**HEALTH IMPACT ASSESSMENT**

# Predicting Effects of Urban Design on Public Health:

## A Case Study in Raleigh, North Carolina


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>> The Blue Ridge Road Corridor Health Impact Assessment (HIA) was led by professors Jacqueline MacDonald Gibson, PhD, and Daniel Rodriguez, PhD, from the University of North Carolina, Chapel Hill, in close cooperation with members of the Blue Ridge Road Corridor Work Group and Project Advisory Board. Throughout the course of this HIA, the stakeholder group, advisory board, and neighborhood residents provided valuable technical and logistical assistance, information, and direction to the project team. Input from residents, employees, and visitors was invaluable in helping the project team to understand and focus on the expressed needs of the Blue Ridge Road Corridor community.

The project team would like to extend a special thanks to Dr. Stuart Levin for all of his help and work towards a healthier Blue Ridge Road Corridor. Finally, this work would not have been possible without the generous funding of the BlueCross BlueShield of North Carolina Foundation. Their funding made it possible to research and test new methods for understanding the health impacts of urban planning decisions.

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## Frequently used acronyms

| | |
|---|---|
| BRRC | Blue Ridge Road Corridor |
| CHD | coronary heart disease |
| FAR | floor area ratio |
| HEAT | Health Economic Assessment Tool |
| HIA | health impact assessment |
| WHO | World Health Organization |

## Frequently used terms

» **Active transportation:** Any active method of getting from place to place, like walking, biking, jogging, or skating.

» **Blue Ridge Road Corridor:** Blue Ridge Road is a major north-south arterial road at the western edge of the City of Raleigh. The Blue Ridge Road Corridor refers to the neighborhoods along Blue Ridge Road from Glen Eden Drive to the north, Hillsborough Street to the south, Edwards Mill Road to the west, and I-440 to the east.

» **Small area plan:** A small area plan is a type of plan that addresses a set of issues at a smaller geographic scale within a city. Small area plans are created for areas which share relevant characteristics such as districts, corridors, or neighborhoods.

# Executive Summary

This report presents results of a Health Impact Assessment (HIA) to quantify the health benefits of a small area plan proposed as a result of the Blue Ridge Road District Study[1], which focuses on increasing density, diversifying land use, and enhancing connectivity within the Blue Ridge Road Corridor (BRRC) in Raleigh, N.C. Blue Ridge Road, located at the western edge of the city, is a major north-south thoroughfare. In spite of the substantial number of residents, employees, and visitors who travel within the BRRC, the area lacks pedestrian infrastructure and has few attractions, residential areas, and retailers that are easy to visit on foot. Focus group discussions indicated that BRRC residents wanted the ability to walk more comfortably and safely within the corridor to a greater number of destinations than currently exist.

In 2011, the BRRC Work Group, made up of representative landowners and users of the BRRC neighborhood (including Rex Healthcare, N.C. State University, the N.C. Museum of Art, the N.C. Department of Health and Human Services, the N.C. Department of Transportation, and others), commissioned the creation of a small area plan that advocated for changes in zoning to allow for mixed-use development at higher densities and the addition of bike lanes and sidewalks to all existing streets, as well as the addition of new streets to increase road network connectivity. In order to increase support for the adoption of the plan, the group solicited funding from the BlueCross BlueShield of North Carolina Foundation and technical assistance from a team of professors from the University of North Carolina, Chapel Hill, to conduct an HIA in order to demonstrate the scope of the health benefits expected from the project.

Based on stakeholder input and priorities, this HIA focused on quantifying the benefits expected from increasing the suitability of the BRRC neighborhood for transportation via walking (termed "walkability") throughout the corridor. The HIA focused on the approximