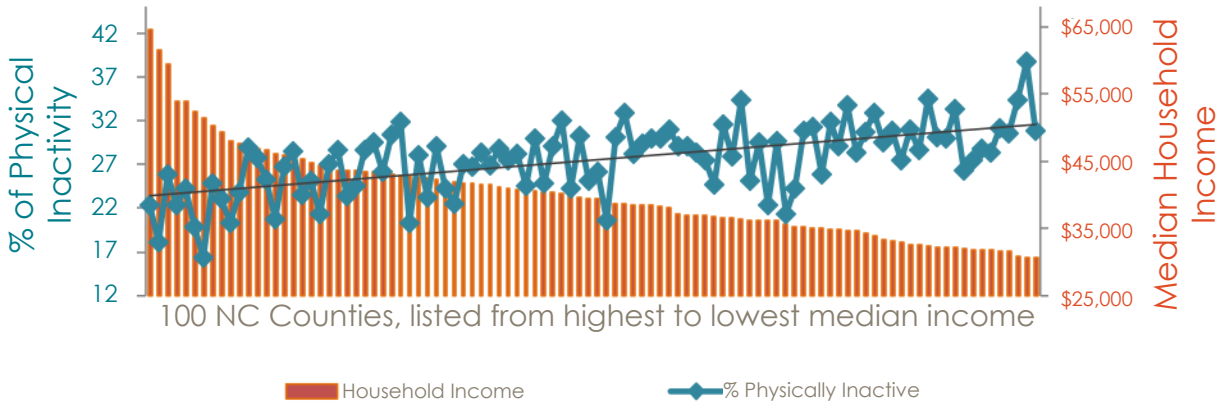
▲ *Source: Trends in Key Health Objectives for North Carolina and the Nation, 2012*

national average (68%) (NC BRFSS, SCHS). Twenty-nine percent are obese, having a body mass index (BMI) of 30 or greater, and 36% of North Carolina adults are overweight, or have a BMI greater than or equal to 25 and under 30 (NC BRFSS, SCHS). Getting the recommended amount of physical activity does not have to include recreational or strenuous activities and can often be incorporated into one's daily routine.

Unfortunately, North Carolina children are not protected from the obesity epidemic. Both at the state and national level, the rate of childhood obesity tripled from 1980 to 2004 (NC DHHS, 2010). In 2011, 16.8% of children ages 10-17 were overweight and 13.8% were obese.

As of 2011 North Carolina fared worse than the US average for many chronic diseases affiliated with physical inactivity (NC BRFSS, SCHS).

Correlation between Income and Physical Inactivity Levels in NC (2009)



▲ *Source: County Health Rankings*, 2012 and US Census, 2010.*
** In some cases, County Health Rankings aggregates data from many years for counties with lower sample sizes.*

Per capita income and physical inactivity levels are inversely related; as income increases, physical inactivity decreases. North Carolina counties with the lowest rates of physical inactivity – Orange, Wake, Mecklenburg and Durham – are within the top ten counties with the highest median income.

In 2011, the percentage of North Carolinians who have been told they have diabetes is 10.7%.

Adjusting for age, those with lower income (below $24,000) have a diabetes rate almost twice that of the state average (20.5%) (NC BRFSS, SCHS). The percentage of North Carolina adults living with diabetes has risen 2.8% from 2001 to 2010, from 6.6% to 9.4% respectively. The rate of those living with high blood pressure is also increasing, and increasing faster than the US average. From 2001 to 2010, the percentage of North Carolinians living with high blood pressure has risen 3.3% whereas the US average has risen 2.7% (NC BRFSS, SCHS).

Prevalence and Percent Change of Chronic Diseases for Selected NC Groups

	Diabetes		Cardiovascular Disease		High Blood Pressure	
	Prevalence (2010)	% Change (2001-2010)	Prevalence (2010)	% Change (2001-2010)	Prevalence (2009)	% Change (2001-2009)
Male	9.5%	2.7%	9.6%	-0.8%	31.7%	6.3%
Female	10.0%	3.3%	8.3%	1.3%	33.0%	3.8%
White	3.3%	3.3%	9.6%	0.7%	32.1%	6.5%
Black	4.7%	4.7%	9.2%	0.6%	41.7%	4.0%
Hispanic	1.4%	1.4%	data unavailable		13.6%	-6.9%

	Meets Physical Activity Recommendations		Obesity*		Physical Inactivity	
	Prevalence (2009)	% Change (2001-2009)	Prevalence (2010)	% Change (2001-2010)	Prevalence (2010)	% Change (2001-2010)
Male	51.1%	4.8%	29.1%	6.3%	22.3%	-0.7%
Female	41.9%	3.0%	29.0%	5.7%	29.0%	-0.5%
White	48.5%	3.8%	26.1%	6.0%	24.3%	1.1%
Black	37.5%	5.1%	43.7%	7.2%	30.1%	-5.2%
Hispanic	49.3%	2.1%	25.8%	4.9%	27.1%	-0.9%

Source: Source: Trends in Key Health Objectives for North Carolina and the Nation, 2012

**Obesity data include those 20 years old or older*

THE SCIENCE OF HEALTH AND TRANSPORTATION

Physical Activity Objectives, Active Transportation and Public Health

The nation's top public health authorities have declared the importance of physical activity and healthy weight as priority health indicators and emphasize built environment approaches in preventing chronic diseases. In fact, four of the US Department of Health and Human Services' 26 Healthy People Leading Health Indicators for its Healthy People 2020 plan are impacted by the transportation system: adults who meet current physical activity guidelines; adults who are obese; children and adolescents who are considered obese; and fatal injuries (http://healthypeople.gov/2020/default.aspx). Similarly, North Carolina's Year 2020 Health Objectives include increasing physical activity in adults and healthy weight among high school students. (Healthy North Carolina 2020: A Better State of Health)

To help address these objectives and increase physical activity levels in communities, the CDC Community Preventive Services Task Force recommends three evidence-based strategies to increase physical activity levels that relate to pedestrian and bicycle transportation. These approaches resulted from an extensive review of the scientific literature (CDC, 2011).

- Street-scale urban design and land-use policies, i.e. small area improvements to street lighting, increasing ease and safety of street crossings, introducing or enhancing traffic calming, enhancing the aesthetics of the streetscape and ensuring sidewalk continuity.
- Community-scale urban design and land-use policies, i.e. community-scale urban design and land-use policies to improve continuity and connectivity of streets, sidewalks and bicycle lanes; zoning regulations and roadway design standards that promote destination walking and co-location of residential, commercial and school properties (mixed land-use zoning), as well as transit-oriented development.
- Active transport to school, i.e. school interventions designed to encourage and support youth to engage in active transportation, Walk to School, Walking School Bus and Safe Routes to School.

More recently, other organizations and task forces have highlighted the health-promoting potential of the transportation system. In subsequent reviews of the best scientific evidence, the Institute of Medicine found that local governments have a vital role in impacting childhood obesity through these strategies to increase active transportation: (Institute of Medicine, "Local Government Actions to Prevent Childhood Obesity" downloaded from http://www.nap.edu/catalog/12674.html).

- Encourage walking and bicycling for transportation and recreation through improvements in the built environment.
- Promote programs that support walking and bicycling for transportation and recreation.

Likewise, CDC released the 24 recommended community strategies to prevent obesity as well as suggested measurements corresponding to each approach. Six of these strategies relate to the transportation system ("Recommended Community Strategies and Measurements to Prevent Obesity in the United States" http://www.cdc.gov/MMWR/preview/mmwrhtml/rr5807a1.htm).

Within North Carolina, state health officials have identifies key consensus strategies and objectives to measure progress relating to active transportation.

Strategies

- Inclusion of bike paths, sidewalks, accessible walking trails and parks in communities
- Review of current transportation policy and traffic patterns to provide safe conditions for walking and bicycling

Objectives

- Increase yearly the number of facilities and/or environments that promote physical activity, such as bike lanes, pedestrian/bicycle signage, sidewalks and greenways.
- Increase yearly the policies, practices and incentives to promote physical activity, such as draft and implement a bicycle plan, draft and implement a pedestrian or sidewalk plan, increase funding for pedestrian/bicycle facilities and pursue policy to dedicate a portion of funds for pedestrian/bicycle facilities on a regular basis.

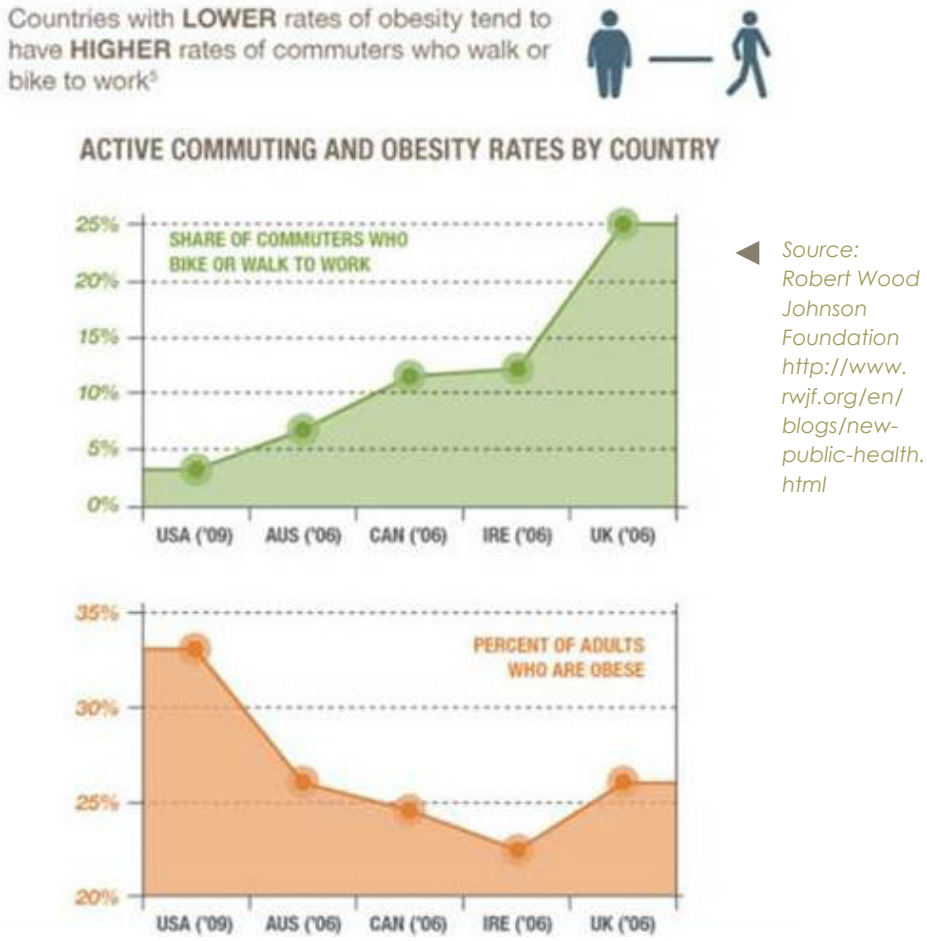
Sources: "North Carolina's Plan to Prevent Overweight, Obesity and Related Chronic Diseases," and "North Carolina Blueprint for Changing Policies and Environments in Support of Increased Physical Activity" (Division of Public Health, NC DHHS).

The Health Benefits of Physical Activity through Active Transportation

Engaging in regular physical activity can help lessen one's risks for chronic disease, control and reduce weight and help reduce premature deaths due to obesity-related

Source: MMWR, 2009, Centers for Disease Control and Prevention

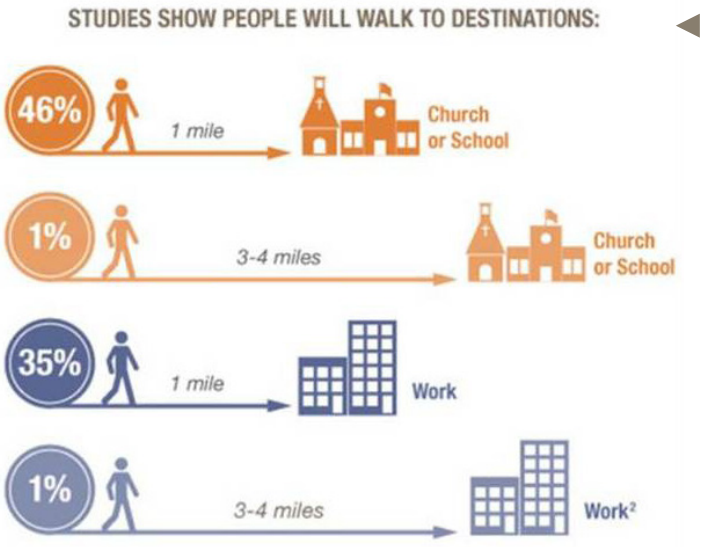
Strategy	Suggested Measurement
Enhance infrastructure supporting bicycling	*Total miles of designated shared-use paths and bike lanes relative to the total street miles (excluding limited access highways) that are maintained by a local jurisdiction.*
Enhance infrastructure supporting walking	*Total miles of paved sidewalks relative to the total street miles (excluding limited access highways) that are maintained by a local jurisdiction.*
Support locating schools within easy walking distance of residential areas.	*The largest school district in the local jurisdiction has a policy that supports locating new schools, and/or repairing or expanding existing schools, within easy walking or biking distance of residential areas.*
Improve access to public transportation.	*The percentage of residential and commercial parcels in a local jurisdiction that are located either within a quarter-mile network distance of at least one bus stop or within a half-mile network distance of at least one train stop (including commuter and passenger trains, light rail, subways and street cars).*
Zone for mixed use development.	*Percentage of zoned land area (in acres) within a local jurisdiction that is zoned for mixed use that specifically combines residential land use with one or more commercial, institutional, or other public land uses.*
Enhance personal safety in areas where persons are or could be physically active.	*The number of vacant or abandoned buildings (residential and commercial) relative to the total number of buildings located within a local jurisdiction.*
Enhance traffic safety in areas where persons are or could be physically active.	*Local government has a policy for designing and operating streets with safe access for all users which includes at least one element suggested by the national complete streets coalition (http://www.completestreets.org)*



Source: Robert Wood Johnson Foundation http://www.rwjf.org/en/blogs/new-public-health.html

illness (Heath et al., 2006). Being physically active can also improve mental health and sense of well-being (CDC, 2011). Health experts have historically attempted to increase leisure-time activity to achieve these goals, but have broadened their view of physical activity to include a lifestyle that integrates physical activity into daily routines (Hoehner et. al., 2005). For example, commuting to work or school is an opportunity for regular physical activity in the form of daily walking or bicycling. Sixty percent of North Carolinians say that better access to sidewalks, trails and paths would encourage them to increase their walking and biking activities (Conti et. al, 2012).

Walking is the most commonly reported physical activity among adults and the most frequently reported activity among adults who meet physical activity guidelines (Kruger et al., 2008, Simpson et. al., 2003). In 2011, the CDC found that 62% of adults say they walked for at least ten minutes or more in the previous week, compared to 56% in 2005. Although the southern states had the lowest rates of walking (47.7% males and 50.6% females), they also saw the greatest increases in walking (CDC, 2012). Walking is a physical activity most people can do because it does not require a special skill or special facilities and can be done indoors or outdoors, alone or with others. In this regard, walking is particularly important for its potential to reduce disparities in health (Lee and Buchner, 2008). Walking and other physical activities have numerous health benefits including weight control, reduced risk for Type II diabetes, cardiovascular disease, certain cancers, strengthened bones and muscles, and improved mental health and mood (Heath et. al., 2006).



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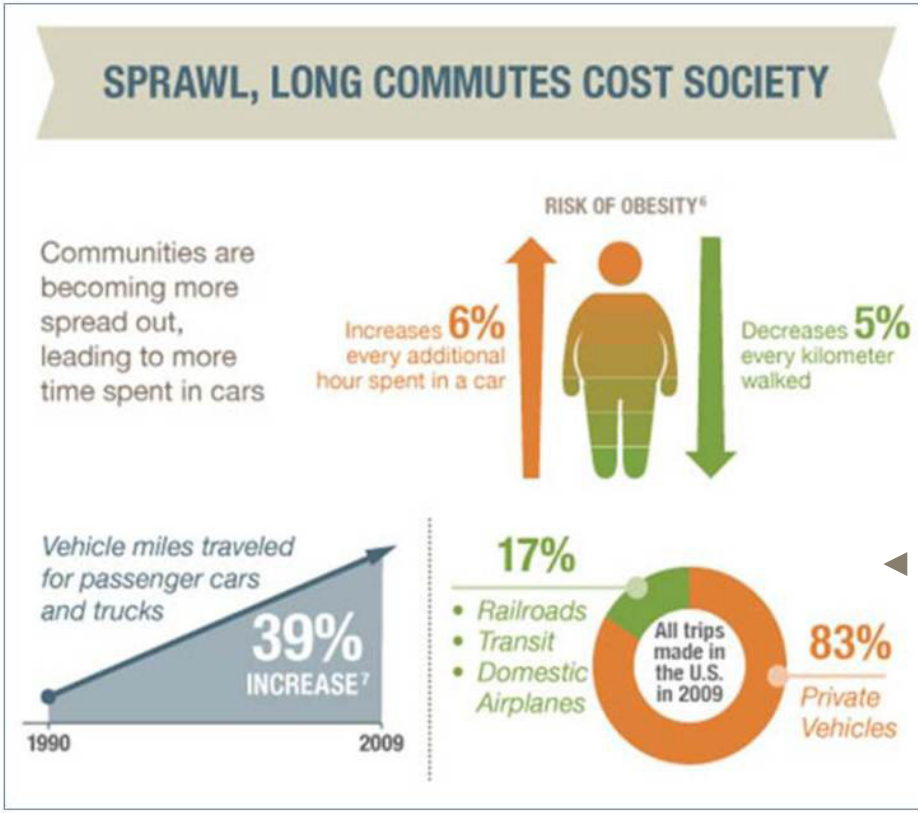


Source: Robert Wood Johnson Foundation http://www.rwjf.org/en/blogs/new-public-health.html

While bicycling is not as prevalent as walking, it is gaining ground in the US. During the past two decades, the number of bike commuters has risen by 64% (Pucher et. al, 2011). Bicycling has also engaged increasingly diverse populations. Between 2001 and 2009, bicycling rates rose fastest among African Americans, Hispanics and Asian Americans. These three groups also account for a growing share of all bike trips, up to 21% in 2009 from 16% in 2001 (Pucher et al., 2011). As communities of color are more likely to be burdened by obesity and associated chronic disease, these increases are especially promising (CDC, 2011). Strong evidence exists for the health benefits of bicycling as a form of physical activity through associated reductions in all-cause mortality, cardiovascular disease and some cancers (Oja, Titze et al. 2011) as well as weight control and mental health (Cavill and Davis, 2007). A number of comprehensive assessments have shown that the health benefits of physical activity achieved while bicycling far outweigh the potential exposures to poor air quality and road traffic. Most recently, researchers comparing risks and benefits of active transportation concluded that even though increased walking and bicycling results in reduced air pollution, the greatest benefit is the health promoting potential of physical activity (Rabl and de Nazelle, 2012). Life years gained among individuals who shift from car to bicycle are estimated to be three to 14 months compared to 0.8 to 40 days lost through increased inhaled air pollution, and five to nine days lost due to an increase in traffic accidents (Johan de Hartog, Boogaard et al. 2010). On balance, the health benefits from bicycling outweigh the risks of exposure to poor air quality and injury.

The Built Environment, Transportation and Health

Generally the built environment is defined as the part of the physical environment that is constructed by human activity. It may consist of land use patterns, the transportation system and urban design (Handy et. al., 2002). While it is up to the individual to make the decision to be physically active, the transportation network can enable or facilitate better health outcomes depending on the safety and feasibility of active transportation alternatives (Conti et. al., 2012). In combination with sprawling development patterns, the transportation network in North Carolina is designed primarily for travel by motorized vehicles (Conti et. al., 2012). Unfortunately, areas where the automobile is the dominant form of transportation for work, school, shopping and leisure activities are associated with physical inactivity, overweight and obesity (Lindstrom, 2008). Additionally, the more time spent in a car increases the likelihood of developing obesity (Frank and Schmid, 2004, Saelens et. al., 2003, Lopez-Zetina et. al., 2006, Pendola and Ren, 2007). Planning and health

researchers in Atlanta found that each additional hour spent in a car per day was associated with a 6% increase in the likelihood of obesity, while each additional kilometer walked per day was associated with a 4.8% reduction in the likelihood of obesity (Frank and Schmid, 2004).

In contrast, residents get more physical activity if they live in traditional neighborhoods developed prior to World War II, as well as residents of new neighborhoods built for walkability, (Sallis et al, 2009). A comprehensive review of studies found that sidewalks and connectivity are commonly correlates of walking (Saelens and Handy, 2008). Factors within these neighborhoods that influence walkability and thus physical activity include: connectivity (limiting construction of new cul-de-sacs or connecting existing cul-de sacs), smaller block size, urban design that promotes enclosure, human scale, transparency, complexity, dense land use mix and higher residential density (Sallis et. al., 2009, Ewing et al., 2006, Dill and Voros, 2007). In Seattle and Baltimore, residents of high-income but low-walkable neighborhoods had a 50% increased risk for obesity compared to high-income, walkable neighborhoods (Sallis et al, 2009).

In terms of bicycling infrastructure, many western states (including California, Oregon and Washington) and larger cities that have implemented a range of efforts, including infrastructure, encouragement programs and policies to promote cycling, have seen the largest increases in walking and bicycling (Pucher et al., 2011). Common to these places is a supportive environment and populations motivated to walk and bicycle. These conditions have not occurred by chance; they are the outcome of intentional policies that address both environment through infrastructure and motivation through non-infrastructure projects (Basset et. al., 2008). Southern states, like North Carolina, that have invested the least in walking and cycling have lower levels of bicycling (Pucher et al., 2011). Greater bicycle infrastructure has consistently been associated with higher levels of bicycling (Pucher et. al., 2010). Dill and Carr (2003) found that each additional bikeway mile per square mile is associated with roughly 1% increase in bicycle trips (Dill and Carr, 2003). These studies demonstrate a clear and convincing association between the built environment and physical activity, but certain aspects of the built environment warrant additional explanation.

Many built environment features are correlated with physical activity and include: pedestrian and bicycle infrastructure, parks, street network density, residential density, land use mix and urban design (Sallis, et al, 2009; Saelens and Handy, 2008; Saelens, Sallis and Frank, 2003). Pedestrian and bicycle facilities are associated with more adults and children meeting physical activity recommendations through both leisure and transportation-related physical activity (Owen et al, 2004; Dill, 2009; Pucher, Dill and Handy, 2010).

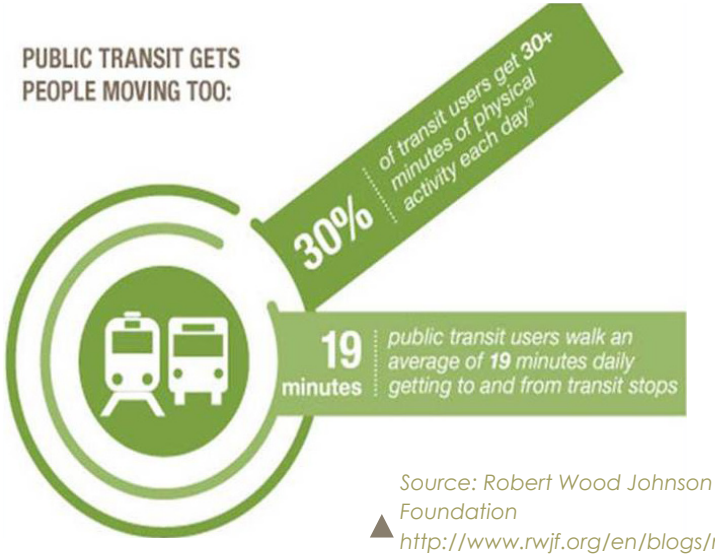
It is important to consider the type of walking and cycling for tailoring interventions. Walking or bicycling for leisure has the strongest associations with the proximity, quantity and quality of recreational facilities (Brownson et al, 2009). On the other hand, walking or cycling for travel is more likely influenced by route directness, proximity of destinations and walking and cycling facilities (Brownson et al, 2009; Dill, 2009; Sallis et al, 2009).

Air Quality Impacts of Active Transportation

Air pollution is an environmental risk to health. Transportation-related air pollutants are one of the largest contributors to unhealthy air quality. Exposure to traffic emissions has been linked to many adverse health effects including: premature mortality, cardiac symptoms, exacerbation of asthma symptoms, diminished lung function, increased

hospitalization and others (Friedman, 2001). Motor vehicles are a significant source of air pollution in urban areas causing about half of the toxic air pollutant emissions in the United States (EPA, Air Pollution). Walking and bicycling, on the other hand, produce virtually no pollution (Frank, et al. 2010). A number of studies have shown that the benefits outweigh the risks associated with potential injury and exposure to poor air quality for walking and bicycling.

Children are particularly vulnerable to poor air quality because they breathe 50% more air per pound of body weight than adults (EPA, Air Pollution). Childhood asthma is one of the most common pollution-related health problems in America, affecting more than 7 million children (CDC, Asthma). With the majority of children being driven to school, children may face exacerbated conditions near schools. Idling in student drop-off and pick-up lines further diminishes air quality around schools (EPA, Idle Free Schools). Safe Routes to School programs can help improve air quality by increasing the number of children walking and bicycling to school and reducing motor vehicle trips. To improve the respiratory and cardiovascular health of the US population as a whole, the CDC includes improving air quality as one of eight priority recommendations for transportation. Possible strategies include promoting transportation choices and innovative transportation measures that reduce emissions, shifting to active transportation and public transportation modes and reducing vehicle miles traveled per capita (CDC, Transportation). Investing in walking and bicycling infrastructure and programs can play a significant role in improving air quality.



Source: Robert Wood Johnson Foundation http://www.rwjf.org/en/blogs/new-public-health.html

Connecting Walking and Bicycling to Healthy Food Access

People who live in low-income communities tend to be underserved by both the food and transportation systems. Inner-city and rural neighborhoods commonly have fewer and smaller grocery stores, with poorer selections of healthy foods and higher prices than their suburban counterparts (PolicyLink, 2010). Lower income populations also have lower vehicle ownership levels and/or access to direct transit routes to grocery stores. Connecting individuals to healthier foods via transportation is important because children living in neighborhoods with access to healthy food and safe play spaces are 56% less likely to be obese than children in neighborhoods without these features (Saelens et. al., 2012). A Los Angeles based study also found that longer distance traveled to reach a grocery store was associated with higher body mass index (Inagami et. al., 2006). Finally, obesity rates are 20% higher in low-income areas with high densities of fast-food and convenience stores compared to low-income areas with lower densities of outlets selling primarily unhealthy foods (PolicyLink, 2008).

Determinants of Walking and Bicycling

A person's decision to walk or bicycle is influenced by a variety of factors including personal reasons, community norms and the built environment. Personal factors include ability, comfort, confidence, habits and perceptions about walking and bicycling that can evolve over one's lifespan, but may also be modified by targeted intervention programs. Community norms that predicate the social acceptability of walking or bicycling also affect individual motivation and may be difficult to shift. The built environment can be shaped by public investments and development policies over time. Natural features, particularly weather and topography, are also important, though beyond the direct reach of policy (Handy, 2010). A growing number of cities have demonstrated the need to implement integrated strategies - policies, projects and programs - that can address both environment (infrastructure) and individual motivation (non-infrastructure) that significantly increases active transportation (Pucher et. al., 2010).

Health Equity

Unequal exposure to positive social, economic and environmental influences can result in health inequities among different populations. For example, lower-income neighborhoods tend to have less access to healthy foods and fewer options for adequate physical activity (Day, 2006). Transportation is a social determinant that can play a major role in influencing people's health and sense of well-being. Communities of color, low-income communities, people with disabilities and people with language barriers are disproportionately impacted by burdens of the transportation system and do not receive an equal share of the benefits (Upstream Public Health, 2012). The National Surface Transportation Policy and Revenue Study Commission, created by Congress in 2005, determined that "The nation's surface transportation network regrettably exacts a terrible toll in lost lives and damaged health." The toll is highest among low-income people and people of color (National Surface Transportation Policy and Revenue Study, 2007).

From an equity standpoint, active transportation presents both challenges and opportunities. Access to adequate walking and bicycling facilities can improve access to jobs, healthcare, healthy food, and physical activity for households with limited access to cars. Additionally, walking and bicycling can reduce health disparities between low-income and more affluent communities. Safety, however, remains a significant concern. The challenge is to increase walking and bicycling safely, primarily because the population groups that could most benefit from increased walking and bicycling are also the most vulnerable to traffic dangers. Overall physical activity levels are lowest among low-income and minority populations despite the fact that low-income households are more dependent on walking and public transit (Pucher and Renne, 2003, Besser and Dannenberg, 2005). Forty percent of the lowest income transit users meet the recommended levels of physical activity solely from walking to and from transit (Besser and Dannenberg, 2005). Without this, their total physical activity would be far less. Walking or bicycling is often the only viable physical activity option for low-income residents who live in neighborhoods without nearby parks, who cannot afford gym memberships and do not have the luxury of leisure time (PolicyLink, 2010). In many low-income and communities of color the quality of pedestrian and bicycling infrastructure is often worse, despite their greater dependence on it, contributing to higher pedestrian fatality rates (Pucher and Renne, 2003).

Transportation, Income and Health

As distances between housing and employment increased

over time, non-drivers have experienced employment barriers. Nationally, 19% of African Americans and 13.7% of Latinos lack access to automobiles, compared with 4.6% of whites. Poverty complicates the problem: 33% of poor African Americans and 25% of poor Latinos lack automobile access, compared with 12.1% of poor whites. Vehicles owned by low-income people tend to be older, less reliable and less fuel-efficient which adds to the unpredictability, expense of commuting and poorer air quality (PolicyLink, 2010).

▲ *Source: Robert Wood Johnson Foundation*
http://www.rwjf.org/en/blogs/new-public-health.html

The potential economic benefits of increased walking and bicycling are apparent. Better health as a result of increased physical activity can reduce healthcare costs while cheaper modes of travel can reduce household spending on transportation (PolicyLink, 2010). Making walking and bicycling more viable, particularly in conjunction with improvements to transit, can increase access while contributing to economic development efforts by encouraging retail stores and restaurants to locate within walking distance of residential areas, particularly in low-income areas (Handy, 2010).

Transportation, Youth and Health

Across the country, children and many adolescents depend on parents and other adults to drive them to school and other activities, a trend that has increased in recent decades (McDonald, 2006). Walking to school dropped from 40.7% of all school trips in 1969 to 12.9% in 2001 (McDonald, 2007). If children were able to safely walk or bicycle more, they would get more physical activity, increase their autonomy and their parents would drive less. However, the risk of injury is a concern: rates of pedestrian and bicyclist fatalities and injuries per capita are highest for those under the age of 15 (Handy, 2010). Parental fears about traffic as well as fear of abductions, or "stranger danger," help explain why children now walk and bicycle less than in the past. According to the U.S. Department of Justice, in 2002 (the most recent year for which data are available), 98% of children reported missing were either family member abductions or were not abductions. In these cases children were lost, injured, or unable to make contact with a caregiver (U.S. DOJ, 2002). Nonetheless, increasing walking and bicycling for children will require addressing removing threats to their safety, both actual and perceived (Handy, 2010).

Transportation, Older Adults, People with Disabilities and Health

Older adults could equally benefit from increased walking and bicycling, but safety remains an issue for them as well. One in five adults ages 65 years and older does not drive, and more than 50% of non-drivers stay home because

they lack transportation options (Handy, 2010). Walking, bicycling and transit can provide an important means of accessing healthcare, food and recreation. However, the decline in physical and mental abilities that make driving unsafe can also make walking and bicycling more difficult. Uneven sidewalks, for instance, can pose a greater obstacle for older adults and persons with disabilities. Likewise, many older pedestrians are fearful at intersections where crossing signals do not allow slower walkers enough time to cross safely. The highest rate of pedestrian fatalities per capita is for those over age 70 (Handy, 2010). Increased walking appears to reduce long-term cognitive decline and dementia (Erickson, et al. 2010). Where safe conditions exist, increased walking and bicycling can improve physical and mental health (Handy, 2010).

In 1990, The Americans with Disabilities Act (ADA) expanded its language regarding transportation options for people with disabilities. ADA requires public bus and rail operators to offer accommodations, such as lifts and ramps, to allow people in wheelchairs to ride. However, most communities' street designs make traveling to and from bus stops difficult and unsafe for people with disabilities. Paratransit systems, which are intended to overcome these barriers and are prevalent in rural communities, are often limited in funding and resources and often require users to schedule transit pick-up well in advance, posing additional challenges (Handy, 2010). Designing a safer streetscape for both older adults and people with disabilities will help with independence and mobility and improve physical and mental health.

Rural Communities

Rural communities comprise around 40% of North Carolina's population and are of particular interest as their cultural, social, economic, and geographic characteristics place them at higher risks for many unfavorable health conditions (Gamm, 2004; Census, 2000). According to the Centers for Disease Control and Prevention (CDC), people are more likely to be physically inactive in remote areas (37%) compared to those in urban locations (27%) (CDC, 1998). Opportunities in the physical environment such as access to walking trails, sidewalks, gyms, "walkable" streets, and parks may be limited or non-existent in rural, lower density areas, which can contribute to physical inactivity among residents (Luttfiya, 2007). Pedestrian and bicycle projects may be more difficult in these areas, but are sorely needed to help improve levels of physical activity.

Best Practices and Promising Examples

Throughout the past decade, health and urban planning researchers have devoted considerable attention to the aspects of the transportation system that impact health. This section briefly describes a number of interventions, both infrastructure and non-infrastructure, that have evidence to support increased active transportation levels. Promising case examples, mostly from within North Carolina, are highlighted as illustrations of successful real-world approaches to support health.

Transportation Infrastructure Interventions

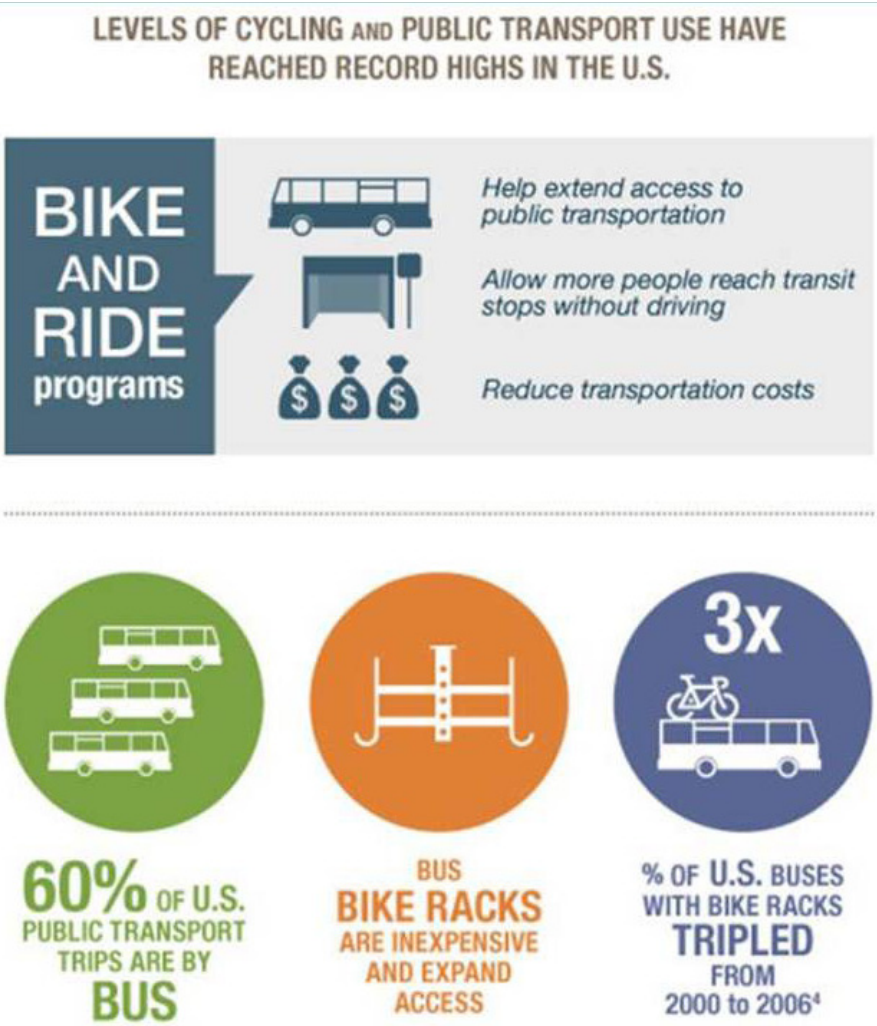
Traffic Calming to Lower Vehicle Speeds

Research shows that low-speed traffic designs are not only more appealing but significantly safer for pedestrians and bicyclists. Perceived safety and traffic speed are often cited as major barriers to walking and bicycling (Pucher and Dijkstra, 2003, Dill and Voros, 2007). Traffic calming has been shown to increase the number of bicyclists. In

one intervention, engineers improved a high-capacity four-lane road (with 15,000 average daily vehicle trips) by introducing new medians, narrowing the road and/or marking bicycle lanes. These changes resulted in a 23% increase in bicycle use per day (MacBeth, 1999).

Designing a Network for all Pedestrians and Bicyclists

Many studies have shown the importance of pedestrian and bicycle infrastructure in increasing the numbers of walking and bicycling trips, particularly sidewalks, separate paths and bike lanes (Pucher, Dill and Handy, 2010, Dill and Handy, 2010, Dill and Carr, 2003, Sallis et. al, 2009, Saelens and Handy, 2008). It is also important to design for all users, including older adults, children, people with disabilities and inexperienced bicyclists. While bike lanes are important and favored by some bicyclists in urban or suburban areas, empirical observations of bicyclist behavior suggest that "a network of different types of infrastructure is important and favored by cyclists, but mainly as connections when routes on low-traffic streets are not available" (Dill, J. 2009)



▲ *Source: Robert Wood Johnson Foundation http://www.rwjf.org/en/blogs/new-public-health.html*

In order to attract new people to cycling, infrastructure beyond bicycle lanes are necessary (Dill, 2009). Even many experienced cyclists are willing to travel far out of their way to access low-stress bikeways such as off-street paths and bicycle boulevards. This suggests that designing for the least experienced users will attract new users and may better serve existing bicyclists (Dill, 2009). Research suggests that by designing for perceived safety concerns and bicyclists' preference, real threats to safety can be mitigated while making bicycling more appealing (Dill, 2009). Many European cities have experienced a decrease in crash rates as the number of pedestrians and bicyclists have increased, referred to as the "safety in numbers" concept (Jacobsen, 2003).

Bicycle Parking

In addition to bicycle lanes, bicycle parking availability has been shown to encourage frequent bicycle commuting (Hope, 1994). Cities with high rates of bicycling have been found to provide ample

bicycle parking (Pucher and Buehler, 2008). Compared to other destination facilities such as showers or lockers, bicycle parking has been shown to be more effective in encouraging bicycle commuting (Stinson, 2004).

Infrastructure Maintenance

Research indicates a lack of infrastructure maintenance in low-income and communities of color, even in neighborhoods with sidewalks and adequate connectivity (Zhu and Lee, 2008). Maintaining existing infrastructure is crucial to improving and sustaining walking for physical activity in these neighborhoods (Sallis et. al., 2009). Infrastructure maintenance is important for bicycling as well. Pavement quality is a significant predictor of bicyclists' rating of a road segment (Landis et al., 1998, Parkin et al., 2008).

Manage Automobile Parking

Managed automobile parking reduces single occupancy vehicle use and increases more active modes of transportation (Litman, 2008). Restrictive parking policies that make parking more difficult have been associated with higher levels of walking (Rodriguez et. al., 2008). Disincentives to drive motor vehicles, including limited parking options or parking fees, lead people to take alternative modes, including walking, bicycling and transit. In California, a state "cash-out" requirement of certain employers led to a 39% increase in the number of employees bicycling and walking to work (Shoup, 1997). This law applies to employers who provide subsidized parking for their employees and requires them to offer a cash allowance in lieu of a parking space.

Non-Infrastructure Transportation Interventions

Wayfinding

Depending on the quality and availability, some experts have suggested that active transportation can increase in association with wayfinding (signage). More importantly, wayfinding efforts should be incorporated into the best practices for encouragement and marketing efforts (VPTI, 2010). While there is limited evidence of the impact on pedestrian and bicycling levels of wayfinding as a singular strategy, the practice is growing (Pucher, Dill and Handy, 2010).

Marketing and Publicity

Marketing programs have been successful in increasing active transportation by 10 to 25% (VTPI, 2010). Impacts from marketing can be expected to decline over time and should be implemented after infrastructure changes have been made to maximize benefit (VPTI, 2010). Evaluations of trip reduction efforts in Portland, OR show increases in bicycling mode share following marketing efforts to encourage active commuting (City of Portland Office of Transportation, 2005).

Enforcement

Heightened enforcement has been found to be a contributing factor to increases in walking and bicycling safety (Pucher, 2003). In addition to traffic codes that favor and prioritize the most vulnerable road users, police are stricter in citing violations such as speeding that might put pedestrians at greater risk. Lower speeds are safer for pedestrians and cyclists: the mortality risk at 20 mph is 5% if hit by a motor vehicle, compared to 45% at 30 mph and 85% at 40 mph (United Kingdom Department of Transportation, 1997) Compared to engineering changes such as traffic calming, however, enforcement effect tend to have temporary impact (Transportation for America, 2009).

Safe Routes to School Programming and Education

Safe Routes to School is designed to promote walking and

bicycling to school through education, encouragement, engineering, enforcement and evaluation strategies. There is strong evidence that this combination of programming increases physical activity among students. At schools with safe routes to school programming, parents report higher rates of active transportation to school in a wide variety of social and built environments (Boarnet, 2005) and these benefits appear to extend to adults in the community-at-large (Watson and Dannenberg, 2008). Safety education, including bicycle helmet promotion, within and outside of these programs has been shown to improve pedestrian and bicycling skills such as timing and choosing safe crossings (Killoran et al., 2006).

Employee Transit Incentive Programs

By definition, transit users are also pedestrians because buses and trains rarely offer door-to-door service. Without a car at the end of a transit trip, the probability of walking between two intermediary destinations is high. Providing incentive to use transit could in turn promote walking. Indeed, having an employer-sponsored transit pass has been shown to have a positive relationship with meeting physical activity recommendations (LaChapelle et. al., 2009).

Temporary Street Closures

Day long street closures to increase physical activity for pedestrians and bicyclists, commonly known as "open streets" or "play streets," are being implemented world-wide and more recently in the US (Pucher, Dill and Handy, 2010). Such programs have the potential not only to promote physical activity, but improve social cohesion (Holt, 2008).

Non-infrastructure projects have shown to increase walking and bicycling levels on their own. However, unless permanent infrastructure is established, the benefit of such efforts is temporary and may not promote long-term changes in physical activity once those incentives or regulations are gone (Dunton et. al., 2010). A mix of environmental, social and individual interventions are most effective for increasing public transportation use in order to reach individuals of varying readiness to change (Giles-Corti and Donovan, 2002).

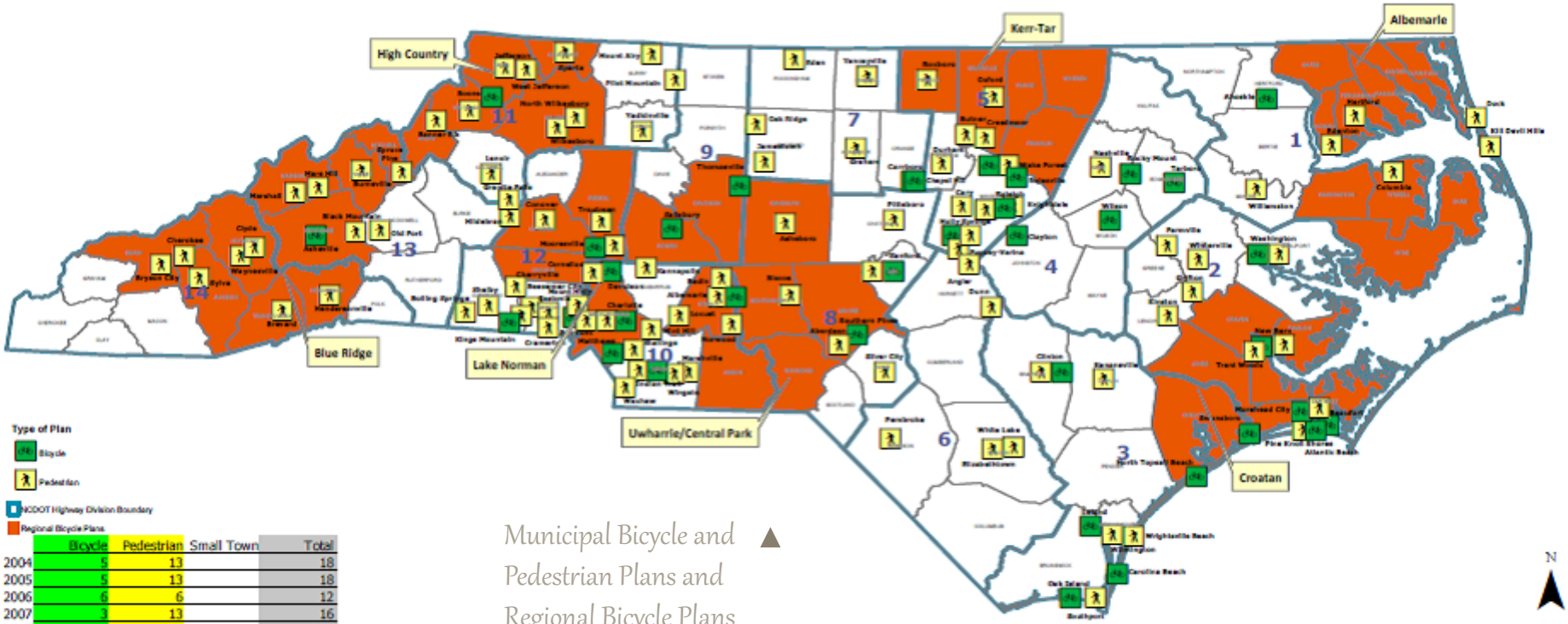
Health Impact Assessment

Health Impact Assessment (HIA) is a relatively new public health tool in the US. More prominent and routine in Europe, HIAs are used to analyze policies, plans, or projects to determine their public health effects. For an HIA to add value, it must be practical and conducted prior to (and inform) the final decision to approve a policy, plan or project (Improving Health in the US, 2011). An HIA may investigate how a policy or project may impact air quality, water quality, noise level, physical activity rates, injury and death rates, access to healthy foods and other potential health factors. HIA identifies the populations affected by a proposed project or policy and, through a six-step process, makes recommendations to key decision makers that are intended to mitigate harmful health effects and promote beneficial ones.

Within North Carolina, a handful of HIAs have been recently completed or are currently underway. Examples include:

- **Aberdeen Pedestrian Transportation Plan (APTP) HIA** - This HIA examined how changes to pedestrian infrastructure such as sidewalks and trails have the potential to increase physical activity rates in children, thereby reducing the risk of obesity. The study listed five major barriers to physical activity for Aberdeen children and identified recommendations for improving access and safe.

- **Haywood County Comprehensive Bicycle Plan HIA** – The Haywood HIA was the first ever conducted in North Carolina for a non-motorized transportation plan and was used to bring a new perspective to the planning process and gather input from non-traditional stakeholders. Planners conducted Rapid HIA and extensive document and data review, a half-day workshop with area health professionals and an assessment of the Bicycle Plan's recommendations (http://bicyclehaywoodnc.org/BikePlan.html).
- **Public Health and Neighborhood Design Standards HIA** - Based in the Town of Davidson, NC, Davidson Design for Life conducted this assessment of the 2011 Senate Bill 731 "Zoning/Design and Aesthetic Controls." The HIA considered the health impacts of this bill, which would limit a municipality's ability to maintain locally adopted design controls in residential areas. The bill was eventually passed by the NC General Assembly despite the HIA's findings. Davidson Design for Life is currently conducting two other related projects: Davidson Planning Ordinance HIA and the Charlotte Red Line Commuter Rail HIA. These projects are funded by a grant from the CDC (http://www.ci.davidson.nc.us/index.aspx?NID=732).
- **Blue Ridge Road Corridor HIA** – Located in Raleigh, NC, Blue Ridge Road connects many



	Bicycle	Pedestrian	Small Town	Total
2004	5	13		18
2005	5	13		18
2006	6	6		12
2007	3	13		16
2008	2	13		15
2009	5	7	2	14
2010	2	10	2	14
2011	5	7	3	15
2012	3	10		13
total	36	92	7	135

Municipal Bicycle and Pedestrian Plans and Regional Bicycle Plans ▲

destinations, including the art museum, fairground, hospital, residences, a greenway and government offices. Although the corridor records the state's highest pedestrian traffic counts, the availability of sidewalks and public transit is poor. The HIA will assess accident risks, lack of physical activity, air pollution and social disintegration to inform development decisions in the corridor. The HIA is being conducted by the UNC Gillings School of Global Public Health and the Department of City and Regional Planning; the Blue Cross Blue Shield of North Carolina Foundation is funding this project.

- **Charlotte LYNX Evaluation: The Effect of Light Rail Transit on Body Mass Index and Physical Activity** – While not an HIA per se, the study evaluated the health impact of the installation of the new LYNX light rail line on nearby residents. Researchers collected information from residents before and after the opening of the rail line to analyze changes in commute mode, body mass index (BMI) and physical activity rates. Residents who switched to using the light rail line weighed an average of six and a half pounds less than those who continued to drive to work. Light rail users were also 81% less likely to become obese over time due to walking to and from transit stops.

North Carolina Leading the Way

North Carolinians are fortunate to live in state that many national experts consider to be a model. For years, NC DHHS has been supporting local health departments to help improve community environments that can promote active transportation. For more than a decade, NC DHHS has done this through training, technical assistance and Eat Smart Move More (ESMM) grant opportunities for local communities. ESMM is a collaborative "statewide movement that promotes increased opportunities for healthy eating and physical activity wherever people live, learn, earn, play and pray." At the state level, ESMM partners released their 2012 Policy Strategy Platform, urging NCDOT to continue developing the Safe Routes to School program in North Carolina, continue to pursue federal funding, and to use this funding efficiently and effectively to encourage children to walk to school.

North Carolina's Department of Transportation was among the first in the nation to create a Division of Bicycle and Pedestrian Transportation (DBPT). In recent years, DBPT developed and implemented an innovation for NCDOT – its bicycle and pedestrian planning grant program. To date, the program has enabled more than 100 North Carolina communities to develop master plans for active transportation.

NCDOT's Complete Streets Policy and design guidelines have the potential to create safer environments for all users, including pedestrians, bicyclists and transit riders. The content of NCDOT's recently approved "Public Health Policy" can be found at the end of this appendix.

Health funders have also contributed to active transportation in the state. Prior to its sunset in 2011, the NC Health and Wellness Trust Fund created the Fit Community Designation and Grant program, which helped many communities develop multi-pronged approaches to improve active transportation. Similarly, Blue Cross Blue Shield of North Carolina Foundation has funded rural community initiatives through its Fit Together grant program. More recently, the Foundation has supported health impact assessment work as well as the health-related components of this document.

Case Studies: Communities Connecting Health and Transportation

Charlotte, NC – Public Transit and Health Impact

Despite Charlotte's past sprawling development, North

Charlotte's light rail line ▲

Carolina's light rail line has become a national model for success, outstripping ridership projections and inspiring millions of dollars in high-density development. Charlotte's successful light rail line presented a unique opportunity to study the impact of transit on physical activity and health. Much research exists that links transit-accessible neighborhoods with more people walking to transit. However, many of these studies are unable to adequately evaluate cause and effect. It may be that people select to live in urban, transit-accessible neighborhoods to fit their active lifestyles. A public health and planning research team examined the health effects of Charlotte's Lynx light rail line before and after the light rail arrived in 2007. They found that people commuting via the light rail reduced their Body Mass Index (BMI) by 1.18 points and were 81% less likely to become obese over time. Participants reported average weight loss equivalent to adding as much as 1.2 miles to a person's daily walking routine. Overall, the results suggest that improving neighborhood environments and increasing the public's use of light rail systems improve health outcomes for many North Carolinians.

Wilmington, NC – Ann Street Bike Boulevard

With the help of a Fit Community grant from the North Carolina Health and Wellness Trust Fund, the City of Wilmington constructed North Carolina's first bicycle boulevard in 2011. The project connects historic neighborhoods, schools, parks, major employers and activity centers with downtown Wilmington and the Riverfront Farmers' Market. A bicycle boulevard gives bicycles limited priority over motor vehicles on an existing roadway corridor. The bicycle boulevard required internal policy changes, as well as modest infrastructure components, such as curb extensions, alley resurfacing, high-visibility crosswalks, pavement markings and signage. The Ann Street Bicycle Boulevard is part of the River to the Sea Bikeway from downtown Wilmington to Wrightsville Beach, making the bicycle boulevard accessible to most of Wilmington's residents. The primary goal of the project was to increase the number of people bicycling to destinations along the routes and to improve

Ann Street Bike Boulevard in Wilmington ▲

access for city residents to purchase fresh local produce, seafood and meat at the Riverfront Farmers' Market. The City of Wilmington also installed machines capable of accepting electronic benefit cards (EBTs) for low-income residents who visit the Riverfront Farmers' Market. These combined efforts have created better access to healthy foods and a safe way to be physically active.

Durham, NC – Bull City Open Streets

In addition to high obesity rates, the UNC Highway Safety and Research Center found that per capita, the city of Durham suffers from more child pedestrian crashes than any community in North Carolina. In an effort to improve the situation, Bull City Open Streets was created to promote health, a sense of community and awareness of pedestrians and bicyclists. Started in 2010 by a coalition of local officials and community organizers, Bull City Open Streets events close selected Durham streets to traffic and allow people to have fun and be active in a safe environment. The first event drew over a 1,000 participants and closed a one-mile loop around the Durham Central Park area and downtown. Free activities and healthy snacks were provided by local organizations, and activities along the route included aerobics, yoga, dance and bicycle tune-ups. Bull City Open Streets was one of the first of its kind in North Carolina, but not the world. The Open Streets idea originated from Bogota, Colombia. Each Sunday, Bogota's "Cyclovia" prohibits automobiles from more than 70 miles of streets, freeing the pavement for walkers, runners and bicyclists. Bull City Open Streets hopes to continue Durham's version by hosting events beyond the downtown, bringing other Durham neighborhoods into the fun. In 2012, Durham was one of ten cities nationwide to be selected for funding open streets events by the Partnership for a Healthier America.

Walking School Bus in Pinehurst ▲

Moore and Montgomery County, NC – Working Across Communities for Safer Routes to School

"Pinehurst Walks!" began in 2008 as a movement to help Pinehurst kids be healthier by walking to school. Led by FirstHealth of the Carolinas, and funded as Fit Community grantee in 2008, the project improved the safety of routes to Pinehurst Elementary School by installing greenway trails and sidewalk infrastructure. Nearly 100 students walk every Wednesday on a greenway between a local park and the school as part of a Walking School Bus. The initiative has adopted a more regional policy approach to ensure that children in Moore and Montgomery counties can walk and bicycle safely as well. The organizers' goal is to ultimately connect existing sidewalks and greenway trails from neighborhoods with high percentages of children to child-centered locations (schools, parks, after-school programs) to encourage bicycle use and walkability. FirstHealth

helped secure funding from the Robert Wood Johnson Foundation to prevent childhood obesity. They were also awarded Safe Routes to School funding from NCDOT. FirstHealth also directed a Health Impact Assessment (HIA) of the Town of Aberdeen's Pedestrian Master Plan, which they hope to use in future transportation planning.

Haywood County, NC – Health Impact Assessment: Haywood County Comprehensive Bike Plan

Bicycle Haywood NC, a local bicycle advocacy group, the Haywood County Recreation and Parks Department and Kostelec Planning conducted a health impact assessment (HIA) to determine the potential health outcomes of the Haywood County Comprehensive Bike Plan. This was the first HIA conducted and adopted in North Carolina associated with a comprehensive pedestrian or bicycle plan. The project added value and a new perspective to the planning process. It positions Haywood County as a health-focused community as it pursues funding and gathers support to implement the Bicycle Plan. The HIA focused on key health outcomes that are strongly linked to bicycle activity, including heart disease, cancer, obesity, Type II diabetes and asthma and air quality. Recommendations included locations for bicycle routes to support areas with poor health and a list of health-specific priorities for the county. Specific outcomes resulting from the HIA's recommendations include a new bicycle purchase grant for Haywood County Schools, discussions with Haywood Community College to locate a "park-n-pedal" lot in a nearby park to encourage active commutes to the campus, and the pursuit of implementation measures for the number one health priority identified in the plan.

Belmont, NC – Fostering a Culture of Connectedness

In many cities and towns in North Carolina, housing, shopping, recreation and jobs are spread farther apart as

An HIA was conducted in association with the Haywood County bike plan ▼

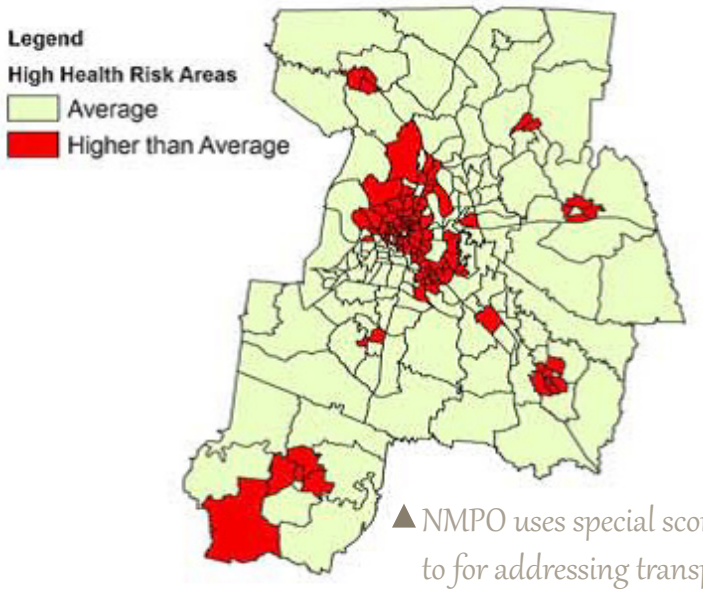
new development happens, leading to more time spent traveling by car. The City of Belmont has worked to reverse this trend. For the past 18 years, new developments in Belmont are required to comply with land codes/zoning that promotes connectivity and walkability. The requirements result in safer and more pleasant walking environments, including sidewalks, street trees, planting strips and houses built closer to the street. This type of development promotes people being more physically active and socially engaged as a community. More recently, Belmont has further focused on health by collaborating with the Gaston County Health Department to encourage active transportation and recreation corridors as public health priorities. With the benefit of an Eat Smart Move More grant, the city installed marked walking loops on the downtown area. They also contributed to a successful Safe Routes to School program at their elementary and middle schools. In 2011, Belmont started bridging this success to promote bicycling in town. They received a grant from NCDOT to

New developments in Belmont are required to comply with land codes/zoning that promote walkability.

develop a bicycle master plan that has already resulted in bicycle lanes as downtown streets are resurfaced. City officials recognize that it takes a multi-layered approach, working with government agencies, schools, businesses and neighborhoods, to create a healthy community that encourages walking and bicycling. It is no surprise that Belmont is attracting new residents and economic opportunities, thus continuing to grow a healthy and vibrant community.

Nashville, TN - Nashville Area MPO Active Transportation Funding Policy

Comprehensive transportation planning and infrastructure development has strong potential for broad impact which, in the Nashville, TN metropolitan area, includes nearly 1.5 million people. The Nashville Area Metropolitan Planning Organization (NMPO) strives to help make it safer and more convenient for people to walk, bike or take transit in and around Nashville. In 2012, the NMPO adopted a policy that dedicates funding for active transportation infrastructure and applies project scoring criteria prioritizing active transportation and health equity. NMPO developed a systematic approach to rating transportation proposals in a way that gives priority for the inclusion of active transportation and for addressing transportation issues in areas with significant health disparities. The NMPO also funds projects based on evidence-based strategies including active transportation, increasing access to and number of places for physical activity and urban design/policy and zoning to facilitate physical activity. Data from the MPO suggest that the policy has been effective by boosting the inclusion of active transportation components within funding proposals. In the most recent funding cycle for the 2035 Regional Transportation Plan, 75% of 420 roadway project proposals incorporated an active transportation component. The policy has also been effective at increasing capital projects for active transportation. In the first round of funding through the Active Transportation Program, the MPO funded eight active transportation proposals (out of ten submissions). While it is too soon to assess the policy's effect on infrastructure and transportation behaviors, the NMPO will measure those outcomes over time.



NMPO uses special scoring criteria to for addressing transportation in at-risk health areas

NCDOT's Board of Transportation – Public Health Policy (Approved October 4, 2012)

The mission of the North Carolina Department of Transportation is to connect people and places safely and efficiently, with accountability and environmental sensitivity to enhance the economy, health and well-being of North Carolina.
Our mission statement includes support of improved public health outcomes. The following policy statement further supports this mission.

Policy Statement

Transportation and public health research has demonstrated there is a link between the built environment and public health. Furthermore, public health may be affected by certain attributes of and risks inherent to the transportation system. Research tends to show that there is a strong connection between the built environment and public health outcomes, including rates of chronic disease, obesity, levels of physical activity, safety and general well-being; therefore, collaboratively planned land use and transportation can create opportunities for improved public health.

Inactivity among North Carolinians has contributed to higher rates of chronic diseases, lower levels of overall health and well-being, and therefore higher health care costs. Increased physical activity has been shown to improve health outcomes and decrease healthcare costs and the benefits of a healthier population include a more productive workforce, a more robust economy and a more globally competitive state.

The North Carolina Department of Transportation may have opportunities to support positive health outcomes by considering public health implications in our decision-making across all transportation modes, programs, policies, projects and services and through all stages of the life of a transportation project from planning to project development, construction, operations and maintenance. Specifically, we can consider:

- a multi-modal transportation system to provide access to and options for customers of all abilities and capabilities;
- the safety for all users and all modes of transportation; and
- the potential for the transportation system to support human health.

Employees are encouraged to develop transportation solutions that consider the health and well-being of North Carolina residents in conjunction with other mobility, fiscal, safety, social, economic and environmental factors.

Omaha, NE – Transforming into a Pedestrian and Bicycle Friendly Community

Residents of Omaha, Nebraska feel their city was built for the automobile. Until recently commuting by bicycle was nearly non-existent. Cyclists have had options on greenways along the city's creeks. But the primary East-West commuting corridors are notoriously challenging for active transportation due to high volume car and truck traffic. In 2005, the newly formed initiative "Activate Omaha" started small: raising awareness of active living through media and social marketing campaigns. From there, Activate Omaha helped organize the employer-based Bicycle Commuter Challenge, a fourteen week program encouraging employees to cycle to work. In the first year, 306 participants rode a combined 77,300 miles. Six years later, the number of bike commuters doubled with over 348,000 combined miles ridden. Activate Omaha now organizes Safe Routes to School initiatives in and around Omaha, helped develop the Omaha-Council Bluffs Metropolitan Bicycle Map and implemented a bicycle program for youth who have never owned bicycles. The growth in active transportation programs has coincided with health funders' support, greater acceptance by city leaders and infrastructure improvements. Financial backing from Alegent Health Systems and other funders helped established the city's first Bicycle/Pedestrian Coordinator position, Bicycle Pedestrian Advisory Committee and created a 20-mile signed bike route system throughout the downtown and nearby neighborhoods. Omaha's mayor and other city leaders now actively support healthier options to get people to where want to go. Activate Omaha, Douglas County Health Department, funders, city government and other partners are helping Omaha realize its vision of becoming a pedestrian and bicycle friendly city.

Commuter cycling has doubled over the last six years in Omaha, NE ▲

Health Impact Assessment Summary of Pedestrian Projects in Three North Carolina Communities

This section provides a summary of the *Technical Report: Quantitative Demonstration Health Impact Assessments in Three North Carolina Communities* that is found at the end of this appendix. For more information on the study, please see the full report starting on page 9.4-51.

A Health Impact Assessment for WalkBikeNC

- Health Impact Assessment (HIA) can be a powerful tool to help state and local decision makers assess the future value of transportation investments that can impact health.

- As part of *WalkBikeNC*, an HIA was conducted to estimate the health and financial impacts of pedestrian and bicycling infrastructure on individuals and communities in our state. Quantitative methods, such as those included in this HIA, enable health and transportation planners to determine the economic value of "active transportation" and for decision makers to consider such investments in a cost-benefit analysis framework.

What is Health Impact Assessment?

- HIA has been used widely in European countries, and more recently in U.S. cities, to better understand the long-term health impacts of proposed policies, plans and development decisions.

- The HIA process includes six consecutive stages: 1) Screening, 2) Scoping, 3) Assessment, 4) Recommendations, 5) Reporting, and 6) Monitoring and Evaluation.

What Health Benefits Can We Expect by Implementing the WalkBikeNC Plan?

- Physical inactivity is a key risk factor that is linked to overall mortality as well as diseases that affect millions of North Carolina residents, including coronary heart disease (CHD), diabetes, hypertension and stroke. The upside is that regular physical activity can be protective in preventing or delaying some of the state's most common health issues.

- Research shows a direct relationship between characteristics of the built environment and the level of active transportation and physical activity in a community. Even in small amounts, regular physical activity can decrease the risk for a wide range of diseases and premature death. Increasing levels of walking and bicycling for transportation reduces the risk of negative health outcomes.

Three NC Communities Chosen to Assess Different Experiences

- As part of WalkBikeNC, three North Carolina communities were chosen for demonstration HIAs: Sparta, Raleigh and Winterville. They were selected from many candidates because of their balance of geography, context and scale of their planned projects. Each demonstration HIA analyzed and compared impacts from building the recommended pedestrian projects to maintaining the status quo of no improvements.

- **Sparta**, a traditional "main street community" located in western North Carolina, completed a Downtown Streetscape Strategy in 2012. The plan calls for significant pedestrian improvements to downtown streets and intersections, such as better signage, pedestrian crossings, signals and streetscape enhancements (e.g., street lights, benches, planters). The Sparta HIA represents an assessment of a transportation corridor plan in a rural context.

- Located just outside **Raleigh's** beltline, the Blue Ridge Road

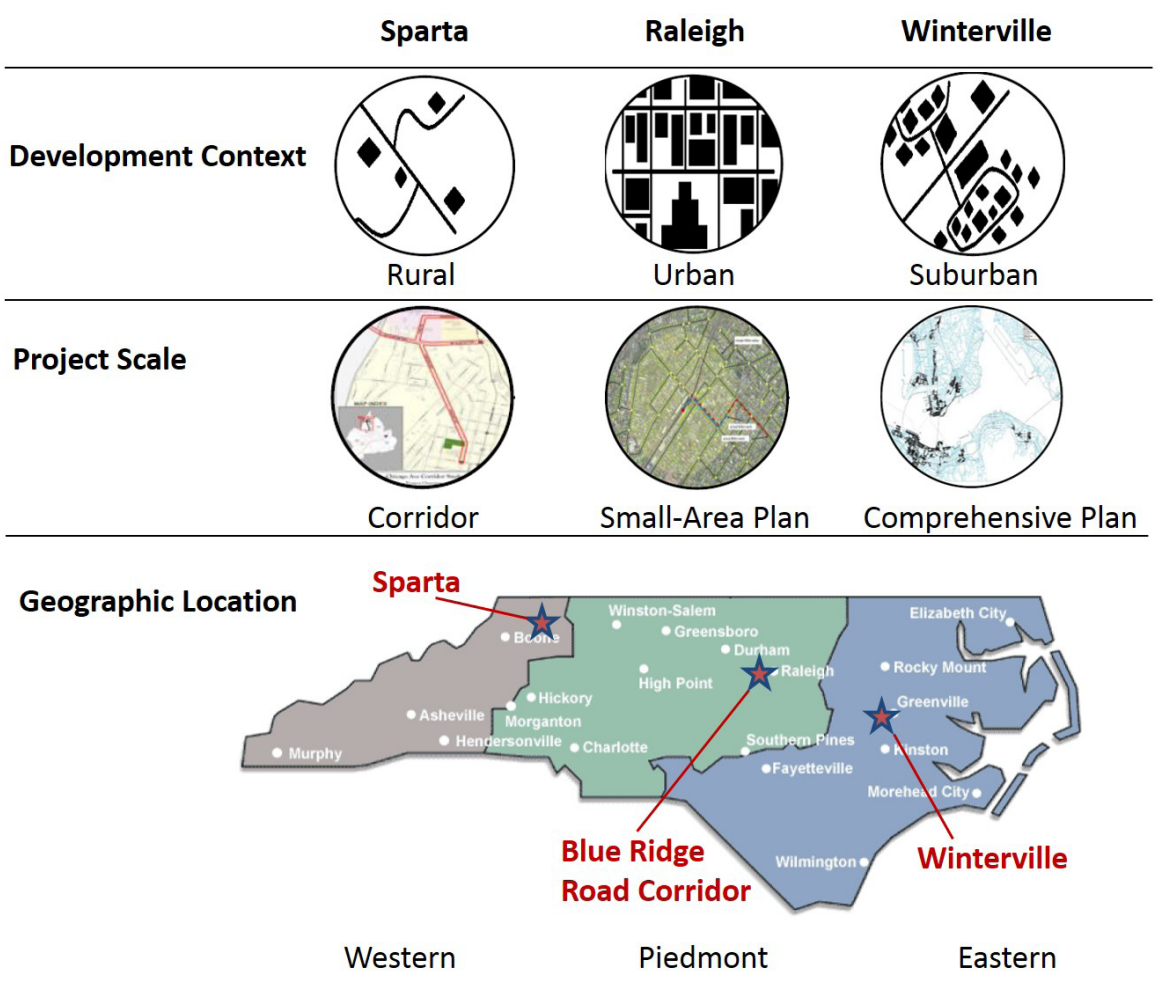
Corridor small-area plan is the result of an ambitious community visioning and planning effort. The small-area plan includes significant land-use changes, new sidewalks and streetscape improvements. The Raleigh HIA is an example of a small-area plan in an urban setting, situated in the Piedmont region of North Carolina.

- Winterville is a small community south of Greenville, North Carolina. In 2011, regional planners completed a Bicycle and Pedestrian Master Plan for the Greenville Metropolitan Area, which includes Winterville. The HIA analyzes the proposed construction of sidewalks within the Town of Winterville. This project represents a comprehensive plan within a suburban context in eastern North Carolina.

The Steps of HIA

1. **SCREENING**
   - Determine whether an HIA is needed and likely to be useful.
2. **SCOPING**
   - In consultation with stakeholders, develop a plan for the HIA, including the identification of potential health risks and benefits.
3. **ASSESSMENT**
   - Describe the baseline health of affected communities and assess the potential impacts of the decision.
4. **RECOMMENDATIONS**
   - Develop practical solutions that can be implemented within the political, economic or technical limitations of the project or policy being assessed.
5. **REPORTING**
   - Disseminate the findings to decision makers, affected communities and other stakeholders.
6. **MONITORING AND EVALUATION**
   - Monitor the changes in health or health risk factors and evaluate the efficacy of the measures that are implemented and the HIA process as a whole.

The HIA process encourages public input at each step.



Community Context: Stakeholders Identify Barriers to Active Transportation

- During the HIA scoping phase, stakeholders and residents in each community highlighted key challenges to walking and bicycling, which are grouped by theme and summarized below.
  - **Built and natural environments** are currently oriented to the automobile and sprawling land-use patterns make it difficult to walk or ride bicycles for transportation. In addition, the mountainous terrain and rural landscape in Sparta can make bicycling very difficult for routine travel.
  - **Transportation infrastructure** tends to lack continuous sidewalks and other safe pathways for walking and bicycling. Streetscapes often feel unsafe and uninviting for pedestrians and bicyclists.
  - **Demographics, culture and prevailing attitudes** also impact active transportation. High rates of poverty require many to walk out of necessity. As a result, walking is viewed as transportation of last resort, especially for the poor. Conversely, bicycling is often viewed as an "elitist" activity done primarily for recreation rather than a viable alternative to travel by motor vehicle.
  - **Transportation services** such as public transit, which have been shown to increase walking for transit users, were also considered to be insufficient in each community.

Pedestrian Enhancements Lead to More Walking and Improved Health

- The protective effects of walking for health are well established in the scientific literature. In all three communities, the HIAs predict that building sidewalks, greenways and making other improvements in pedestrian safety increase walking and lower the risk for CHD, diabetes, hypertension, stroke and early death.
- For Winterville and Raleigh, the HIA predicts an increased likelihood of people choosing walking trips over other means (7% and 11%, respectively) and improved sidewalk networks that will result in more time spent walking for transportation (43% and 47%, respectively).
- For Sparta, sidewalk quality, ease of street crossings, topography and local street connectivity are expected to result in a similar increase in time spent walking for transportation (43%) and an increase in weekly walking distances (0.57 miles/week).
- In each demonstration HIA community, five health outcomes were considered over a period of 50 years: 1) prevented mortality; 2) prevented cases of CHD; 3) prevented cases of diabetes; 4) prevented cases of hypertension; and 5) prevented cases of stroke. It is safe to assume that active transportation behavior would stay the same in the baseline scenario and would increase due to changes in the built environment after the sidewalks and other infrastructure are in place.
- The estimated number of illnesses prevented varies among the three HIA demonstration communities, but the cases of hypertension avoided are most significant in all three locations. The greatest increase in disease cases avoided would occur in the first 10 years after the pedestrian projects are completed. This suggests relatively rapid returns on investment

due to health care savings, higher quality of life and a healthier community overall.

We Can Expect Significant Health Care Savings from Pedestrian Enhancements

- While health outcomes are important in and of themselves, it is also valuable to estimate the economic value of improved health associated with investments in infrastructure for active transportation (i.e. pedestrian projects).

- For Sparta, detailed construction cost estimates enabled benefit-cost calculations. In Sparta, health care cost reductions are predicted to exceed $10 million within 20 years of construction and increase to more than $15 million at 40 years. Given a typical project lifespan of 20 to 40 years, health care savings associated with implementation of the Downtown Sparta Streetscape Strategy will exceed its costs. Every dollar spent on construction would generate a savings of 19 to 22 dollars in health care costs.

- For Raleigh and Winterville, rough cost estimates were developed using unit costs for sidewalk construction. In Winterville, reduced mortality and lower incidence of CHD, diabetes, hypertension and stroke are expected to reach nearly $9 million 20 years after construction and will exceed $12 million within 40 years – resulting in a savings of 1.1 dollars in health care casts per dollar spent 40 years post-construction. In Raleigh, health care cost reductions are predicted to eclipse $25 million within 20 years of construction and will rise to nearly $36 million at 40 years. Each dollar spent on construction would yield 6 to 9 dollars of health care cost savings.

Recommendations for Demonstration Communities, NC DOT and Other Critical Partners

- The WalkBikeNC HIA includes several important recommendations that can improve health and positively impact the economies in Sparta, Winterville and Raleigh. The HIA also suggests NCDOT actions that can support WalkBikeNC recommendations identified by other methods. Finally, partner agencies and other stakeholders play key roles in improving data systems and strategies to help measure the health potential of active transportation in North Carolina.

Demonstration Community Recommendations

- Build out sidewalk networks in Winterville as proposed in the Greenville Bicycle and Pedestrian Master Plan. In addition, invest in programs and promotional strategies to address stigmas and negative perceptions of those who engage in active transportation.

- In Raleigh, ensure all new and reconstructed roads in the Blue Ridge Road Corridor are built with sidewalks on both sides of the street.

- Complete the pedestrian improvements in the Sparta Downtown Streetscape Strategy.

- In each of these communities, coordinate with local and regional institutions (e.g. Metropolitan and Rural Planning Organizations, health departments) to include active transportation-related questions in future local surveys.

Health Impact Assessment Predicted Impacts Following Pedestrian Project Completion

	Raleigh	Winterville	Sparta
Sidewalk Length	*+388%*	*+360%*	*N/A*
Walking for Transportation (150+ min per week)	*+7.1%*	*+2.3%*	*+1.4%*
No Walking for Transportation	*-2.5%*	*-0.9%*	*-8.8%*
Health Care Dollars Saved at 20 Years	*$25.6 million*	*$9 million*	*$13 million*
Benefit-to-Cost Ratio at 20 Years	*6:1*	*0.8:1*	*19:1*

Source: Mansfield and McDonald (2013)

▲

Results of the quantitative health impact assessment (HIA) conducted as part of this planning process. See page 9.4-51 for full report and analysis.

- In each of these communities, coordinate with partners to explore traditional and non-traditional funding options for pedestrian projects, including local, state, regional, private and non-profit resources.

HIA Recommendations Aligned with *WalkBikeNC*

- **Mobility** - Expand community-oriented pedestrian facilities. Provide pedestrian and bicycle access to transit.
- **Safety** - Create a strategic, consistent and connected pedestrian and bicycle network.
- **Public Health** - Increase active living environments. Increase the safety, connectivity and accessibility of the bicycle and pedestrian network.
- **Economic Competitiveness** - Increase attractiveness and quality of life through walkable and bikeable communities. Measure return on investment of active transportation investments. Use return on investment analyses to inform transportation decision making.

Recommendations for Research, Data Systems and Future HIA Efforts

- Improve the data infrastructure for sidewalk and bicycle networks as well as more refined prevalence data for cancer, CHD, diabetes, hypertension and stroke.
- Measure active travel in units relevant to future epidemiological studies (e.g., minutes of physical activity rather than mode choice, number of trips, reductions in vehicle miles travelled).
- Regularly include active transportation questions in the NC Behavioral Risk Factor Surveillance System.
- Continue to develop local communities' capacity to conduct HIA by providing training and resources. Adapt and advance HIA methods to inform decision making on health and economic impacts of proposed policies, plans and development.

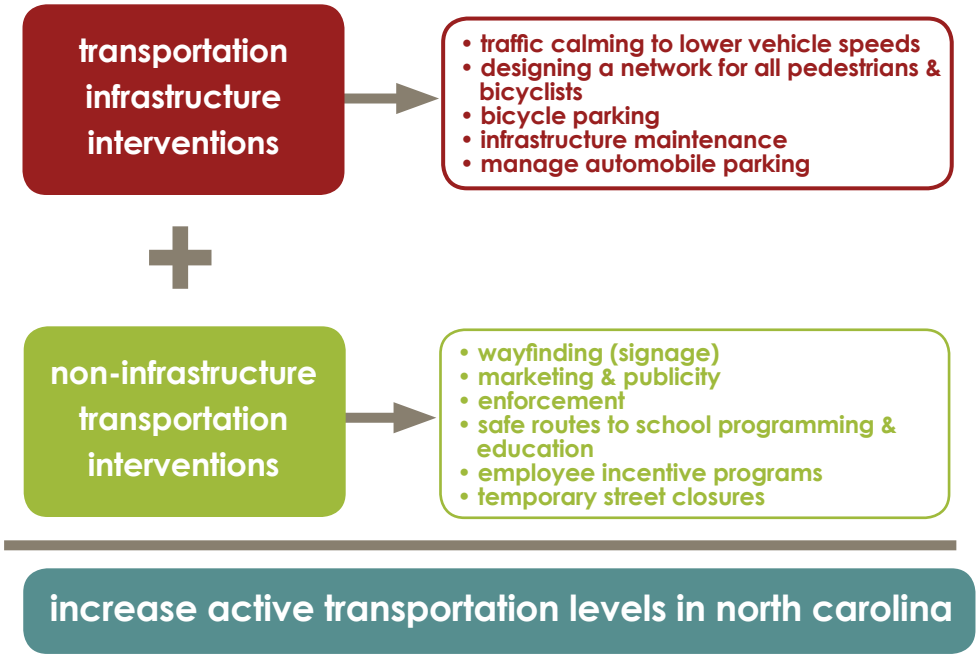
The full HIA Technical Report can be found on page 9.4-51.

Recommendation Steps

To improve health among North Carolina's adults and children, it will be vital to use a multi-pronged approach, including making physical activity options, like active transportation, more accessible for all residents. Many of these recommendations to improve health overlap with other pillars of the state plan.

Proposed Performance Measures for Health Impact

Refer to pages 9.4.42- 9.4.44



	Issue	Direction	Actions
1	*Many citizens and non-traditional community leaders are typically left out of local transportation planning processes.*	*Improve community engagement of non-traditional groups into local transportation planning, i.e. low-income, people of color, older adults, youth, people with disabilities.*	*• NCDOT reach out to other organizations, including non-profits, to identify appropriate ways to boost resident engagement in transportation planning.* *• NCDOT contract with groups under to engage and build DOT's capacity to achieve resident engagement targets (e.g. Chicago's DOT contracting with Active Transportation Alliance).* *• Update NCDOT planning guides and/or checklists during planning processes (e.g. CTPs) to prioritize inclusion of low-income, people of color, older adults, youth, people with disabilities.* *• NCDOT notify statewide and regional organization, including non-profits, as routine transportation planning efforts.*
2	*Walking and bicycling are not necessarily viewed as desirable forms of transportation among some population groups or cultures in North Carolina.*	*Encourage walking and bicycling with culturally-specific approaches and messages.*	*• NCDOT and/or NC DHHS conduct targeted social media, advertisements, marketing campaigns and/or other promotional efforts to increase active transportation.* *• NCDOT and/or NC DHHS work with non-traditional organizations, e.g. El Pueblo, NAACP, NC Alliance of Disability Advocates, to identify the most effective and appropriate messages to encourage increased active transportation among low-income, people of color, youth, older adults, people with disabilities.* *• NCDOT and/or NC DHHS develop a focused outreach approach to increase bicycling among woman and girls.*
3	*Pedestrians, bicyclists, transit riders and wheelchair users have limited identity as important user groups and influence in transportation planning and project prioritization.*	*Build a more robust, organized and engaged constituency for active transportation in North Carolina.*	*• Convene an annual pedestrian summit with broad engagement of non-traditional groups and organizations.* *• Continue to convene an annual bicycle summit; expand to include broader engagement of non-traditional groups and organizations.* *• Establish user on-line and other networks to educate non-traditional groups and organizations about transportation issues and opportunities.*
4	*Local health officials and other health advocates are either sporadically involved in transportation planning or not at all.*	*Institutionalize health officials, professionals and advocates into transportation planning processes.*	*• NC DHHS reach out to local health directors and boards of health to communicate the importance of participation in local/regional transportation planning.* *• NC DHHS and NCDOT develop educational and informational materials for local health departments and boards of health regarding transportation planning and implementation.* *• NC DHHS identify and implement incentives for local health officials to collaborate on transportation planning efforts.*

	Issue	Direction	Actions
5	*Many community leaders, elected officials and boards/ commissions are unaware of the potential health, economic and other benefits of active transportation.*	*Provide consistent and actionable information, tools, and other products and approaches to better inform community leaders about the health potential of active transportation.*	*• NC DHHS and NCDOT develop educational materials for local leaders, elected officials and boards/commissions regarding the benefits of active transportation and informational materials on transportation planning and implementation.* *• NCDOT work through state councils and organizations to reinforce (to local leaders and officials) the importance of health considerations in local planning, e.g. NC League of Municipalities, NC Association of County Commissioners.*
6	*Local public health professionals and advocates do not typically promote safe and active transportation.*	*Integrate better education and encouragement approaches to reinforce and complement built environmental/capital improvements.*	*• NC DHHS provide materials and reach out to local health departments through training and technical assistance to promote active transportation as significant public health goal.* *• NCDOT coordinate with NC DHHS and other agencies to develop materials and other methods to encourage active transportation.*
7	*"Health and well-being" are currently part of NCDOT's mission statement, yet health-related data are not typically considered in transportation planning or project performance.*	*Incorporate practical measures/indicators for transportation planning to prioritize healthy design and for performance to evaluate positive health-related outcomes.*	*• NC DHHS, including the NC State Center for Health Statistics, prepare health data sets and reports that can be used in transportation planning, implementation and performance evaluation.* *• NCDOT continue to convene meetings with NC DHHS and other partners to develop the most relevant and practical indicators for* *• NCDOT and NC DHHS identify and implement the collection of new indicators for ongoing surveillance, such as children walking to school, active commuters, etc.* *• NCDOT set targets and incorporate performance standards, such as mode shift, VMT, women bicycling.*
8	*North Carolina lacks routinely collected data on built environments that impact active transportation.*	*Develop systems and methods to routinely collect built environment data for pedestrian and bicycle facilities on state roads.*	*• NCDOT explore options for utilizing data from existing internal sources, i.e. standard data collected on all state road segments could include presence of sidewalk, bike lane or wide shoulder.* *• NCDOT collaborate with other agencies and provide a data interface/"upload" option for locally obtained data on state roads within municipalities, e.g. sidewalks, bike lanes or wide shoulders.* *• Provide funding, resources and tools for local communities to collect longitudinal data (i.e. measuring the economic and health impacts) before and after pedestrian*

	Issue	Direction	Actions
9	*Roadway planning and construction processes do not explicitly or routinely prioritize health or health equity.*	*Prioritize transportation planning and projects in communities and locations that are more likely to benefit vulnerable groups, i.e. low-income, people of color, older adults, youth, people with disabilities.*	*• Develop criteria that can be easily and objectively rated to indicate transportation projects that are likely to serve low-income, people of color, youth, older adults, and people with disabilities.* *• Include health/equity criteria in project prioritization.*
10	*Motor vehicle and design speeds are too high in many locations for the safety of pedestrians and bicyclists.*	*Lower vehicle speeds in areas that are likely to have pedestrians and bicyclists, particularly in locations known to be hazardous.*	*• Implement public awareness campaigns such as "Watch For Me NC."* *• Increase use of real-time speed counters in communities.* *• Increase the use of traffic calming measures in areas with high active transportation use and latent demand.* *• Conduct a review of and update NCDOT's design speed standards.* *• NCDOT identify and implement specific goals and design standards to control speeds, e.g. "20 is Plenty" for residential areas.*
11	*Motor vehicles are often in conflict with pedestrians and bicyclists. Pedestrian right of way laws typically go unenforced.*	*Increase public awareness of walking and bicycling laws regarding right-of-way.*	*• Increase enforcement efforts of vehicles for pedestrian right of way* *• Enhance driver's education curriculum and testing to broaden the content regarding pedestrians and bicyclists. Shift to a model of "mobility education" that includes instruction and appreciation for all modes.* *• Increase funding, at the local and state level, for pedestrian*
12	*Schools are typically not involved in pedestrian and bicycle encouragement programs for students or transportation infrastructure planning.*	*Increase Safe Routes to School programs and school officials' participation in transportation planning.*	*• Continue and expand the current Safe Routes to School Program* *• NCDOT collaborate with NC DPI to incorporate more local school officials into transportation planning efforts* *• Provide small grants and other incentives to schools and community organizations who implement pedestrian and bicycle programs for children to/from school.* *• Partnership with state law enforcement (and/or DMV) and schools (DPI) to develop PE/safety education – how to be a pedestrian/cyclist*
13	*North Carolina's current transportation system prioritizes motor vehicles. In some case, motor vehicles are prioritized to the exclusion of active transportation modes.*	*Invest in the transportation infrastructure to improve access, connectivity, convenience and safety.*	*• Increase state funding for pedestrian and bicycle transportation infrastructure projects, such sidewalks, bike lanes* *• NCDOT promote the eligibility of Powell Bill funds to be used by municipalities for roadway pedestrian and bicycle projects.* *• NCDOT create more separated ped-bike paths and greenways. DOT explore easing the barriers to approval and implementation of separated pathways, e.g. utility easements (sewer, electric), DENR water quality conflicts, railroad abandonment*

	Issue	Direction	Actions
14	*Current land use patterns decrease feasible options for active transportation.*	*DOT and other state agencies create an incentives structure to improve land use to reduce distances between important destinations*	*• NCDOT provides increased access to funding – places that receive their money, part or all, for local communities and regions that are bringing destinations together and health equity* *• Encourage all local comprehensive plans to include a health component that includes mixed-use development, higher density and accommodations for active transportation.*
15	*Rural and unincorporated areas rarely provide pedestrian (as well as bicycle) infrastructure.*	*Increase pedestrian infrastructure, e.g. sidewalks/crossings, in unincorporated areas where actual and latent demand exist, i.e. activity centers, trip generators.*	*• Revise NCDOT Policy to include building and maintenance of sidewalks outside municipalities.*
16	*Many North Carolinians live close enough and could walk, ride, or take transit to work but are not supported by their employers.*	*Work with employers to encourage and support active commuting.*	*• NCDOT, NC DHHS and/or partner organizations provide materials, best practices and incentives for employers to promote active commuting.*
17	*North Carolina residents represent a range of user types requiring different accommodations for active transportation.*	*Support the development of active transportation networks in communities that accommodate all users.*	*• Continue the NCDOT Pedestrian and Bicycle Planning Grant Program, which requires communities to specify accommodations for all users during planning.*
18	*Most destinations prioritize motor vehicle parking over other modes.*	*Increase access to bicycle parking and transit stop accommodations. Limit motor vehicle parking accommodations.*	*• NCDOT work with local governments to encourage the establishment of commercial site design standards with bicycle parking and transit stops (where appropriate).*

Performance Measure	Indication of Progress Towards Desired Change or Outcome	Readily available	Requires collecting/ organizing existing information	Requires new data collection program
	INPUT			
Percentage of proposed projects that include active transportation component compared to those that do not. (e.g. Nashville Area MPO)	*Increase in percentage of projects*			
	OUTPUT			
Proportion of elementary schools with a Safe Routes to School program	*Increase in number of programs*			
Percentage of active transportation projects near census tracts that have a higher than average rate of poverty, minority populations, and zero car households. (e.g. Nashville Area MPO)	*Increase percentage of projects.*			
Percentage of active transportation projects within 2 miles of a school. (e.g. Nashville Area MPO)	*Increase percentage of projects.*			
Percentage of active transportation projects within 1 mile of a full-service grocery store. (e.g. Nashville Area MPO)	*Increase percentage of projects.*			

Performance Measure	Indication of Progress Towards Desired Change or Outcome	Readily available	Requires collecting/ organizing existing information	Requires new data collection program
Ratio sidewalks to roads on state roads (within municipalities)	*Increase in ratio*			
Ratio bicycle lanes/trails to roads on state roads (within municipalities) – modified from Performance Indicators for Transport (the World Bank, 2004)	*Increase in ratio*			
Percentage of signalized intersections with pedestrian crossing signals on state roads (within municipalities)	*Increase in ratio*			
	OUTCOME			
Percent of person trips/passenger miles travelled by cycling/ walking - Health Indicators of sustainable cities in the Context of the Rio+20 UN Conference on Sustainable Development	*Increase in percentage*			
Private bicycle ownership (% of households). - Performance Indicators for Transport (the World Bank, 2004)	*Increase in percentage*			
Vehicle Miles Travelled	*Decrease or zero growth*			
Transportation mode shift (Percent of person trips/passenger miles travelled by cycling/walking - Health Indicators of sustainable cities in the Context of the Rio+20 UN Conference on Sustainable Development)	*Shift from automobiles to active modes (Increase in percentage of active trips)*			
Percentage of North Carolinians reporting walking for leisure (BRFSS)	*Increase in rates*			
Percentage of North Carolinians reporting bicycle for leisure (BRFSS)	*Increase in rates*			
Percentage of elementary school children who walk or bicycle to school at least one day per week.	*Increase in rates*			
Physical inactivity rates (BRFSS)	*Reduction in rates*			

Performance Measure	Indication of Progress Towards Desired Change or Outcome	Readily available	Requires collecting/ organizing existing information	Requires new data collection program
Obesity and diabetes rates (BRFSS)	*Reduction in rates*			
Number of asthma-related emergency room visits	*Reduction in asthma-related emergency room visits*			
Number of emergency room visits from bicycle and pedestrian crashed	*Reduction in bicycle and pedestrian-related emergency room visits*			
Pedestrian and bicyclist deaths as a proportion of total traffic mortality; and pedestrian and bicyclist deaths/1000 miles of pedestrian/bicycle travel - Health Indicators of sustainable cities in the Context of the Rio+20 UN Conference on Sustainable Development	*Decrease in proportion*			

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TECHNICAL REPORT: QUANTITATIVE DEMONSTRATION HEALTH IMPACT ASSESSMENTS IN THREE NORTH CAROLINA COMMUNITIES

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In 2012-2013, the North Carolina Department of Transportation updated its Statewide Bicycle and Pedestrian Master Plan, known as *WalkBikeNC*. The plan contains five "pillars" that relate to bicycling and pedestrian transportation: mobility, safety, health, economy and environment. As part of the Health component of *WalkBikeNC*, this report summarizes the projected health impacts following pedestrian and bicycle project implementation in three North Carolina communities.

Health Impact Assessment (HIA) is a powerful tool for communicating to decision-makers the value of investments that support improved health outcomes. However, HIA practice in the United States often relies heavily on qualitative methods that may have limited relevance to decision-making processes, particularly in sectors that have developed highly technical decision-making practices, such as transportation.[1] Further, transportation agencies are facing pressure from funding scarcity and federal policy directives, including the recently re-authorized federal transportation funding bill, MAP-21, to demonstrate the value of transportation investments.[2,3] Quantitative HIA methods provide a means for placing an economic value on health impacts, allowing transportation agencies to demonstrate the value of transportation investments that support an active lifestyle and enabling decision-makers to consider such investments in a cost-benefit analysis framework.[4] To demonstrate the ability of HIA to quantitatively estimate the health impacts of active transportation[a] infrastructure, including construction of new sidewalks, streetscape improvements, and improved pedestrian crossings, we conduct three HIAs on pedestrian improvements throughout North Carolina focusing on state-of-the-art quantitative modeling methods.

The HIA process includes six consecutive stages: 1) Screening; 2) Scoping; 3) Assessment, 4) Recommendations, 5) Reporting; and 6) Monitoring and Evaluation. During the Screening stage, the HIA is broadly defined and it is determined whether or not the HIA is likely to succeed and add value. Scoping includes data collection, stakeholder outreach, and preliminary research to outline and establish goals for the HIA. Health impacts relative to baseline conditions are estimated during the Assessment stage, and the results are translated into useful units and disseminated during the Recommendations and Reporting stages. Monitoring and Evaluation includes an objective assessment of the quality of the HIA performed, the efficacy of the HIA in influencing future decisions, and outcome assessment once the project has been completed and health impacts are observable in the population.[5] We complete the first four stages of this process in this HIA and prospectively discuss reporting, monitoring, and evaluation. Our principle aim is to apply quantitative methods to estimate the health impacts, and related economic implications, of investments in pedestrian amenities in three North Carolina communities.

Screening

As part of the overall Health component of WalkBikeNC, a Health Advisory Team was formed to help establish goals and provide guidance for the HIA demonstration component of the plan. The Health Advisory Team was co-

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[a] Active transportation includes walking and biking for transportation, and walking or biking to/from public transit

led by staff members at Active Living By Design and the Department of Environmental Sciences and Engineering at the Gillings School of Global Public Health at UNC-CH. A full list of team members and affiliations appears in Appendix 1 of this report.

The Health Advisory Team met three times to provide guidance to researchers at UNC-CH. The principal aim of the project – to demonstrate quantitative HIA methods applied to active transportation infrastructure improvements in a variety of contexts throughout North Carolina – was defined during the initial meeting. After developing a list of candidate projects to undergo demonstration HIAs, the Health Advisory Team helped develop several selection criteria to screen projects and develop a final list of three projects. We chose projects so that three development contexts would be represented (urban, suburban, and rural), three project scales would be represented (comprehensive plan, small area plan, project/corridor) and the three geographic regions of North Carolina would be represented (eastern, piedmont, and western). Additionally, we only selected projects for which the results of the HIA could help inform a future decision, such as the allocation of funding for project construction. Based on these criteria, we selected the Blue Ridge Road project in Raleigh, NC; projects from the Greenville Metropolitan Planning Organization (MPO) Bicycle and Pedestrian Master Plan in Winterville, NC; and the second phase of the Downtown Streetscape Strategy in Sparta, NC (see Table 1).

The Health Advisory Team also discussed potential modeling tools that could be applied to conduct a quantitative HIA. Three models were considered: the Health Economic Assessment Tool (HEAT) for Walking and Cycling, developed by the World Health Organization,[6] the Dynamic Modeling for HIA (DYNAMO-HIA) model, developed by the National Institute for Public Health and the Environment in the Netherlands,[7] and the Prevention Impacts Simulation Model (PRISM), developed with the support of the Centers for Disease Control and Prevention (CDC).[8] After discussing the advantages and disadvantages of each modeling tool, we selected the DYNAMO-HIA model due in large part to the power and flexibility of the modeling framework, which are described in detail in the Methods section. Table 2 compares the advantages and disadvantages of these three modeling tools.

Table 1. HIA Demonstration Projects

Planning Scale	Development Context: Rural	Suburban	Urban
Corridor	Sparta Downtown Streetscape Strategy		
Small Area			Blue Ridge Road Neighborhood (Raleigh)
Comprehensive		Greenville Bicycle and Pedestrian Master Plan (Winterville)	

Geographic Context: Eastern North Carolina; Piedmont; Western North Carolina

Table 2. Comparison of HIA Tools

Model	Advantages	Disadvantages
HEAT	• *Minimal data needs* • *Epidemiological evidence built-in* • *User-friendly*	• *Stationary* • *Rigid model structure*
DYNAMO-HIA	• *Dynamic* • *Flexible* • *Modular*	• *Significant data needs* • *Requires disease prevalence & incidence* • *Epidemiological evidence not built-in* • *Difficult to use*
PRISM	• *Dynamic* • *Minimal data needs* • *Epidemiological evidence built-in* • *User-friendly*	• *Model structure not customizable* • *Cannot specify new risk factors or interventions not included in base model* • *Difficult to focus specifically on built environment interventions*

Greenville MPO Bicycle and Pedestrian Master Plan, Winterville, NC

Winterville is a suburban community located just south of Greenville, NC. In 2011, the Greenville MPO completed a Bicycle and Pedestrian Master Plan for the Greenville Metropolitan Area, which includes Winterville. We conducted an HIA on the complete build-out of the pedestrian elements of the plan in Winterville compared to the baseline, status quo scenario. The plan includes the construction of new sidewalks as well as the construction of bicycle facilities, which are not assessed (Figure 1). This project is in the suburban context, at the comprehensive plan scale, and in the eastern portion of the state.

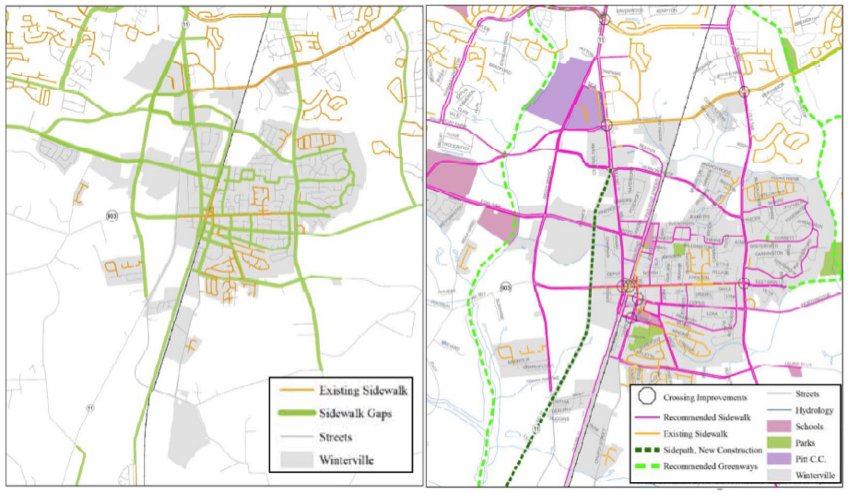

Figure 1. Winterville existing pedestrian facilities (left) and proposed improvements (right)

Blue Ridge Road Project, Raleigh, NC

Situated just outside the beltline in Raleigh, NC, the Blue Ridge Road project is the result of an ambitious community visioning and planning effort. Blue Ridge Road is a key transportation link in a small-area plan that envisions an urban future for the Blue Ridge corridor. We conducted an HIA comparing the built-out vision of Blue Ridge Road as envisioned in the small-area plan to the status quo scenario (i.e., current conditions). The small area plan includes significant land-use change, construction of new sidewalks, and streetscape improvements (Figure 2). The BRRC project is classified as an urban project at the small-area plan scale in the Piedmont region of North Carolina.

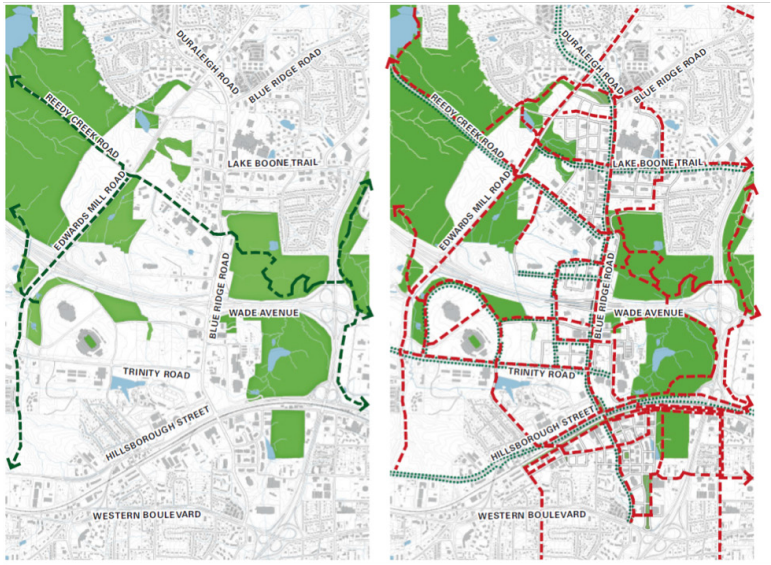

Figure 2. BRRC existing open space and trails (left) and proposed open space, trails, and improved sidewalks (right)

Downtown Streetscape Master Plan, Sparta, NC

Sparta, NC, is a traditional "main street community" located in western North Carolina. The town of Sparta recently completed a Downtown Streetscape Strategy in 2012, including significant pedestrian improvements to downtown. We conducted an HIA on the implementation of the plan and compared the results to the status quo scenario. The project contains streetscape and street crossing improvements along Main Street, which runs through downtown Sparta, as well as complementary improvements to several side streets (Figure 3). This project is in the rural context, at the corridor scale, and is located in western North Carolina.

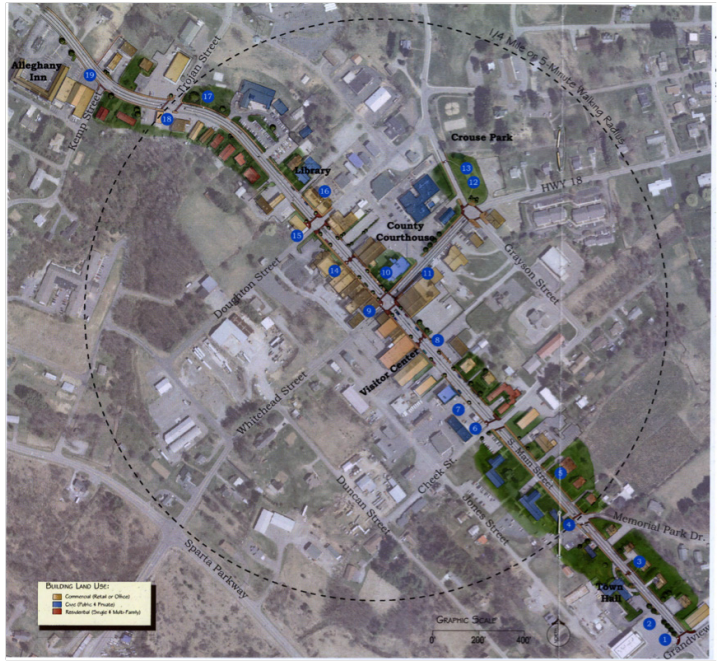

Figure 3. Sparta proposed downtown streetscape improvements

Our three demonstration HIAs share a common decision point: the implementation of one or more projects as articulated in a planning document. Thus, the results of our HIAs may be used to inform project prioritization processes at the local and state levels. We intend for the results of our HIAs to be used by local decision makers in each community – not only do we demonstrate quantitative methods in conducting HIAs, but we also demonstrate how quantitative health impacts may help inform decision-making processes and enable the consideration of the health impacts in allocating funds for transportation infrastructure in the state of North Carolina. While we selected three demonstration projects to demonstrate the value and validity of quantitative HIA methods across different contexts, caution should be exercised in generalizing the findings of this HIA to other cities and towns in North Carolina.

Scoping

We divided the scoping phase into two primary stages: 1) meetings with local decision-makers in each community to identify existing health concerns and barriers to active transportation behaviors; and 2) screening and selection of appropriate diseases for inclusion in our model.

Community Meeting Summary: Winterville

On December 10th, 2012, we hosted a project meeting in the Town of Winterville offices to identify health disparities and local contextual factors. Three common themes emerged: 1) Underlying socio-demographic characteristics and cultural norms that influence health outcomes; 2) inadequacies in physical infrastructure that present barriers to active transportation; and 3) land use patterns that present barriers to active transportation. The importance of correctly framing active transportation as a normative rather than elitist behavior was also mentioned several times – that is, the perception of cycling as an elite activity may be a barrier for new cyclists whereas the perception of walking as the opposite may also be a barrier. Key health barriers organized by broad topic areas are summarized in Table 3; a full meeting summary and list of participants is provided in Appendix 2 of this report.

Table 3. Winterville Community Meeting Key Issues

Issue Area	Identified Barriers
Built Environment and Land Use	• *Non-walkable development scales* • *Car-oriented development* • *Segregated land uses* • *Lack of services and employment within Winterville proper* • *School siting*
Transportation Infrastructure	• *Lack of sidewalks* • *Poor sidewalk connectivity between developments* • *Road widening projects undertaken without supplementary improvements such as the addition of sidewalks and bike lanes* • *Barriers presented by the highway and rail line that bisect Winterville* • *Aesthetic quality of many streetscapes, including NC 11*
Demographic and Cultural Factors	• *High rates of poverty* • *High prevalence of risk factors (smoking, alcohol consumption, etc.)*
Services	• *Lack of public transit service* • *Poor access to facilities that offer affordable healthcare*
Social and/ or economic conditions	• *Stigmatized perception of walking and biking for transportation* • *Poor awareness of the rules of the road by drivers, cyclists, and pedestrians in multi-modal situations*
Natural Environment	• *Noise and air pollution due to NC Highway 11*

Focusing specifically on physical inactivity, participants noted that lack of physical activity is a risk factor for a range of health outcomes including overweight/obesity, heart disease, and mental health. Specific populations susceptible to physical inactivity were identified primarily based on geography rather than socio-demographic characteristics; that is, the workshop participants felt that neighborhood quality was more important than individual characteristics in explaining the propensity to use physically active transportation modes.

Community Meeting Summary: Sparta

On December 18th, 2012, we hosted a project meeting in the Sparta Town Hall to identify health concerns in the community. Three central themes emerged during our discussions: 1) barriers to active transportation related to poor pedestrian safety (both real and perceived); 2) inadequacies in physical infrastructure that present barriers to active transportation; and 3) health disparities associated with high prevalence of poverty and a high number of seasonal workers. Participants also suggested framing active transportation as an issue of personal choice: expanding infrastructure that is supportive of active transportation expands personal choice and gives individuals new opportunities to choose to be active as part of their daily routine. Key issues are summarized in Table 4; a full summary and list of participants is provided in Appendix 2 of this report.

Table 4. Sparta Community Meeting Key Issues

Issue Area	Identified Barriers
Built Environment and Land Use	• *Incomplete sidewalk network* • *Heavy traffic along key routes* • *Segregated land uses* • *Rural school siting*
Transportation Infrastructure	• *Lack of sidewalks* • *Width and quality of existing sidewalks (e.g., electric poles in the middle of sidewalks)* • *Lack of passing zones (to pass cyclists) on rural roads* • *Wide lanes throughout Sparta that encourage high travel speeds* • *Downtown aesthetics not conducive to walking*
Demographic and Cultural Factors	• *High rates of poverty* • *Older population* • *High proportion of population without health insurance* • *Cultural bias towards the car due in part to Sparta's rural setting* • *Poor nutrition/access to healthy foods* • *Cultural norms that support tobacco use*
Services	• *Lack of public transit service* • *Fragmentation of government services downtown - services were historically housed in a single building and residents would park once in downtown and walk to other destinations; now services are offered in different buildings and residents are more likely to drive to each building*
Social and/ or economic conditions	• *Stigmatization of walking for transportation* • *Large percentage of the population on fixed incomes* • *Large number of seasonal workers*
Natural Environment	• *Extreme elevation changes in the community make cycling very difficult; largely a recreational activity* • *Lack of programmed open space (e.g., sports fields, playgrounds, etc.)*

Focusing specifically on physical inactivity as a determinant of health, participants identified the lack of safe opportunities to cross the street, high traffic speed, and traffic signaling that is unsafe for pedestrians (e.g., right turn green arrows and protected right turn lanes) as primary barriers to increased walking due to negative effects (real and perceived) on pedestrian safety. Participants also identified several sub-populations that may be impacted by targeted improvements, including students who are unable to walk to school due to gaps in the sidewalk network, seasonal workers who do not have a car and must walk to work since there is no public transit, and carless households that also must rely on walking as a primary mode of transportation.

Scoping Summary: Blue Ridge Road Corridor (BRRC)

Five facilitated focus group interviews were previously completed for the BRRC to gather public input regarding health disparities in the community.[12] Specifically, the focus groups were structured around on three general topics:

1. What elements of the BRRC neighborhood and environment, as it currently exists, do stakeholders identify as a concern to public health?
2. What health effects, both positive and negative, can be identified in the BRRC that might be affected through planning, design, and change to infrastructure?
3. How can existing plans or conceptual designs for the BRRC address specific health concerns?

Key issues raised by stakeholders in focus group discussions are summarized in Table 5. Major themes that emerged during focus group discussions included the lack of sidewalks and crosswalks posing a threat to public health, the perception of the BRRC as a dangerous place due to the threat of injury, the lack of convenient public transit,

the environment of BRRC being stressful, and the large gaps that exist between destinations along the corridor limiting pedestrian and bicycle travel. Stakeholders specifically defined stress and safety from injury as an important public health impact related to the current design of the BRRC. Focus group discussions were structured to also give participants an opportunity to identify preferred design changes for addressing health concerns in the BRRC. The top seven design changes for the corridor were: 1) Make BRRC more aesthetically pleasing; 2) Ensure that sidewalks and crosswalks are built on the majority of roads; 3) Build more things to walk to (e.g., coffee shops, restaurants, etc.); 4) Build bike lanes and install bike racks; 5) Improve connections to and between modes of public transit; 6) Provide educational opportunities; and 7) Improve publicity (e.g., better mapping, signage, etc.) A number of these design interventions are linked directly to walkability – and active transportation infrastructure is addressed as a specific design intervention for improving public health in the BRRC area.

Table 5. BRRC Focus Groups Key Issues

Issue Area	Identified Barriers
Built Environment and Land Use	• *Lack of adequate sidewalks in the BRRC area* • *Lack of adequate crosswalks in the BRRC area* • *Large gaps between pedestrian destinations*
Transportation Infrastructure	• *Lack of adequate sidewalks in the BRRC area* • *Lack of adequate crosswalks in the BRRC area* • *Intersections and roads designed primarily for private automobiles* • *Lack of an efficient roadway network* • *Lack of clear trail indicators (e.g., wayfinding signs, maps, etc.)* • *Not all pedestrian facilities open at night*
Demographic and Cultural Factors	• *Presence of drunk/distracted drivers*
Services	• *Lack of public transit service* • *Poor connections to and in between public transit services*
Social and/ or economic conditions	• *No barriers identified*
Natural Environment	• *No barriers identified*

Assessment: Methods

We use the DYNAMO-HIA model to estimate the health impacts of active transportation improvements in the three study areas. DYNAMO-HIA is a powerful, flexible, and dynamic health impacts modeling tool developed by the National Institute for Public Health and the Environment in the Netherlands. To our knowledge, DYNAMO-HIA has not been used in the United States nor has it been applied to a transportation infrastructure project to date; thus, our analysis offers an innovative and unique approach to estimating the health outcomes of active transportation infrastructure. The DYNAMO-HIA modeling framework enables users to combine epidemiological evidence, public health and demographic data, and transportation behavior information to predict age- and sex-specific health outcomes over time. This state of the art model is a significant methodological advancement compared to common HIA practice in the United States today. Specifically, DYNAMO-HIA uses a Markov Chain modeling approach in which the population is divided into a number of baseline health states at the beginning of the simulation and transitions between health states (healthy, diseased, or deceased) are modeled as the population ages through time. Transitions between states are characterized by epidemiological evidence, baseline disease data, and risk factor exposures. The model moves forward through time in 1-year time increments, maintaining population data between time periods. In a sense, the model divides the population into 95 male and 95 female one-year age cohorts and tracks each cohort through time. Previous applications of the DYNAMO-HIA model have predicted the health impacts of smoking cessation in Great Britain and changes in alcohol consumption in Sweden.[13] Outside of the health sector, Markov Chain approaches have been applied to model a wide range of phenomena, stock prices, asset price volatility, and political transitions from authoritarian to democratic regimes.[14-16] Thus, while our modeling approach is unique, a significant body of work exists documenting the ability of Markov Chain approaches to model conceptually similar dynamic processes in the public health field and in other sectors.

Model Development

DYNAMO-HIA provides a great deal of flexibility to the user. While the model contains a predefined structure, the user is free to add layers of detail to the model in a modular fashion. In particular, the user is free to select any number of diseases they wish to include in the model and to select and characterize a single risk factor. We base our DYNAMO-HIA model on a conceptual model in which active transportation infrastructure increases active transportation behavior, and thereby increases physical activity levels in the population, which in turn has an effect on the prevalence of disease and mortality from all causes. This conceptual model is supported by research in transportation behavior that establishes a relationship between built environment characteristics and active transportation behavior and research indicating that physical activity, even at low to moderate intensity and for relatively short durations, has significant implications for a wide range of diseases as well as for all-cause mortality.[17-21] Thus, we selected physical inactivity as the risk factor in our model.

In selecting diseases to include in our model, we reviewed epidemiological evidence to ensure that included diseases are linked to walking for transportation. While recent research has established connections between a wide range of diseases and physical activity, the intensity of physical activity plays a critical role in characterizing this

relationship for certain health outcomes. For certain diseases, both moderate and vigorous physical activity reduce disease risk; however, epidemiological studies suggest that the risk of some diseases is attenuated only by vigorous physical activity. Given the typically moderate physical activity levels accrued during active transportation, we focused our attention on diseases with a proven epidemiological link to moderate physical activity.[22] Initially, this process resulted in the identification of seven diseases: 1) Breast Cancer; 2) Chronic Pulmonary Obstructive Disorder (COPD); 3) Colon Cancer; 4) Coronary Heart Disease (CHD); 5) Diabetes; 6) Hypertension; and 7) Stroke. However, this initial list required further screening prior to inclusion in the DYNAMO-HIA model. Diseases were first screened based on the availability of baseline prevalence data at an appropriate geographic scale (the county, if available, or multi-county regions if county data were unavailable) and subsequently screened based on peer-reviewed epidemiological studies linking moderate transportation physical activity to disease risk. After this multi-stage screening process, four diseases were selected for final inclusion in the DYNAMO-HIA model: 1) CHD; 2) Diabetes; 3) Hypertension; and 4) Stroke. Breast and Colon Cancer were not included due to data limitations at the county level while COPD was not included due to a lack of epidemiological studies linking transportation-derived physical activity to health outcomes. The combination of these diseases address many stakeholder concerns identified during the Scoping phase. However, we were unable to consider obesity explicitly in our model due to a lack of detailed epidemiological evidence linking non-vigorous and transportation physical activity to obesity outcomes.

The final choice left in constructing our DYNAMO-HIA model was the characterization of the physical activity risk factor. A comprehensive review of epidemiological studies was used to determine the strength of the relationship between non-vigorous physical activity and health outcomes as well as the manner in which non-vigorous physical activity was measured. Epidemiological studies link physical activity to various health outcomes using relative risks (RR), which is the risk of developing a certain health outcome when exposed to a risk factor divided by the risk of developing the same health outcome when not exposed to the risk factor. Mathematically, a relative risk is defined as:

$$RR = \frac{p_{event\ when\ exposed}}{p_{event\ when\ not\ exposed}}$$

In the context of physical activity, increasing levels of walking for transportation reduces the risk of negative health outcomes. Thus, RR values are less than 1 and lower RR values represent a more powerful relationship between transportation physical activity and the health outcome. Values for RR are typically defined at different levels of transportation physical activity; thus, RR is a function of the level of physical activity as well as the specific health outcome. Disease-specific studies consider physical activity from transportation as a distinct independent variable and classify activity using the same categories (0 minutes per week; 1-149 minutes per week, or 150 or more minutes per week) and provide relative risks for males and females.[18-20] Thus, we characterize the physical activity risk factor as a categorical variable with the same categories as are used in the epidemiological studies reviewed. For

all-cause mortality, a recent meta-analysis was identified that provides a continuous dose-response model for transportation physical activity.[21] From these data, we derived RR values for all-cause mortality for each defined risk factor class by calculating the RR value at the mid-point of the middle category (75 minutes per week) and the low point of the higher category (150 minutes per week). These data are not disaggregated by sex. When studies provided several models controlling for various confounding variables, we select the least adjusted RR values because our model does not address typical confounders such as smoking and education. These data are summarized in Table 6 and our final DYNAMO-HIA model is presented schematically in Figure 4.

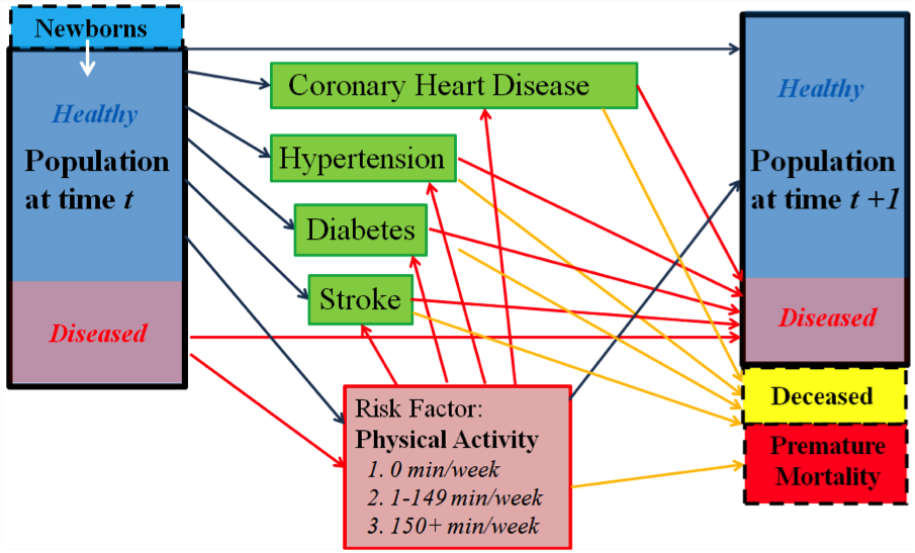

Figure 4. Model Schematic, representing simulation of one time step

Table 6. Summary of Epidemiological Studies Used to Relate Physical Activity to Health Risk

Disease	Study	Sex	Relative Risk of Health Outcome			Model Controls
			No PA	1-149 min/wk	150+ min/wk	
CHD	Hu et al. 2007	Male	1	0.88	0.80	Age, study year
		Female	1	0.89	0.64	
Diabetes	Furie and Desai 2012	Combined	1	0.77	0.69	Race, education, income, smoking
Hypertension	Furie and Desai 2012	Combined	1	0.76	0.69	Race, education, income, smoking
Stroke	Hu et al. 2005	Male	1	0.86	0.82	Age, study year
		Female	1	0.83	0.80	
Mortality, all-cause	Woodcock et al. 2010	Combined	1	0.926	0.898	n/a; meta-analysis

RRs for each risk factor category reported for all-cause mortality relative to reference category

Baseline Data: Population

We collected baseline demographic and health data for each study area from the North Carolina State Center for Health Statistics (NCSCHS). All data were collected for the year 2009 because the 2009 Behavioral Risk Factor Surveillance System (BRFSS) survey contained an additional question regarding active transportation behavior in 2009. Population data, stratified by age and sex at the county level, were taken from NCSCHS population estimates.[23] The age distribution of these data within census age groups were then applied to 2009 census data for specific block groups for each study area to refine these data and provide age- and sex-specific populations for each study area. To estimate newborns, the 2009 county birthrate and male to female ratio, both taken from the NCSCHS Vital Statistics records, was assumed to remain constant throughout the study period.[24] Newborns for each year were estimated to equal population size times the birthrate, growing the base population yearly by the natural population growth rate, also reported in the NCSCHS Vital Statistics data. This process is documented in greater detail in Appendix 3 of this report.

Baseline Data: Disease Prevalence

We use a method similar to the one applied to population data to refine disease prevalence into smaller age categories. Four questions from the 2009 BRFSS survey, each corresponding to a different disease, were used to develop population disease prevalence estimates.[25] Questions and corresponding disease are listed in Table 7. In the 2009 BRFSS public data, county-level data for all diseases are reported split into two age groups (18-44 and 45+) whereas regional data are reported split into six age groups (18-24, 25-34, 35-44, 45-54, 55-64 and 65+). We assume that the observed distribution for the five-age group data at the regional level underlies the reported two-age group data at the county level. Thus, we use the five-age range distribution to estimate county-level disease prevalence in the same five age groups by adjusting regional-level values using county-level population estimates and observed prevalence values. We then estimate age-specific prevalence functions for each disease using a fitted second-order numerical function. We then use these continuous disease prevalence functions to estimate prevalence for each 1-year age group used in DYNAMO-HIA (i.e., 1, 2, 3, etc.) This process is described in Appendix 3 of this report.

Table 7. 2009 BRFSS Survey Questions Used

Question	Wording	Data
9.2[a]	*Has a doctor, nurse, or other health professional ever told you that you had angina or coronary heart disease?*	*CHD Prevalence*
6.1[a]	*Have you ever been told by a doctor that you have diabetes?*	*Diabetes Prevalence*
7.1[a]	*Have you ever been told by a doctor, nurse, or other health professional that you have high blood pressure?*	*Hypertension Prevalence*
9.3[a]	*Has a doctor, nurse, or other health professional ever told you that you had a stroke?*	*Stroke Prevalence*
16.1[b]	*In the past week, how much time did you walk or bicycle for transportation, such as to and from work or shopping?*	*Baseline PA from Transportation*

[a]*CDC core section question* [b]*North Carolina added question*

Baseline Data: Disease Incidence

The 2009 BRFSS survey data report disease prevalence – the percentage of the population with a given disease at a given time – but do not report disease incidence – the rate of new disease cases in the population over time.[5] However, the DYNAMO-HIA model requires both prevalence and incidence for each disease included. We estimate disease incidence using a method developed by Ralph Brinks, a researcher at Institute for Biometry and Epidemiology in Düsseldorf, Germany.[26] Conceptually, we use age-specific prevalence data, combined with age-specific mortality estimates for individuals with and without the disease, to estimate the rate at which individuals of different ages must develop the disease for the prevalence data to be realized as observed in the 2009 BRFSS survey. This method is described in Appendix 3.

Baseline Data: Walking for Transportation

For the Winterville and Sparta study areas, we obtained baseline active transportation behavior from the 2009 BRFSS, in which the state of North Carolina included a supplementary question regarding active transportation. These data are available at the county level; however, they are not stratified by gender or age. Thus, we assume that active transportation behavior prevalence is constant across all ages and for both genders. For the Blue Ridge Road study area, we used a survey conducted in 2010 based on the International Physical Activity Questionnaire (IPAQ), a validated survey that has been used in a wide range of physical activity studies.[12,27] For both active transportation behavior data sources, we assume that the distribution of minutes of activity per week is constantly distributed within each time category in each survey and that half of all BRFSS respondents who report more than 2 hours of active transportation per week are engaged in active transportation less than 2.5 hours per week and half are engaged in active transportation more than 2.5 hours per week. We use these data to estimate the prevalence of each risk factor category (0 minutes per week, 1-149 minutes per week, or more than 150 minutes per week) in our model.

Baseline Data: Winterville

Baseline data for the Winterville study area are summarized below. Figure 5 shows the 2009 population distribution by age and sex. In total, the study area has a population of 9,269 residents, of which 4,944 are female and 4,320 are male. The study area contains a relatively large number of residents above age 30; however, there are relatively few residents in the 15-30 age range.

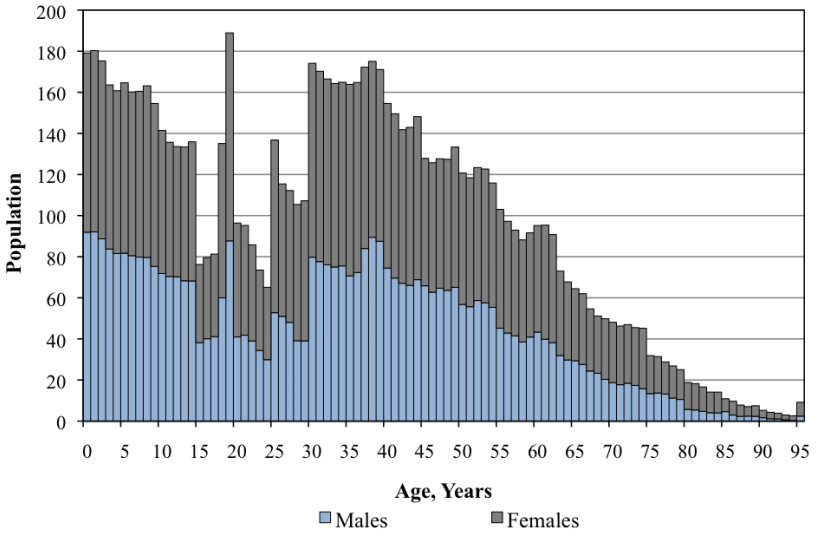

Figure 5. Winterville 2009 Population Distribution by Age

Baseline disease prevalence and estimated incidence by age for CHD, Diabetes, Hypertension, and Stroke for the Winterville study area are summarized in Figure 6. Observed prevalence data are plotted with black crosses and a fitted age-specific prevalence function is plotted with a solid black line. Estimated incidence data are plotted with red crosses and a fitted red line. Data are shown for ages 18-75 only.

Baseline active transportation behavior for the Winterville study area, taken from the 2009 BRFSS survey is presented in Table 8, in both raw form and aggregated based on our physical activity risk factor classifications.

Table 8. Baseline Walking for Transportation, Winterville

2009 BRFSS Survey Results		Grouped Based on Risk Factor Categories	
Min. Transportation PA per Week	Percentage of Population	Min. Transportation PA per Week	Percentage of Population
0	84.3%	0	84.3%
1-29	3.4%	1-149	12.3%
30-59	2.5%	1-149	12.3%
60-119	2.9%	1-149	12.3%
120+	6.9%	150+	3.4%

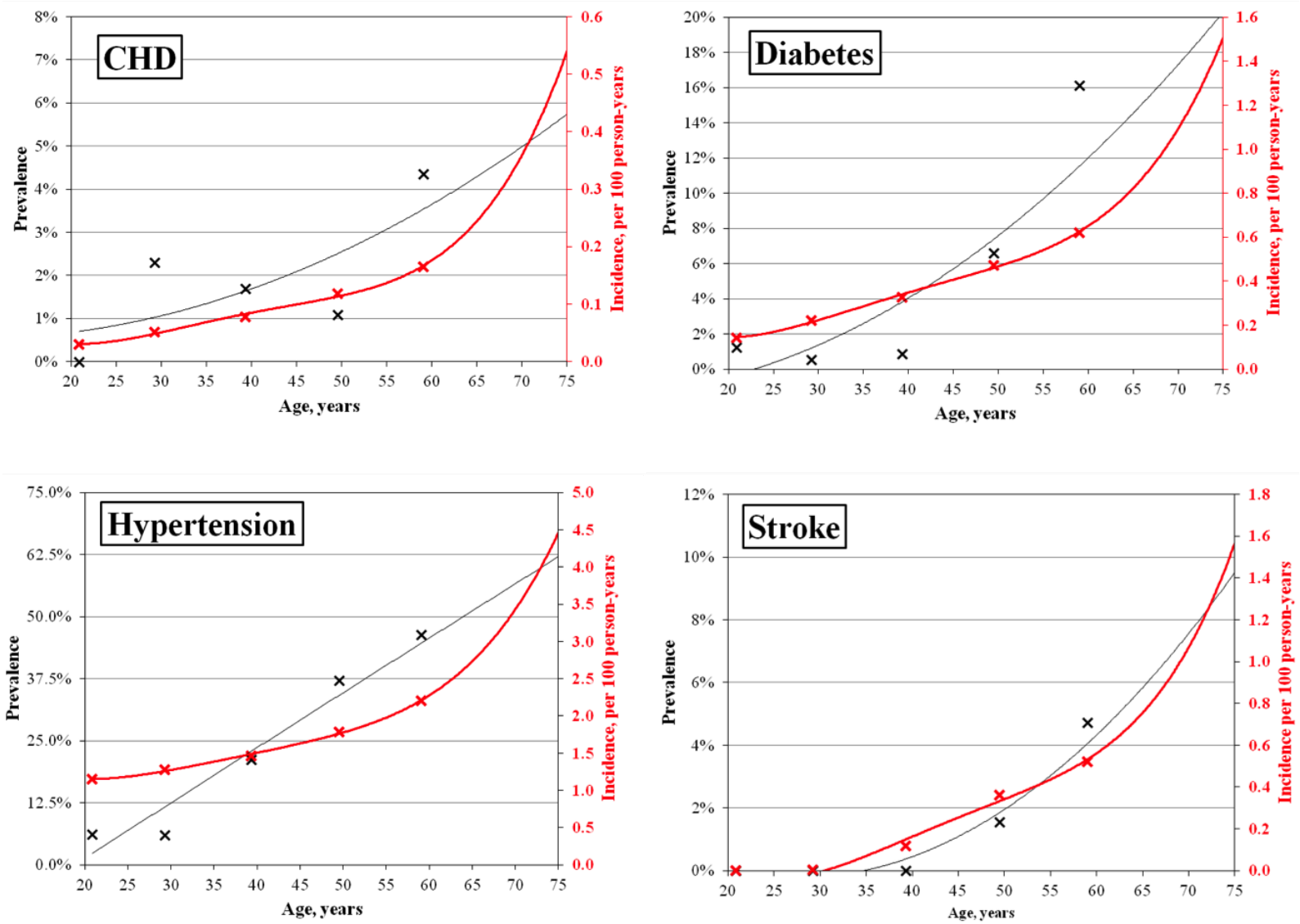

Figure 6. Winterville 2009 Disease Prevalence and Incidence, by Age

Baseline Data: Blue Ridge Road

Baseline data for the BRRC study area are summarized below. Figure 7 shows the 2009 population distribution by age and sex. In sum, the study area contains 10,929 residents, of which 6,056 are female and 4,873 are male. The study area contains a relatively large number of residents between the ages of 18 and 24, especially females in this age group, partially due to its proximity to Meredith College. Baseline disease prevalence and estimated incidence by age for CHD, Diabetes, Hypertension, and Stroke for the BRRC study area are summarized in Figure 8.

Baseline active transportation behavior for the BRRC study area is summarized Table 9, in both raw form and aggregated based on our physical activity risk factor classifications.[12]

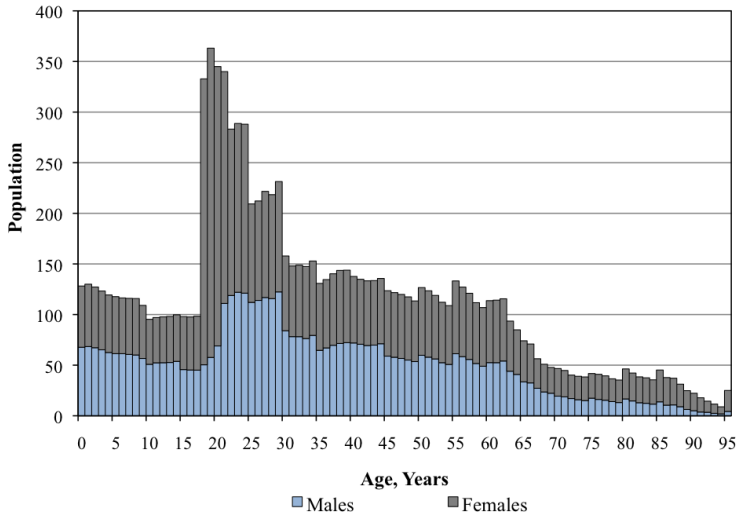

Figure 7. BRRC 2009 Population Distribution by Age

Table 9. Baseline Walking for Transportation, BRRC

BRRC Survey Results		Grouped Based on Risk Factor Categories	
Min. Transportation PA per Week	*Percentage of Population*	*Min. Transportation PA per Week*	*Percentage of Population*
0	*40.7%*	*0*	*40.7%*
1-60	*23.3%*	*1-149*	*40.8%*
61-120	*14.5%*	*1-149*	*40.8%*
121-140	*2.1%*	*1-149*	*40.8%*
141-160	*1.8%*	*1-149*	*40.8%*
161+	*17.6%*	*150+*	*18.5%*

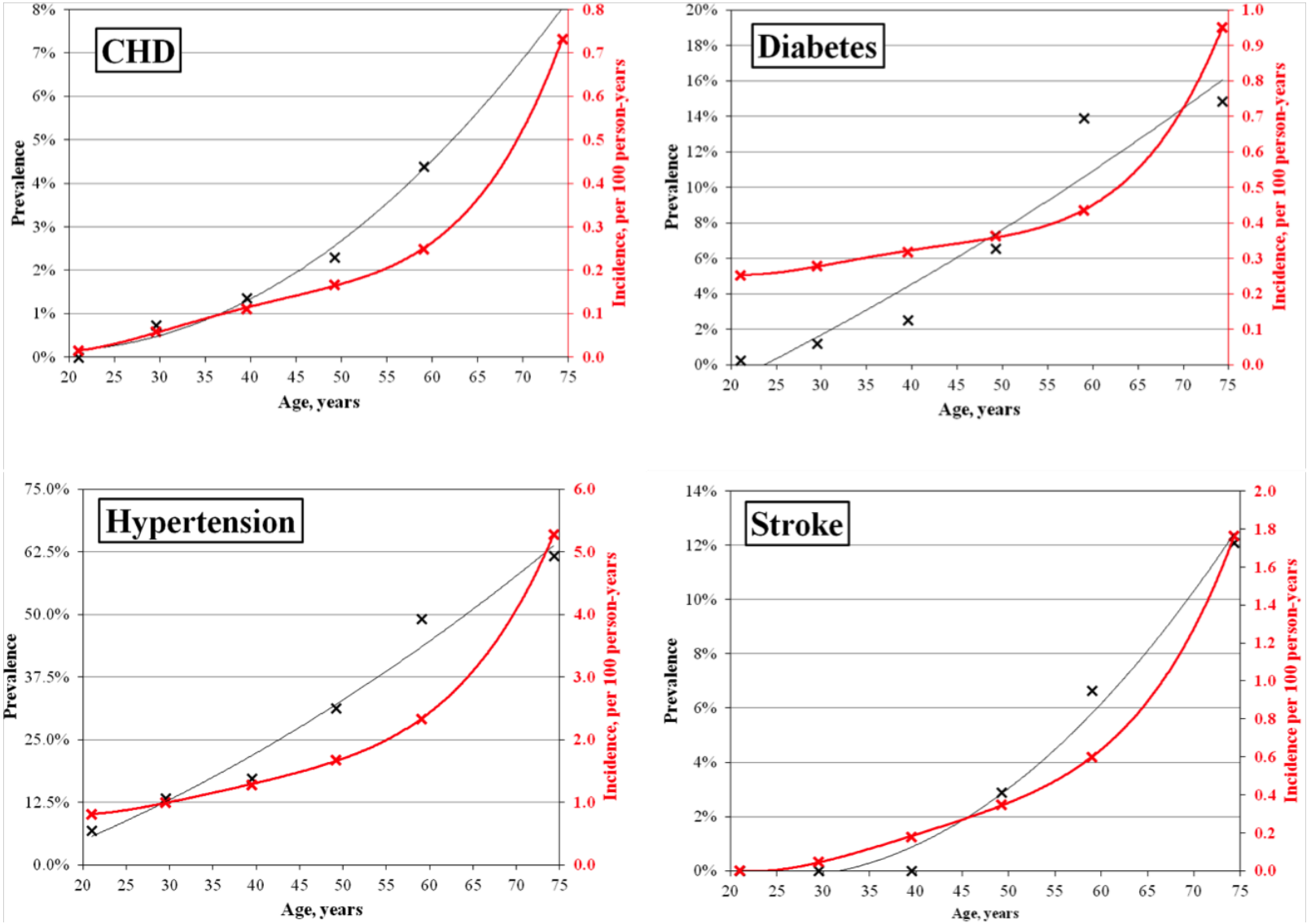

Figure 8. BRRC 2009 Disease Prevalence and Incidence, by Age

Baseline Data: Sparta

Baseline data for the Sparta study area are summarized below. Figure 9 shows the 2009 population distribution by age and sex. The study area contains a total of 1,770 residents. The study area contains a more equal distribution of males to females than Winterville and the BRRC, with 882 female residents and 888 male residents. Sparta is also relatively older than both other study areas, with population distributed fairly evenly up to 75 years of age. Baseline disease prevalence and estimated incidence by age for CHD, Diabetes, Hypertension, and Stroke for the Sparta study area are summarized in Figure 10.

Baseline active transportation behavior for the Sparta study area, taken from the 2009 BRFSS survey is presented in Table 10, in both raw form and aggregated based on our physical activity risk factor classifications.

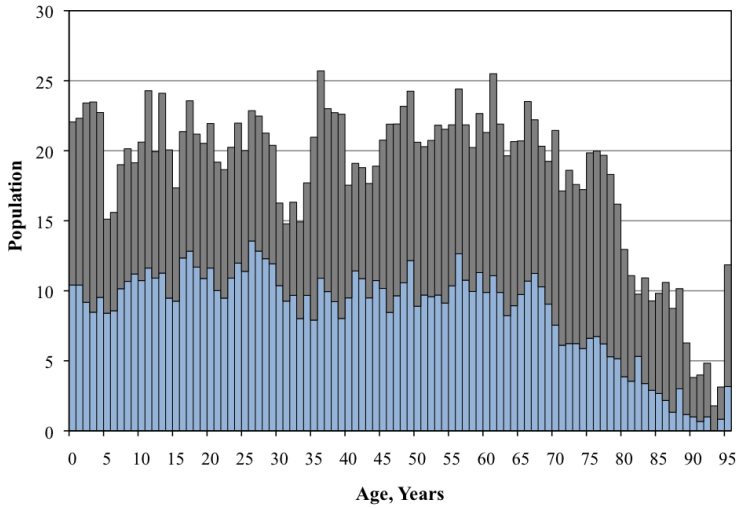

Figure 9. Sparta 2009 Population Distribution by Age

Table 10. Baseline Walking for Transportation, Sparta

2009 BRFSS Survey Results		Grouped Based on Risk Factor Categories	
Min. Transportation PA per Week	*Percentage of Population*	*Min. Transportation PA per Week*	*Percentage of Population*
0	*83.8%*	*0*	*83.8%*
1-29	*4.4%*	*1-149*	*13.5%*
30-59	*3.3%*	*1-149*	*13.5%*
60-119	*3.0%*	*1-149*	*13.5%*
120+	*5.5%*	*150+*	*2.8%*

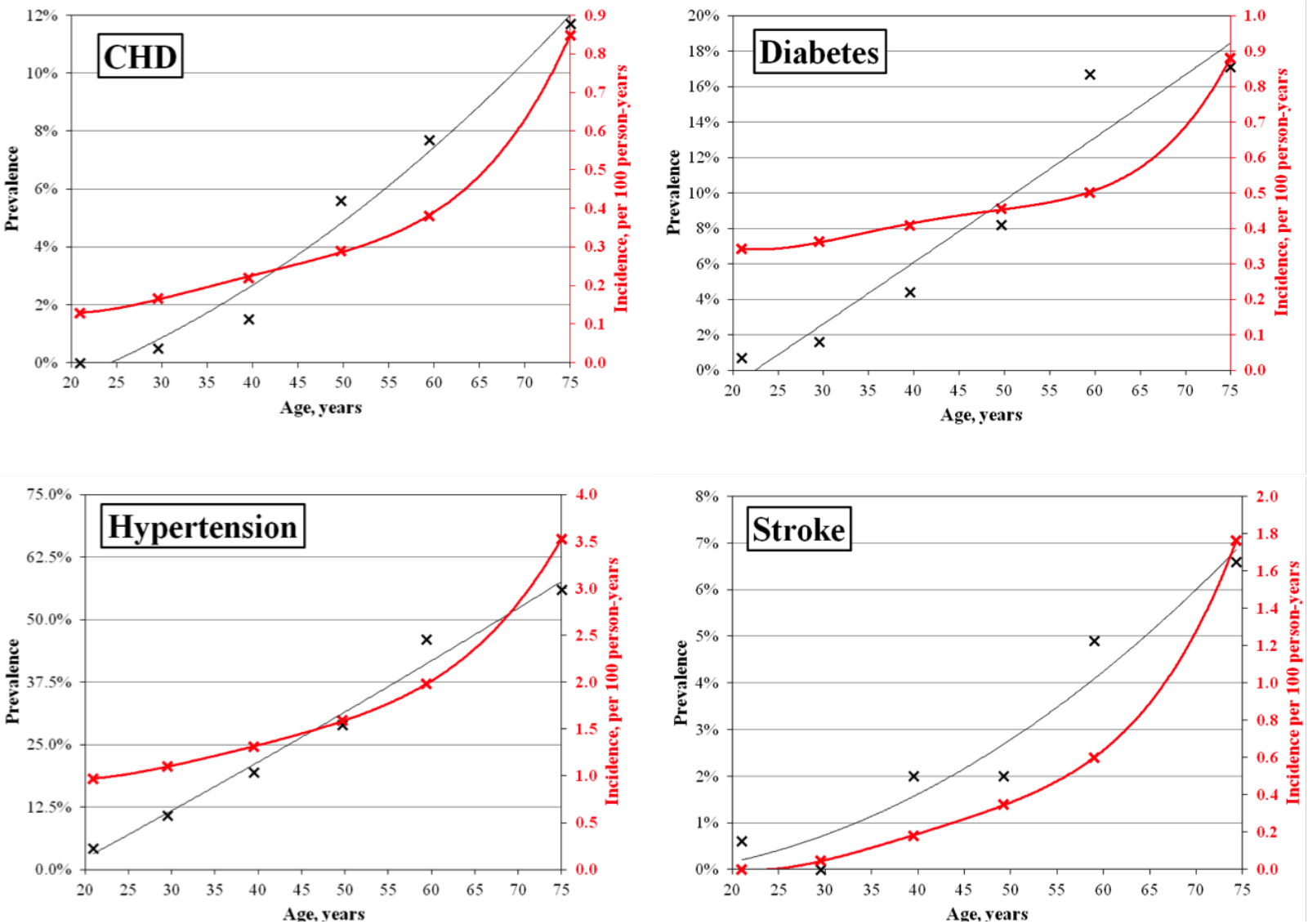

Figure 10. Sparta 2009 Disease Prevalence and Incidence, by Age

Assessment: Results

We constructed separate models to estimate the health impacts of active transportation infrastructure improvements in each community. In each model, we considered five health outcomes, disaggregated by gender: 1) avoided all-cause mortality; 2) avoided cases of CHD; 3) avoided bases of diabetes; 4) avoided cases of hypertension; and 5) avoided cases of stroke. Each model compares two scenarios, a baseline scenario and an intervention scenario, through time. We assumed that active transportation behavior would stay constant in the baseline scenario and would increase due to changes in the built environment in the intervention scenario. Thus, the health impacts of changes in the built environment are captured by the differences in health estimated outcomes over time between the two scenarios. We ran each model for 50 years, starting in 2009. The starting date of the simulation is somewhat arbitrary. We used 2009 because data for walking for transportation are only available in the 2009 BRFSS; however, we interpreted model outputs in terms of "years from the present," assuming that in some future year the project will be implemented and health impacts will grow through time from that future date.

The baseline and intervention scenarios are identical aside from one aspect: the percentage of the population in each risk factor category. Differences in health status between the two scenarios emerge through time as the population ages, distributed differently into higher and lower risk groups. All cohorts in the intervention scenario born in 2009 and thereafter spend all of their lives with a greater chance of being in a lower risk group due to increased physical activity from active transportation while population cohorts born prior to 2009 spend relatively smaller percentages of their lives with a greater chance of being in a lower risk group. Therefore, younger populations and those born in 2009 and later have a greater chance of being at reduced risk for adverse health outcomes throughout their lives due to the built environment interventions considered. Thus, improved health outcomes in the intervention scenario become more pronounced over time as individuals spend a greater portion of their total lives in lower risk factor categories resulting from transportation physical activity.

Intervention Data: Walking for Transportation

For each study area, we calculate pre- and post-project built environment variables and use these data to estimate changes in active transportation behavior in the community. For Winterville and the BRRC, we focus on the construction of new sidewalks and greenways while in Sparta we consider improvements to existing sidewalks. We calculate pre- and post-project sidewalk length, measured in miles, and sidewalk density, measured in miles of sidewalk per square mile of land. Sidewalks on two sides of the same street are both counted (i.e., a one mile length of road with sidewalks on both sides is considered two miles of sidewalks) and greenways are included in sidewalk length totals. We translate pre- and post-project built environment to estimate changes in physical activity from transportation using behavioral evidence in three ways: 1) increased average walking time due to increases in the extent of the sidewalk network; 2) increased odds of making a walking trip due to increases in the density of the sidewalk network; and 3) increased per capita walking distance in neighborhoods with a higher Pedestrian

Environment Factor (PEF). While the travel behavior literature is generally consistent in its findings,[17] it is difficult to generalize findings across cities and regions; however, we used methods consistent with the best evidence in the literature today. Methods are described in greater detail in Appendix 3.

Previous research conducted using built environment variables and travel survey data in the Raleigh-Durham-Chapel Hill Metropolitan Statistical Area found that a 1% increase in total sidewalk network length results in a 0.12% increase in average walking time per person. Additionally, every additional mile of sidewalk per square mile increases the odds of an individual having taken a walking trip by 1.4%.[17,28] Thus, we use total sidewalk length to estimate the increased walking time for existing walkers and sidewalk density to estimate the number of new walkers. The time spent walking by new walkers is assumed to be distributed in a similar manner as for existing walkers and new walkers are added to each category appropriately. For Sparta, we consider improvements to the quality of the pedestrian environment using the PEF developed in Portland, Oregon.[29-30] We estimate the pre- and post- PEF for the downtown area, considering sidewalk quality, ease of street crossings, topography, and local street network configuration. We assume that a transition from the lowest third of PEF to the middle third of PEF results in an average increase of 0.71 miles walked per person per week and from the lowest third to the highest results in an increase of 1.32 miles walked per person per week.[30] We assume a conservative average walking speed of 2.5 miles per hour to convert to time.[31]

Intervention Data: Winterville

Pre- and post-project built environment variables of interest, as well as predicted effects on walking behavior consistent with the behavioral literature reviewed, are presented in Table 11. Implementing all projects included in the Pitt County Pedestrian and Bicycle Master Plan, as well as other currently proposed sidewalks, would increase the length of sidewalk in Winterville from 14.3 to 65.7 miles. This results in an increased walking time amongst existing walkers of 43.2%. These new sidewalks would also increase sidewalk coverage, measured in sidewalk density, from 1.3 miles of sidewalk per square mile of land area to 4.8 miles of sidewalk per square mile of land area. This results in an increase in the odds of someone taking a walking trip during the week by 6.8%, meaning that some individuals who do not walk for transportation before the construction of the sidewalks will do so after the construction of the sidewalks.

Table 11. Pre- and Post-project Built Environment Variables, Winterville

	Pre-project	Post-project	Change	Behavioral Response
Sidewalk Length	*14.3 mi*	*65.7 mi*	*+360%*	*Increase in average walking time:* ***43.2%***
Sidewalk Density	*1.3 mi/mi²*	*6.1 mi/mi²*	*+4.8 mi/mi²*	*Increase in odds of taking a walk trip:* ***6.8%***

Predicted active transportation behavior after the proposed built environment change, as well as the difference relative to the baseline, are presented in Table 12. A small shift from the non-walking category into a walking category is predicted. Additionally, a larger shift from the lower walking category to the upper walking category is predicted, with a large increase in the percentage of the population walking greater than 150 minutes per week and a related decline in the percentage of the population walking less than 150 minutes.

Based on these predicted changes in physical activity from walking for transportation, we predict significant positive health impacts. Fifty years after the construction of the project, 2 lives will be saved, and a modest percentage of future cases of each disease considered will be avoided. Modeled health impacts through time for both genders are shown in Figure 11, with lives saved plotted on the left axis and percentage of disease cases avoided on the right axis. These results are disaggregated by gender and displayed in Table 18 with numbers of disease cases rather than percentage of disease cases avoided to ease comparisons across projects for three time periods.

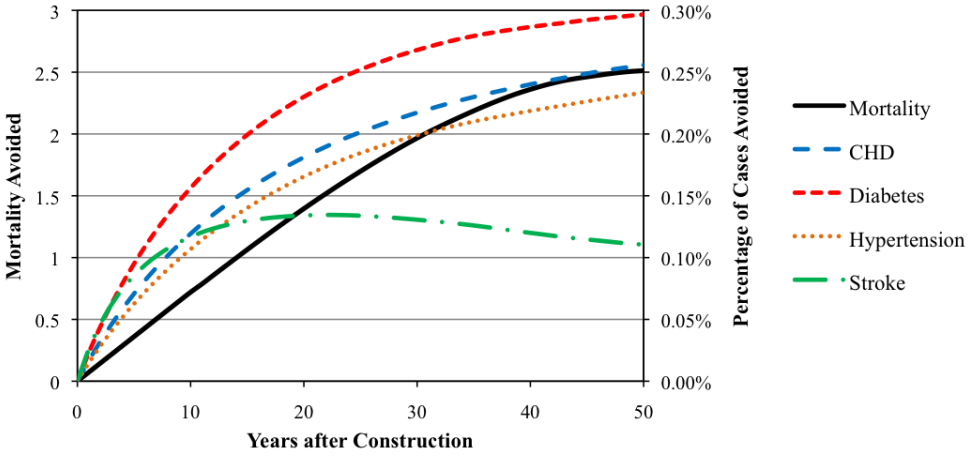

Figure 11. Winterville Predicted Health Outcomes

Table 12. Post-Intervention Walking for Transportation, Winterville

Estimated Intervention Active Transportation Behavior		Grouped Based on Risk Factor Categories		
Min. Transportation PA per Week	*Percentage of Population*	*Min. Transportation PA per Week*	*Percentage of Population*	*Change, Relative to Baseline*
0	*83.4%*	*0*	*83.4%*	***-0.9%***
1-29	*3.6%*	*1-149*	*10.9%*	***-1.4%***
30-59	*2.6%*	*1-149*	*10.9%*	***-1.4%***
60-119	*3.1%*	*1-149*	*10.9%*	***-1.4%***
120+	*7.3%*	*150+*	*5.7%*	***+2.3%***

Intervention Data: BRRC

Pre- and post-project built environment variables of interest, as well as predicted effects on walking behavior consistent with the behavioral literature reviewed, are presented in Table 13. Predicted active transportation behavior, as well as the difference relative to the baseline, are presented in Table 14.

Table 13. Pre- and Post-project Built Environment Variables, BRRC

	Pre-project	Post-project	Change	Behavioral Response
Sidewalk Length	*5.0 mi*	*24.2 mi*	*+388%*	*Increase in average walking time:* ***46.6%***
Sidewalk Density	*2.0 mi/mi²*	*9.9 mi/mi²*	*+7.9 mi/mi²*	*Increase in odds of taking a walk trip:* ***11.2%***

Table 14. Post-Intervention Walking for Transportation, BRRC

BRRC Survey Results		Grouped Based on Risk Factor Categories		
Min. Transportation PA per Week	*Percentage of Population*	*Min. Transportation PA per Week*	*Percentage of Population*	*Change, Relative to Baseline*
0	*38.1%*	*0*	*38.1%*	***-2.5%***
1-84	*24.3%*	*1-149*	*36.2%*	***-4.6%***
85-116	*10.3%*	*1-149*	*36.2%*	***-4.6%***
117-140	*5.7%*	*1-149*	*36.2%*	***-4.6%***
141-168	*4.9%*	*150+*	*25.7%*	***+7.1%***
169+	*22.4%*	*150+*	*25.7%*	***+7.1%***

Based on these predicted changes in physical activity from walking for transportation, we predict significant positive health impacts. Fifty years after the construction of the project, 7 lives will be saved and approximately 1% of future cases of both diabetes and CHD will be avoided, along with around 0.7% of future cases of hypertension and 0.4% of future cases of stroke. These health impacts are shown though time for both genders in Figure 12. Lives saved are plotted on the left axis while the percentage of cases avoided for each health outcomes are plotted on the right axis. Health outcomes are disaggregated by gender for three time periods – 10, 20, and 40 years in the future – in Table 19.

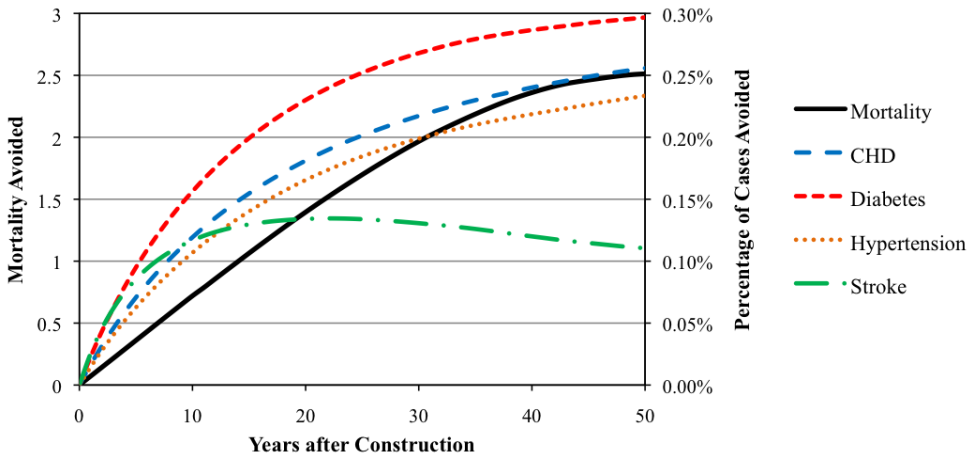

Figure 12. BRRC Predicted Health Outcomes

Intervention Data: Sparta

Pre- and post-project built environment variables of interest, as well as predicted effects on walking behavior consistent with the behavioral literature reviewed, are presented in Table 15. We assume that implementing all sidewalk improvements and street crossings as detailed in the Sparta Downtown Street Strategy will improve the PEF score from the lowest category to the middle category. Additionally, the construction of a new greenway segment would increase the total length of sidewalks and greenways in Sparta from 2.8 miles to 3.1 miles, resulting in an increased walking time amongst existing walkers of 43.2%, and would increase coverage from 1.2 miles of sidewalk per square mile of land area to 1.3 miles of sidewalk per square mile of land area, resulting in a negligible increase in the odds of someone taking a walking trip.

Predicted active transportation behavior after the proposed built environment change, as well as the difference relative to the baseline, are presented in Table 16. A large shift from the non-walking category into a walking category is predicted, as well as a moderate shift from the 1-150 minutes per week category into the greater than 150 minutes per week category.

Table 15. Pre- and Post-project Built Environment Variables, Sparta

	Pre-project	Post-project	Change	Behavioral Response
Downtown PEF	*Range: 4 to 8*	*Range: 8 to 12*	*+4*	*Increase in weekly walking distance:* ***0.57 miles per week***

Table 16. Post-Intervention Walking for Transportation, Sparta

Estimated Intervention Active Transportation Behavior		Grouped Based on Risk Factor Categories		
Min. Transportation PA per Week	*Percentage of Population*	*Min. Transportation PA per Week*	*Percentage of Population*	*Change, Relative to Baseline*
0	*75.0%*	*0*	*75.0%*	***-8.8%***
1-43	*13.2%*	*1-149*	*20.8%*	***+7.4%***
44-74	*3.3%*	*1-149*	*20.8%*	***+7.4%***
75-134	*3.0%*	*1-149*	*20.8%*	***+7.4%***
135+	*5.5%*	*150+*	*4.2%*	***+1.4%***

Based on these predicted changes in physical activity from walking for transportation, we predict significant positive health impacts. Fifty years after the construction of the project, 2 lives will be saved, and significant percentages of cases of CHD, Diabetes, Hypertension, and Stroke will be avoided. Modeled health impacts through time for both genders are shown in Figure 13. Lives saved are plotted on the left axis while the percentage of cases avoided for each health outcome are plotted on the right axis. Additionally, health outcomes are disaggregated by gender for three time periods – 10, 20, and 40 years in the future – in Table 20.

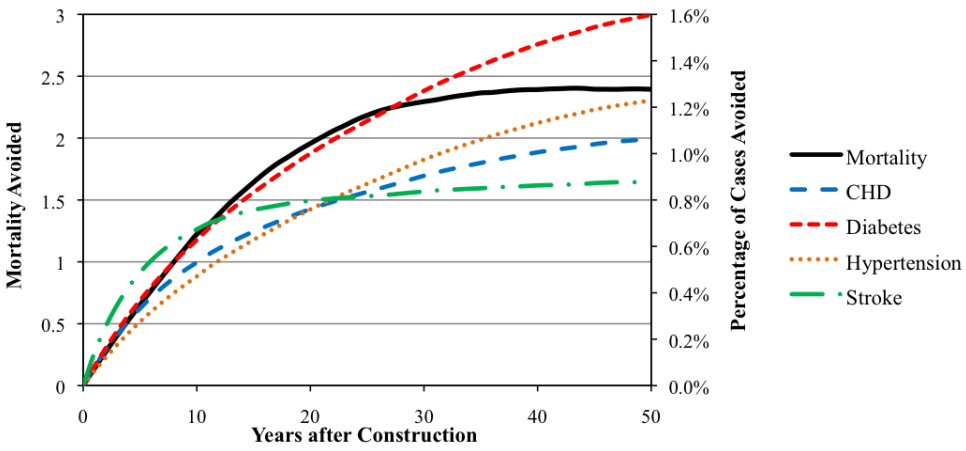

Figure 13. Sparta Predicted Health Outcomes

Economic Implications

While health outcomes are important in and of themselves, it is difficult to compare health to other outcomes without a consistent frame of reference. This is especially critical for the allocation of funds for transportation projects, wherein a large number of projects compete for funds that are limited relative to funding needs. In order to demonstrate the economic value of improved health outcomes attributable to active transportation infrastructure, we used established values for an individual's life and yearly disease cost to estimate total economic benefits to society resulting from improved health outcomes.[32-33] Health outcome valuations are detailed in Table 17. To account for reduced present value of health outcomes predicted to occur in the future, we used a traditional discounting procedure, in which the present value (PV) of a future income stream, C, received over k years in the future is adjusted based on a discount rate, d:

$$PV = \sum_{k=1}^{n} C(1+d)^{-k}$$

Selecting an appropriate discount rate is a contentious issue when monetizing health outcomes. Some argue that the future value of life should not be discounted, supporting a 0% discount rate, while others argue for a more traditional discounting approach. However, some recent work supports a discount rate between 3% and 4%.[34-35] We estimated the present value of health impacts using three discount rates to account for this uncertainty: 3.5%, 5%, and 7%. The Office of Management and Budget (OMB) requires federal agencies to use a 7% discount rate;[36] however, USDOT suggests a lower discount rate (5%) when considering the value of statistical life.[33] We consider the OMB recommended discount rate of 7%, a low case (3.5%) to match assumptions elsewhere in WalkBikeNC and to be consistent with recent literature,[35] and one intermediate case. We summarize the estimates at three points in the future that are useful from a decision-making perspective: 10, 20, and 40 years. Additionally, we estimate project costs, using either costs provided in the project documentation or new estimates based on per unit construction costs and compare them to projected benefits. While this simple cost-benefit analysis (CBA) is rather crude, it illustrates a manner in which these results can be included in decision-making processes. A benefit-cost ratio equal to 1 suggests that the project would have no net financial benefit to society, a ratio less than 1 suggests the project would be a net financial loss, and a ratio greater than 1 suggests that the project would be a net gain.

Table 17. Health Outcome Monetization Sources

Health Outcome	Monetary Value (2009 USD)	Source
CHD	*$9,048 per case per year[a]*	*An Unhealthy America: The Economic Burden of Chronic Disease[32]*
Diabetes	*$9,844 per case per year[a]*	*An Unhealthy America: The Economic Burden of Chronic Disease[32]*
Hypertension	*$8,831 per case per year[a]*	*An Unhealthy America: The Economic Burden of Chronic Disease[32]*
Stroke	*$15,573 per case per year[a]*	*An Unhealthy America: The Economic Burden of Chronic Disease[32]*
Mortality	*$8,600,000 per statistical life[b]*	*Guidance on Treatment of the Economic Value of a Statistical Life in USDOT Analyses[33]*

[a]Monetary value for North Carolina [b]Monetary value for the United States

Economic Valuation: Winterville

The estimated present value, in 2012 dollars and for each discount rate assumed, for the health impacts of the Winterville projects in the Pitt County Bicycle and Pedestrian Master Plan are shown in Figure 14. Full results are summarized in Table 18 for 10, 20, and 40 years post project construction, assuming a 3.5% discount rate and including project costs. We estimate the value of reduced mortality and reduced incidence of CHD, diabetes, hypertension, and stroke attributable to build-out of the Greenville MPO Bicycle and Pedestrian Master Plan to reach nearly $9,000,000 20 years after construction and exceed $12,500,000 within 40 years of construction. These projected economic benefits exceed estimated project cost by a factor of 0.5 to slightly above 1.0, increasing over time.

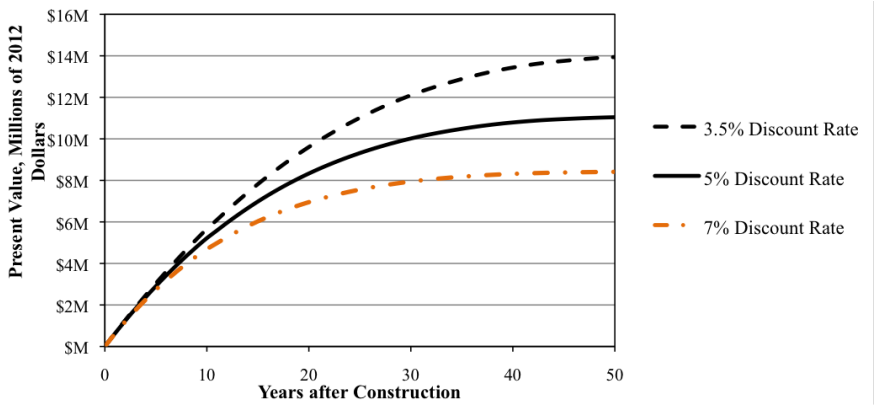

Figure 14. Winterville Economic Valuations

Table 18. Complete Winterville Results

	10 Years Post Construction			20 Years Post Construction			40 Years Post Construction		
Avoided Cases of:	Men	Women	Total	Men	Women	Total	Men	Women	Total
Mortality	0.4	0.4	0.7	0.7	0.7	1.4	1.2	1.2	2.4
CHD	0	0.3	0.3	0	0.5	0.5	0	0.7	0.7
Diabetes	0.4	0.6	1.0	0.7	1.0	1.7	1.1	1.5	2.6
Hypertension	1.1	1.4	2.5	2.0	2.4	4.4	2.9	3.6	6.5
Stroke	0.2	0.2	0.4	0.3	0.3	0.6	0.3	0.4	0.7
Economic Value		**$5,290,000**			**$8,980,000**			**$12,550,000**	
Cost Estimate		**$11,088,000**			**$11,088,000**			**$11,088,000**	
Benefit-Cost Ratio		**0.48**			**0.81**			**1.1**	

Economic Valuation: BRRC

The estimated present value, in 2012 dollars and for each discount rate assumed, for the health impacts of the BRRC small area plan are shown in Figure 15. Full results are summarized in Table 19 for 10, 20, and 40 years post project construction, assuming a 3.5% discount rate and including project costs. We estimate that the health impact of build-out of the BRRC small area plan will eclipse $25,000,000 within 20 years of construction and continue to rise above $36,000,000 40 years post-construction. Thus, we estimate that the benefits of active transportation infrastructure components of the BRRC plan will exceed the costs of construction by a factor of 4 to 9, once again increasing over time.

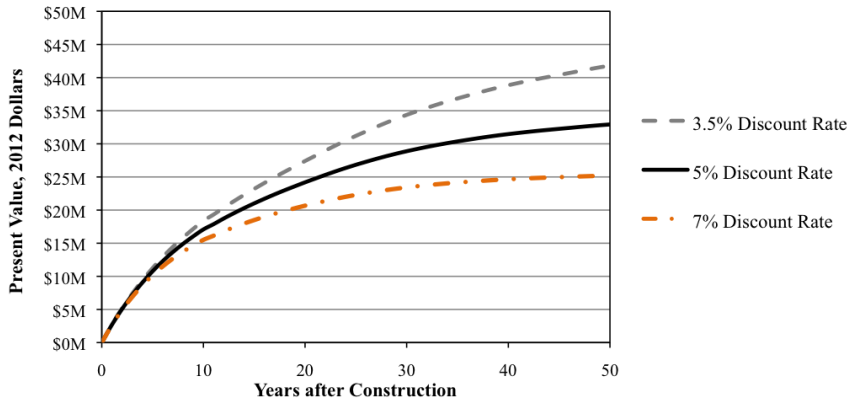

Figure 15. BRRC Economic Valuations

Table 19. Complete BRRC Results

	10 Years Post Construction			20 Years Post Construction			40 Years Post Construction		
Avoided Cases of:	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*
Mortality	*1.0*	*1.3*	*2.3*	*1.8*	*1.8*	*3.7*	*3.3*	*3.1*	*6.4*
CHD	*0*	*1.4*	*1.4*	*0*	*2.7*	*2.7*	*0*	*4.5*	*4.5*
Diabetes	*1.6*	*2.1*	*3.7*	*3.0*	*3.9*	*6.9*	*5.0*	*6.5*	*11.5*
Hypertension	*5.2*	*4.2*	*9.4*	*7.5*	*9.5*	*17.0*	*11*	*14.3*	*25.3*
Stroke	*0.7*	*0.9*	*1.6*	*1.2*	*1.7*	*2.9*	*1.8*	*2.5*	*4.3*
Economic Value		***$17,180,000***			***$25,610,000***			***$36,300,000***	
Cost Estimate		***$4,055,040***			***$4,055,040***			***$4,055,040***	
Benefit-Cost Ratio		***4.2***			***6.3***			***9.0***	

Economic Valuation: Sparta

The estimated present value, in 2012 dollars and for each discount rate assumed, for the health impacts of the Downtown Sparta Streetscape Strategy are shown in Figure 16. Full results are summarized in Table 20 for 10, 20, and 40 years post project construction, assuming a 3.5% discount rate. Given a typical project lifespan of 20 to 40 years, we predict that the health outcomes associated with implementation of the Downtown Sparta Streetscape Strategy will exceed the costs by a factor in the range of 13 to 22.

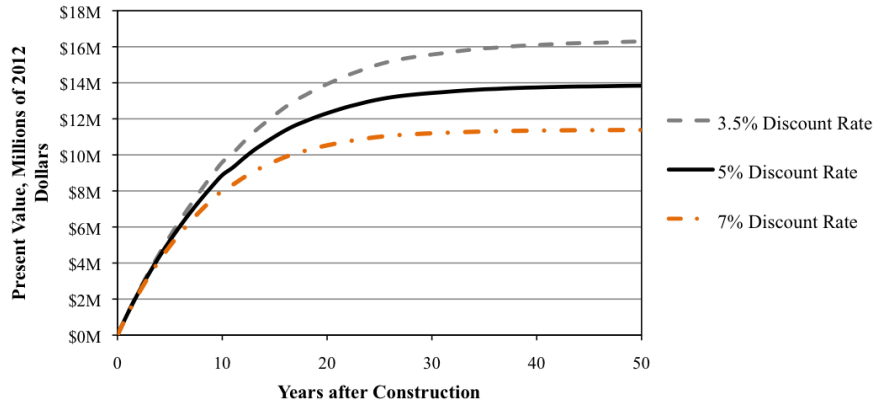

Figure 16. Sparta Economic Valuations

Table 20. Complete Sparta Results

	10 Years Post Construction			20 Years Post Construction			40 Years Post Construction		
Avoided Cases of:	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*
Mortality	0.6	0.6	1.2	1.0	1.0	2.0	1.3	1.1	2.4
CHD	0.1	0.5	0.6	0.1	0.7	0.8	0.2	0.8	1.0
Diabetes	0.4	0.6	1.0	0.7	1.0	1.7	1.0	1.3	2.3
Hypertension	1.0	1.3	2.3	1.7	2.0	3.7	2.3	2.6	4.9
Stroke	0.2	0.4	0.6	0.3	0.5	0.8	0.3	0.6	0.9
Economic Value		***$8,960,000***			***$13,010,000***			***$15,040,000***	
Cost Estimate		***$686,257***			***$686,257***			***$686,257***	
Benefit-Cost Ratio		***13.1***			***19.0***			***22.0***	

Assessment: Limitations

While the quantitative methods applied in this study represent the state of the art in HIA, several limitations should be addressed. First, our model does not explicitly consider obesity due to a lack of relative risk data linking walking for transportation to overweight/obesity. However, this may represent the lack of a direct causal linkage between non-vigorous physical activity and overweight/obesity when controlling for confounding factors such as diet. Further, the uncontrolled RR values selected linking the disease in our model to walking for transportation do not control for obesity, thereby implicitly assuming a similar prevalence of overweight and obesity in the study population used in the epidemiological study and the populations in our three study areas. Regardless, the inability of our model to explicitly consider obesity likely results in more conservative model results. Similarly, data limitations at the county level for cancer prevalence and incidence by age and sex prevent the inclusion of these health outcomes in our model. However, the prevalence of cancer is small; thus, the change in prevalence relative to the baseline would likely be limited in this assessment should we have been able to include cancer outcomes. Finally, Chronic Obstructive Pulmonary Disease (COPD) is not considered due to limited epidemiological evidence linking non-vigorous physical activity to the prevalence or incidence of COPD, although evidence does recommend physical activity as a means to reduce mortality in those already diagnosed with COPD.[37] This likely does not bias our results because changes in mortality in individuals diagnosed with COPD would be included in a population-level all-cause mortality relative risk for physical activity, assuming prevalence of COPD is roughly similar across populations. In sum, diseases not included in this assessment likely result in a small, conservative under-estimate of total health benefits.

A second limitation arises from the nature of the Behavioral Risk Factor Surveillance System (BRFSS) data used to estimate population prevalence and incidence. The BRFSS question listed in Table 7 asks whether respondents have ever been told that they have a given disease; thus, the prevalence of reversible diseases (e.g. hypertension) is likely over-estimated. While the incidence estimation results in its own uncertainty, this is compounded for reversible disease with potentially unreliable prevalence estimates. However, the data used for this HIA are the most accurate publicly available data sources for disease prevalence.

A third significant limitation is the uncertainty associated with transportation behavior estimates. While the estimates are generally feasible and supported by a growing body of literature, the majority of travel behavior studies focus on trip numbers or mode choice – which are important for transportation planners but less so for public health practitioners – rather than trip duration or distance. Therefore, estimates in this report are based on single studies and subject to uncertainties when applied to other geographic areas. Additionally, in the Sparta study area, the built environment variable used is based on subjective criteria (sidewalk and crossing quality) and is not statistically significant in the model used by Boarnet et al. However, we use the lowest model coefficient and assume a modest change in Pedestrian Environment Factor to be conservative. We also assume that only 25% of the Town of Sparta – the area of the town within a 0.25 mile buffer of the proposed street improvements – is affected by this built environment change.

Finally, we consider only walking for transportation and do not consider cycling for transportation or purely recreational physical activity (i.e., from recreationally using a greenway). Behavioral studies linking built environment characteristics to cycling behavior and purely recreational physical activity from transportation are limited. These limitations result in conservative estimates of post-intervention physical activity from transportation, particularly in Winterville and the BRRC where topographical constraints do not present a barrier to cycling. While not considered in this assessment, these domains of physical activity may be included in future iterations of this model as behavioral studies improve.

The complexity of DYNAMO-HIA presents a significant limitation for wider use of the methods performed in the assessment. However, the depth and quantitative nature of the findings warrant a significant effort to adapt DYNAMO-HIA model components into a more user-friendly package. Further, the DYNAMO-HIA model was applied despite significant data limitations; thus, a similar model with a more user-friendly interface would likely be extremely useful to researchers and practitioners alike interested in quantitative HIA methods.

Recommendations

From the findings of this report, we developed three broad sets of recommendations: 1) Project-specific recommendations; 2) Recommendations from WalkBikeNC that are directly supported by this analysis; and 3) Recommendations for practice. These are summarized below:

Project-specific recommendations: Winterville

1. Build out sidewalk network in Winterville as proposed in the Greenville Bicycle and Pedestrian Master Plan
2. Use modeled health impacts to help advocate for funding from potential funding sources, as identified in the Greenville Bicycle and Pedestrian Master Plan
3. Investigate programs to counteract negative perceptions (both stigmas and elitist perception) of active transportation behavior in the community
4. Coordinate with local institutions to include active transportation-related questions in future local surveys

Project-specific recommendations: BRRC

1. Coordinate with NCDOT to ensure that reconstruction of all state owned right-of-way in the project area is accompanied by construction of sidewalks on both sides of the street
2. Ensure that all new roads in the study area are initially built with sidewalks on both sides of the street
3. Coordinate with local partners (state of North Carolina, Art Museum, etc.) to explore creative funding options for sidewalks infrastructure

4. Coordinate with local institutions to include active transportation-related questions in future local surveys

Project-specific recommendations: Sparta

1. Build out the pedestrian improvements as proposed in the Sparta Downtown Streetscape Strategy
2. Leverage the results of this report to advocate for funding from a variety of potential partners
3. Coordinate with local institutions to include active transportation-related questions in future local surveys

Supported WalkBikeNC recommendations:

Mobility

1. Expand community-oriented pedestrian facilities
2. Provide pedestrian and bicycle access to transit

Safety

1. Create a strategic, consistent, and connected pedestrian and bicycle network

Public Health

1. Increase active living environments
2. Increase the safety, connectivity, and accessibility of the bicycle and pedestrian network
3. Improve public health outcomes

Economic Competitiveness

1. Increase attractiveness and quality-of-life through walkable and bikeable communities
2. Measure return on investment of active transportation investments
3. Use return on investment analyses to inform transportation decision-making

Recommendations for research and practice:

1. Develop improved data infrastructure for the following:

   a. Sidewalk and bicycle networks

   b. More refined prevalence data for cancer (by type), CHD, diabetes, hypertension, and stroke.

2. Ensure that future studies of the built environment and travel behavior report active travel in units relevant to epidemiological studies (i.e., minutes of physical activity rather than mode choice, number of trips, or reductions in vehicle miles travelled)
3. Using optional state-specific questions, include active transportation as a regularly asked question in the BRFSS (e.g., 2009 North Carolina BRFSS)
4. Develop local capacity to conduct HIAs by providing training, technical assistance, and other resources.
5. Advance HIA methods to focus on methods that help inform decisions on proposed policies, plans, and development from a quantitative perspective, including the use of monetization of health impacts.
6. Develop a practitioner-focused tool that combines a Marko Chain approach with a more user-friendly interface and linked to publicly available data sources.

Reporting

The findings of this report will be disseminated in three ways: 1) inclusion in WalkBikeNC; 2) presentation of results to local leaders and decision-makers in each HIA community; 3) presentation at appropriate public meetings and venues; and 4) publication in academic literature and presentation at appropriate academic conferences.

This report is included in its entirety as a technical appendix in the North Carolina Statewide Bicycle and Pedestrian Master Plan, known as WalkBikeNC. Further, a brief summary and key HIA findings appear within the main text of the plan.

Post-project meetings will be held in each community to present results and obtain feedback from local leaders and decision-makers in each community.

A brief presentation highlighting the findings of this analysis, as well as broad lessons learned, will be presented as appropriate meetings as part of the post-WalkBikeNC period. Meetings that will be targeted include outreach meetings with WalkBikeNC stakeholders, community transformation grant meetings, and Municipal Planning Organization (MPO) and/or Rural Planning Organization (RPO) meetings in each project region.

The results of this analysis will also be translated into an academic paper to be submitted to an appropriate journal and will be submitted for presentation at academic conferences such as the National Health Impact Assessment (HIA) Meeting. These publications will focus on the technical methods, limitations, and implications for future work – with the aim of developing a user-friendly, practitioner-ready quantitative HIA tool in the future.

Monitoring and Evaluation

Looking to the future, monitoring and evaluation should focus on the build-out of the projects as analyzed in this report as well as changes in active transportation behavior in each community. While health outcomes are measured over time, the predicted magnitude of change and the large number of external factors that may affect health outcomes prevent a significant barrier to using health outcomes for evaluation. Active transportation behavior, however, is a more sensitive intermediary and can be used as a proxy for health outcomes with proven links to physical activity from transportation. Build-out of projects provides a more tangible measure and is a suitable proxy for the efficacy of local institutions in providing funding for active transportation infrastructure in their community. Along with these measures, efforts should be made to capture perceptions of active transportation in each community and document changes over time that may be attributable to infrastructure changes, active transportation programs, and/or demographic or cultural shifts. These data could be collected opportunistically as potential partners administer related surveys in each community over time.

Acknowledgements

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Appendix 1: Health Advisory Team

Participant	Organization
Lauren Blackburn	*NC Department of Transportation*
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Monique Bethell	*NC Department of Health and Human Services*
Chuck Flink	*Alta/Greenways*
Matt Hayes	*Alta/Greenways*
Jackie Epping	*Centers for Disease Control and Prevention*
Candace Rutt	*Centers for Disease Control and Prevention*
Jennifer MacDougall	*Blue Cross Blue Shield of NC Foundation*
Jackie MacDonald-Gibson	*UNC Environmental Sciences and Engineering*
Ted Mansfield	*UNC Environmental Sciences and Engineering*
Tim Schwantes	*UNC Active Living By Design*
Philip Bors	*UNC Active Living By Design*

Appendix2:CommunityMeetingDocumentation

Winterville

Participant	Organization
Jo Morgan	*Pitt County*
James Rhodes	*Pitt County*
Daryl Vreeland	*Greenville MPO*
Jennifer Smith	*Vidant Health*
Alan Lilley	*Town of Winterville*

The meeting began with a broad scoping exercise designed to identify a wide range of factors that may have negative health impacts in the community. Broadly, the participants identified several built environment factors that may negatively affect health outcomes in Winterville, including non-walkable development scales, car-oriented development, segregated land uses, lack of services and employment within Winterville proper, and school siting. Participants also identified demographic and cultural factors, including poverty and a high prevalence of risk factors, as negative influences on the health of their community. Specific to physical infrastructure in Winterville, participants identified the lack of sidewalks, poor sidewalk connectivity between developments that do contain sidewalks, road widening projects undertaken without supplementary improvements such as the addition of sidewalks and bike lanes, and physical barriers presented by NC11 and the railroad tracks that bisect Winterville as having a potentially negative effect on public health. Considering services, participants identified the lack of public transit and poor access to facilities that offer affordable healthcare as potential detriments to public health. The participants also noted that Winterville has successfully employed joint-use agreements in many schools to provide recreational facilities outside of school hours; however, the positive health impacts of these agreements may be limited due to poor school siting and poor bicycle and pedestrian infrastructure around schools. Considering social and/or economic conditions that may impact health, the participants noted concern over the stigmatized perception of walking and biking as a mode of transportation (rather than recreationally) in Winterville. They also stressed the importance of correctly framing the message to encourage active transportation as a normative rather than elitist behavior. Participants also identified concerns over poor awareness of drivers, cyclists, and pedestrian of the "rules of the road" in multi-modal situations. Finally, the participants expressed concerns over the degree to which NC11 degrades the natural environment and, in turn, public health, due to

noise and air pollution. The overall aesthetic quality of many streetscapes, including NC11, was also identified as negatively influencing public health ("there are sidewalks on NC11, but who would want to walk on them?") Overall, three themes emerged in discussing determinants of health in broad terms: 1) Underlying socio-demographic characteristics and cultural norms, 2) Inadequacies in physical infrastructure, and 3) Land use patterns.

Upon concluding the broad scoping exercise, a more focused exercise was conducted to gain further insight relevant to the Bicycle and Pedestrian Master Plan. Focusing specifically on physical inactivity as a determinant of health, the participants identified the lack of physical infrastructure, specifically outside of downtown and outside of newer subdivisions built in the wake of subdivision regulations requiring the construction of sidewalks, as the primary barrier to increasing physical activity. Participants noted that lack of physical activity is a risk factor for a range of health outcomes including overweight/obesity, heart disease, mental health, etc. Susceptible populations were identified primarily based on geography rather than socio-demographic characteristics; that is, the workshop participants felt that neighborhood quality was a more important than individual characteristics in explaining the propensity to use physically active transportation modes. A final point that was made during discussion is that it is important to "make infrastructure a part of your day," reinforcing the need to frame active transportation in a way that helps develop a positive cultural norm for its use, rather than an elite activity for the "lycra crowd." The two-phased scoping exercise conducted in Winterville provided the project team with invaluable information regarding the broad contextual drivers of health outcomes in the community as well as specific concerns relevant to the Pedestrian and Bicycle Master Plan. Further, a brief discussion of framing the message encouraged the use of economic development, quality of life, and social equity as frames to discuss active transportation. However, it was also noted that it is difficult to get chronic disease on the public agenda because of historic emphasis on communicable disease as well as the view that "health is only important until you don't have it" – providing support for frames other than public health to discuss active transportation.

An informal discussion followed on a variety of issues, including other relevant projects that may be included in the analysis and potential sources for more granular health data. The participants encouraged the project team to consider several of the broader infrastructure recommendations included in the Bicycle and Pedestrian Master Plan, including improvements to Old Tar Road and NC11. In response to this request, the project team will likely prepare two implementation scenarios – one including only projects identified as "Priority Projects" in the plan and one including these projects as well as several additional projects high-profile identified in the plan – in addition to the "do-nothing" scenario. Regarding data, participants stressed that Pitt County is a Behavioral Risk Factor Surveillance System (BRFSS) oversampled county, so risk factor data are more robust than in many other geographies.

Sparta

Participant	Organization
Jennifer Greene	*Appalachian Health District*
Kevin Dowell	*Town of Sparta*
Bryan Edwards	*Sparta Town Manager*
Jane Wyatt	*Town of Sparta*
Eric Woolridge	*Destination by Design*
Teresa Buckwalter	*Destination by Design*
Beth Fornadley	*Appalachian Health District*
Rachel Miller	*Appalachian Health District*

The meeting began with a broad scoping exercise designed to identify a wide range of factors that may have negative health impacts in the community. Broadly, the participants identified several built environment factors that may negatively affect health outcomes in Sparta, including: 1) incomplete sidewalk network, 2) heavy traffic along key routes, 3) segregated land uses, and 4) rural school siting. Participants also identified demographic and cultural factors including: 1) poverty, 2) age (older population), 3) high proportion of population lacking health insurance, 4) a cultural bias towards the car due in part due to Sparta's rural setting, 5) poor nutrition/ access to healthy foods, and 6) cultural norms regarding tobacco use. Specific to physical infrastructure in Sparta, participants identified the lack of sidewalks, the width and quality of existing sidewalks (an example of a sidewalk with an electrical pole in the middle was given), the lack of passing zones (to pass cyclists) on rural roads, and the large lane widths on roads throughout Sparta (encouraging high travel speeds) as having a potentially negative effect on public health. However, the participants also identified several new trails that have been completed recently in Sparta and anecdotally characterized the use of these trails as fairly significant. Considering services, participants identified the lack of public transit and the fragmentation of government services downtown (i.e., previously, residents would "park once" in downtown and walk to use government services, but now that services are offered in different buildings, individuals seem more likely to drive to each building) as negatively affecting health. Considering social and/or economic conditions that may impact health, the participants noted that walking is stigmatized in

the community and that several economic conditions, including a large parentage of the population of fixed incomes and a large number of seasonal workers, may have a negative influence on public health. However, the participants did note that Sparta has a strong sense of community and that there are generally a large number of active volunteers in the community, which may improve well-being directly and may be leveraged to counteract the negative walking stigma in the future. Participants also identified concerns over proper education of drivers and cyclists and inconsiderate behaviors of drivers towards pedestrians in general. Finally, the participants noted that, while the natural environment of Sparta is largely pristine, the aesthetics of downtown are not conducive to walking. Further, the extreme elevation changes in the community make cycling very difficult and thus more of a recreational activity. Additionally, participants noted that Sparta does have a great deal of open space, but lacks programmed open space (i.e., sports fields, playground equipment, etc.) which may reduce the effectiveness of open space as a recreational resource. Overall, three central themes emerged in our broad discussions of health determinants in Sparta: 1) the real and perceived safety of pedestrians, including the perception of pedestrians from the drivers' point of view, 2) inadequacies in physical infrastructure, and 3) difficulties associated with high prevalence of poverty and a high number of seasonal workers/population. Similar to the meeting in Winterville, framing the message was stressed at several points during the scoping exercise. Participants in Sparta suggested framing active transportation as an issue of personal choice: expanding infrastructure that is supportive of physically active transportation expands personal choice and gives individuals a new opportunity to choose to be physically active as part of their daily routine.

A more focused scoping exercise was also conducted to gain additional information relevant to the Downtown Sparta Streetscape Strategy. Focusing specifically on physical inactivity as a determinant of health, the participants identified the lack of safe opportunities to cross the street, high traffic speed, and traffic signaling that is unsafe for pedestrians (e.g., right turn green arrows and protected right turn lanes) as primary barriers to increased walking due to negative effects (real and perceived) on pedestrian safety. Participants did not consider bicycling due to natural environment factors (e.g., steep slopes) that present significant barriers to cycling. Participants also identified several sub-populations that may be impacted by targeted improvements, including students who are unable to walk to school due to gaps in the sidewalk network, seasonal workers who do not have a car and must walk to work since there is no public transit, and carless households that also must rely on walking as a primary mode of transportation. The scoping exercises conducted in Sparta provided some insight into cultural, social, and economic drivers of health outcomes in the community in addition to specific health concerns relevant to the Downtown Streetscape Strategy and specific sub-populations that may be more affected than others by the plan.

After completing the discussion on scoping, a brief discussion on data sources and complementary projects in Sparta was conducted. A number of projects were identified, including a greenway plan and a

pedestrian plan that may be used to develop an additional implementation scenario at the discretion of the project team. It was stressed that, while Census data for Sparta are not geographically specific, several additional sources of data are available that may be useful, including physical activity survey data from a recent county recreational plan.

Blue Ridge Road Corridor

A discussion guide was developed to guide focus group participants through a discussion of the breadth of health concerns, real, potential and/or perceived, that are known to people who live, work and visit the BRRC. During 1.5 hours of facilitated discussion, focus group participants were asked to provide thoughts and comments on the following three general topics:

1. What elements of the BRRC neighborhood and environment, as it currently exists, do stakeholders identify as a concern to public health?
2. What health effects, both positive and negative, can be identified in the BRRC that might be affected through planning, design, and change to infrastructure?
3. How can existing plans or conceptual designs for the BRRC address specific health concerns?

Facilitators began each session by briefly introducing the City of Raleigh's Blue Ridge Road District Study and outlined HIA methods and the objectives of the Blue Ridge Road Corridor Health Impact Assessment Project. A discussion then followed based on the outline of the discussion guide with details and examples provided by the facilitator to ensure discussion of all relevant topic areas and contribution by all focus group participants.

Focus group participants were recruited from citizens and officials who had attended the City of Raleigh's February 9, 2012 Blue Ridge Road Corridor design charrette and from contacts provided by the Blue Ridge Road Corridor Health Impact Assessment Project advisory committee. Focus group meeting times and locations were selected to provide opportunities for a broad range of stakeholders to participate. Evening meetings were held to allow residents from neighborhoods both north and south of Wade Avenue to attend and lunch time meetings were scheduled to allow business owners, those employed in the BRRC, and government officials to attend.

The group of 40 participants was primarily composed of people employed within the BRRC (14), residents of neighborhoods adjacent to the BRRC (12) or officials from the City of Raleigh, Wake County or state agencies (11). Two people with business interests along the corridor and one planning student also participated. All focus group participants were familiar with at least some portion of the BRRC from personal and/or professional experiences.

Focus group participants raised over 70 concerns about threats to public health in the BRRC. 17 of these concerns were raised in more than one focus group and 11 concerns were raised the majority of focus group meetings. Only one concern, the lack of adequate sidewalks in the BRRC area, was identified as a public health concern in all five focus groups.

Focus group meetings are summarized below:

Location	Date	Attendees	Notes
Private residence in the Westover community, adjacent to the State Fairgrounds	*February 28th 2012*	*6*	*Stakeholders present were all neighbors of the BRRC (6)*
Urban Design Center, downtown Raleigh	*March 1st 2012*	*9*	*Stakeholders present were state and local officials, also were members of the BRRC HIA Advisory Council (9)*
Wake Internal Medicine Building, 3100 Blue Ridge Road	*March 6th 2012*	*7*	*Stakeholders present were primarily neighbors of the BRRC north of Wade Avenue (6) and one member who was a business owner with property interest along the BRRC (1).*
North Carolina Museum of Art, 2110 Blue Ridge Road	*March 8th 2012*	*12*	*Stakeholders present all employees or volunteers of the NC Museum of Art (12).*
NCSU Vet School	*March 20th 2012*	*6*	*Participants in this focus group were a mix of stakeholder types including local officials (2), employees working within the BRRC (2), a local business owner (1) and a student of urban design (1).*

Eight concerns to public health that were raised by a majority of focus groups and that were described as having relatively high weight as a concern to public health:

- Lack of adequate sidewalks/crosswalks
- Intersections and roads designed primarily for cars
- Lack of public transportation
- Drunk/distracted drivers
- Lack of efficient road system
- Lack of clear trail indicators (signs, maps, etc.)
- Large gaps between pedestrian destinations
- Not all pedestrian facilities open at night

Focus group participants identified 19 health impacts related to development of the BRRC. Five of these health impacts were raised in more than one focus group and two health impacts, stress and safety from injury, were identified as a public health concern in all five focus groups. Safety from injury was the one health impact identified by all focus groups and weighted as relatively important compared to other health impacts.

Focus group participants identified 27 potential changes to the BRRC that could positively impact public health. Twelve of these ideas were raised in more than one focus group and one idea, improving the aesthetics of the BRRC environment was raised at every focus group meeting.

Seven ideas to improve public health that were raised by a majority of focus groups:

1. Make BRRC more aesthetically pleasing
2. Sidewalks/crosswalks on major roads
3. Build more things to walk to (coffee shops, restaurants, etc.)
4. Bike lanes/bike racks
5. Improved connections to and between modes of public transit
6. Educational opportunities
7. Better publicity, signage, maps, etc.

Broadly, the major themes expressed by focus group participants are as follows:

- A lack of sidewalks and crosswalks is a serious threat to public health.
- Design of the BRRC roads at present does not well serve non-vehicular transportation.
- The BRRC is perceived as a dangerous area due to the potential for injury on streets.
- A lack of convenient public transportation is perceived as a deterrent to public health.
- The environment of the BRRC is perceived as stressful.
- Environmental degradation and/or improvements from development activities were perceived as important, but not clearly linked to public health in the BRRC.
- Noise and light pollution were perceived as important, but not strongly linked to public health in the BRRC.
- Limited signage and wayfinding materials limit pedestrian and bicycle travel.
- Lack of bicycle lanes and bicycle parking identified as limits to bicycle transportation to and within the BRRC.
- Large gaps exist between existing destinations along the corridor, limiting pedestrian and bicycle travel.
- Efforts to increase the density of service and recreational destinations along the BRRC perceived as a positive effort to support public health.
- Efforts to improve the aesthetic feel of the BRRC perceived an important role in public health.

Appendix 3: Technical Methods

Population Age Distribution Estimation

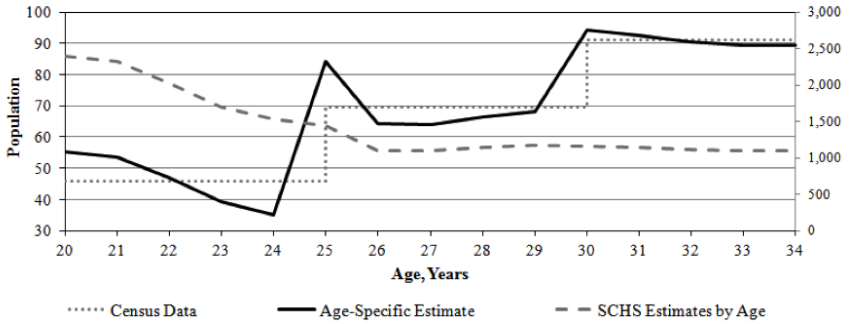
The DYNAMO-HIA requires baseline population estimates for all ages ranging from 0-95; however, census data are given in larger age groups. The NC SCHS provides county-level population estimates by sex and age. We use the distribution of the SCHS population by age to estimate the distribution of population by age within each census age group, holding the total population in each census age group constant. To do this, we do the following for each sex:

1. Calculate the percentage of SCHS population at each age as a percentage of total population in the associated census age group
2. Multiply census data grouped populations by the appropriate SCHS population percentage

An example calculation and graphical representation of the process are presented to the right:

	County-Wide Data						Study Area Data					
	NC SCHS Estiamtes			Percentage, by Census group			Census Data			Age-Specifc Estimates		
	Gender		Total	*Gender*		Total	*Gender*		Total	*Gender*		Total
Age	Female	Male		Female	Male		Female	Male		Female	Male	
↑												
20	2,401	2,020	4,421	24.1%	22.0%	23.1%	230	186	416	**55**	**41**	**96**
21	2,314	2,062	4,376	23.2%	22.5%	22.9%	↓	↓	↓	**53**	**42**	**95**
22	2,029	1,922	3,951	20.4%	21.0%	20.6%				**47**	**39**	**86**
23	1,697	1,693	3,390	17.0%	18.5%	17.7%				**39**	**34**	**74**
24	1,526	1,474	3,000	15.3%	16.1%	15.7%				**35**	**30**	**65**
25	1,439	1,446	2,885	24.2%	22.9%	23.6%	347	230	577	**84**	**53**	**136**
26	1,103	1,398	2,501	18.6%	22.2%	20.4%	↓	↓	↓	**64**	**51**	**118**
27	1,098	1,318	2,416	18.5%	20.9%	19.7%				**64**	**48**	**114**
28	1,135	1,073	2,208	19.1%	17.0%	18.0%				**66**	**39**	**104**
29	1,167	1,071	2,238	19.6%	17.0%	18.3%				**68**	**39**	**105**
30	1,162	1,033	2,195	20.7%	20.8%	20.7%	456	384	840	**94**	**80**	**174**
31	1,141	1,005	2,146	20.3%	20.2%	20.3%	↓	↓	↓	**93**	**78**	**170**
32	1,114	985	2,099	19.8%	19.8%	19.8%				**90**	**76**	**166**
33	1,100	971	2,071	19.6%	19.5%	19.6%				**89**	**75**	**164**
34	1,101	978	2,079	19.6%	19.7%	19.6%				**89**	**76**	**165**
↓												

Example Age-specific Population Estimate: Female Population in Winterville



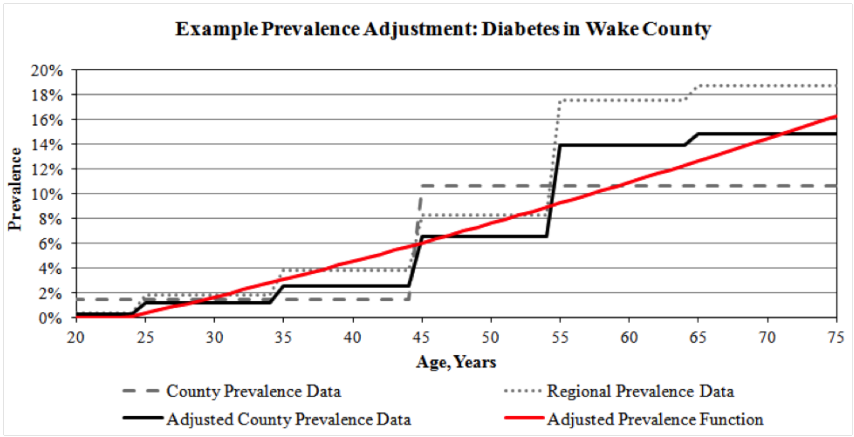
Population Disease Prevalence Estimation

Like population data, the DYNAMO-HIA requires age-specific baseline prevalence estimates for each disease specified. We use 2009 BRFSS data to estimate these values; however, these data are reported in two age groups at the county level and six age groups at the regional level. We follow a conceptually similar process as for population data as described previously. We use the finer-grained regional disease prevalence rates to estimate prevalence rates in the same age ranges at the county level constrained to given disease prevalence in the larger age ranges at the county level. To do this, we do the following for each disease:

1. Calculate the number of individuals in each county-level age group with each disease using 2009 NC SCHS population estimates and county-level prevalence estimates
2. Calculate the number of individuals in each regional age group with each disease using 2009 NC SCHS population estimates and regional prevalence estimates
3. Sum the total number of individuals with the disease from the regional prevalence estimates applied to county population (i.e., sum values from #2 into county-level age groups)
4. Calculate an adjustment factor, equal to the sum from #3 divided by the total from #1
5. Adjust the county-specific prevalence estimates using the six regional age groups by the adjustment factor calculated in #4
6. Use the six age group prevalence estimates to fit a second-order continuous prevalence function, assuming each prevalence value occurs at the population-weighted age midpoint of the six age groups
7. Use the continuous function above to estimate disease prevalence at 1-year intervals (i.e., 0, 1, 2, 3, etc.); subject to the following:
   - Disease prevalence below age 18 is always zero;
   - Disease prevalence is always positive;
   - Disease prevalence always increases with age (if a portion of the prevalence curve had a negative slope, values prior to the low point of the function were replaced with the low point so that the slope was equal to zero); and
   - Prevalence is constant after age 75.

An example calculation and graphical representation are presented below, for Diabetes prevalence in Wake County:

County Prevalence Data				Regional Prevalence Data				Estimated Prevalence Data	
Age Group	Prevalence	County Population	Individuals with Disease	Age Group	Prevalence	County Population	Individuals with Disease	Adjusted Number of individuals	Adjusted Prevalence
18-44	1.5%	386,848	5,803	18-24	0.4%	93,774	375	250	**0.3%**
				25-34	1.8%	140,898	2,536	1,693	**1.2%**
				35-44	3.8%	152,176	5,783	3,860	**2.5%**
						SUM:	***8,694***	**5,803** ✓	
						ADJUSTMENT FACTOR:	***0.667***		
45+	10.7%	286,403	30,645	45-54	8.3%	133,472	11,078	8,745	**6.6%**
				55-64	17.6%	84,177	14,815	11,696	**13.9%**
				65+	18.8%	68,754	12,926	10,204	**14.8%**
						SUM:	***38,819***	**30,645** ✓	
						ADJUSTMENT FACTOR:	***0.789***		



Population Disease Instance Estimation

Using a differential equation-based method developed by Ralph Brinks, age-specific incidence rates are derived for each study area population.[6] While this method is only applicable to chronic disease with no remission, the prevalence data on which incidence data are estimated are generally stated in the form of "Has your doctor every told you have [disease]?" or similar;[5] thus, the data available implicitly ignore the possibility of remission into a healthy state. While this may lead to overestimates of prevalence in the population for disease such as hypertension, it also ensures the validity of the incidence estimation procedure employed. To perform incidence rate estimations, the following steps were conducted for each study area (see Figure A1 for an example of this process):

1. Fit a second-order function, $s(a)$ to given prevalence data
2. Take the derivative of the prevalence function, ds/da
3. Define the function $c=((ds/da))/((1-s))$
4. Estimate age-specific incidence using the following function; only used to predict incidence at ages for which prevalence is known $i(a)=c(a)+m(a)\times(1-(s(a)\times (R(a)-1)+1)^{-1})$
5. Fit a fourth-order function to the estimated incidence data between points. Assume incidence is zero below age 18 and constant above age 75.

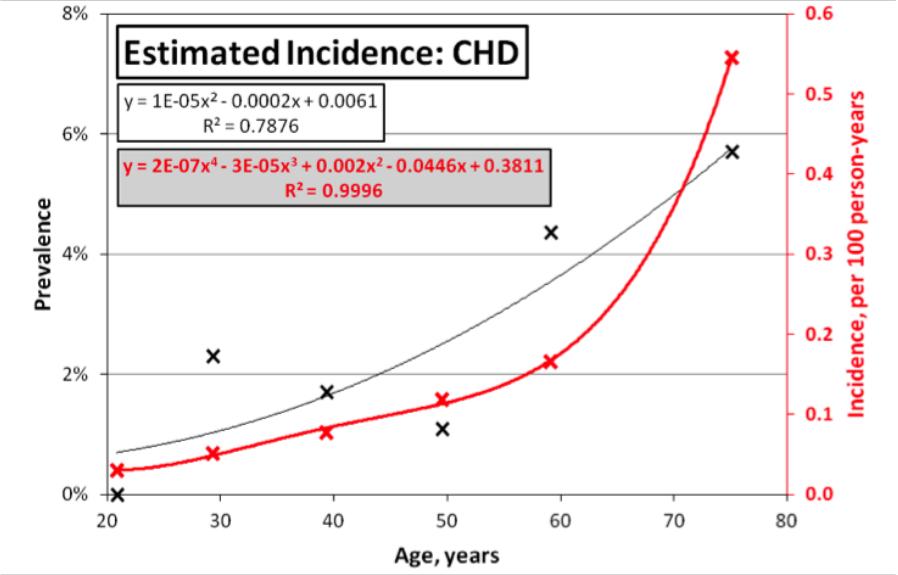


Figure A1. Estimated Incidence of CHD, Winterville Study Area

Transportation Behavior Estimation

We estimate increased physical activity from walking for transportation using behavioral evidence from studies of the built environment and transportation behavior. For the Winterville and BRRC study areas, we are interested in the total length and density of the sidewalk network because the plans we investigate include the construction of new sidewalks. In the Sparta study area, we are interested in the quality of the pedestrian environment because the Downtown Streetscape Strategy includes pedestrian improvements but no new sidewalk construction.

Considering sidewalk length and density, we focus on a dissertation exploring transportation behavior in the Raleigh-Durham-Chapel Hill Metropolitan Statistical Area completed by Yingling Fan, now an assistant professor at the University of Minnesota. The study considers transportation from three different perspectives and develops several predictive models linking built environment variables to transportation behaviors. Specifically, the study estimates that a 1% increase in total sidewalk length is associated with a 0.12% increase in average walking time. The study also estimates that a 1 mile per square mile increase in sidewalk density increases the odds of an individual having reported walking by 1.4%. We consider these two effects to be distinct effects that influence two different populations: average walking time influencing existing walkers and increases in the odds of walking influencing existing non-walkers. We estimate that the average increase in walking time applies evenly to each walking time category; thus, we multiply the average walking time of each walking time category by the predicted change and hold the percentage of the population in each walking time category constant. We then calculate the observed odds of walking, apply the predicted increase in odds, and multiply the total number of walkers by a factor so that the new odds equal the predicted increased odds. We assume that new walkers are distributed proportionally across all walking time categories based on the existing distribution. Conceptually, we increase the mean walking time of each walking time category ("expanding" each walking time category) using changes in total sidewalk length and move a portion of non-walkers into the walking time categories using changes in sidewalk density.

Considering improvements to sidewalk quality, we use the concept of a Pedestrian Environment Factor (PEF) first developed in the LUTRAQ project in Portland, Oregon. The PEF is a 12-point index that assesses the quality of the pedestrian environment based on four variables: 1) sidewalk quality; 2) ease of street crossings; 3) topography; and 4) local street network configuration. Each characteristic is assessed on a 3-point scale (1, 2, or 3) and the values are summed to derive the PEF; thus, the PEF can range from 4-12. As applied in research, PEF scores are divided into thirds; thus, the absolute PEF value in a given geography is less important that the relative value of the PEF compared to other geographies in the study area. For our purposes, we assume that topography and local street network characteristics remain constant pre- and post-project; however, both sidewalk quality and ease of street crossings increase in a subjective rating from 1 to 3. This results in a predicted increase in PEF of 4 points for the areas in the vicinity of the downtown streetscape improvements. We conservatively assume that this is analogous to a move from the lowest PEF third to the middle PEF third. Using a study by Boarnet et al. from 2008, we thus assume that this results in an increase of 0.71 miles per week per person living in the vicinity of the downtown streetscape project. We translate this value into a 13.6 minute increase in minutes

walked per person per week living within 0.25 miles of the streetscape improvements and apply this increased walking time to both existing walkers and to non-walkers. Using GIS, we calculate that 25% of the total land area of the Town of Sparta is within 0.25 miles of the proposed improvements, thus we assume that only 25% of the population in each walking time category increases his or her walking time by this amount per week.

Appendix 4: DYNAMO-HIA Technical Documentation

DYNAMO-HIA Data Requirements

	Data	Source
Population	**Newborns:** *number of projected newborns for the given population*	*Unidentified*
	Overall DALY Weights: *percentage of disability*	*National Surveys*
	Overall Mortality: *observed mortality rate by age and sex*	*NC SCHS*
	Size: *population size by age and sex*	*Census/ACS*
Diseases	**Excess Mortality:** *additional mortality when having the disease*	*Epidemiological studies*
	Incidence: *number of cases per person-years, by age and sex*	*NC SCHS*
	Prevalence: *age and sex specific prevalence of the population*	*NC SCHS*
	Relative Risks from Diseases: *relative risk of contracting the disease when having another disease, by age and sex*	*Epidemiological studies*
	Relative Risks from Risk Factor: *Information on how the underlying risk factor affects the risk of contracting the given disease; differs slightly based on risk factor*	*Epidemiological studies*
	DALY Weights: *percentage of disability caused by disease*	*Unidentified*
Risk Factors	**Prevalance Data for Lack of Physical Activity:** *percentage in each exposure category for each age and gender (e.g., percent of population that is physically inactive*	*BRFSS or local surveys*
	Relative Risk for Death (optional): *relvative risk of the risk factor on total mortality; age and sex specific*	*Epidemiological studies*
	Relative Risk for Disability (optional): *relative risk of the risk factor on total disability; age and sex specific*	*Epidemiological studies*
	Transitions: *age and sex specific probability of switching from one risk factor category to another (key model component for our purposes)*	*Elasticities from literature on behavioral change due to changes in the built environment*

Data Preparation

For inclusion in the DYNAMO-HIA model architecture, data must be converted into .xml files with specific structures, depending on the type of data. This is accomplished using Excel Macros provided to the user during the DYNAMO-HIA model installation. Model files are entered into a folder with the following form: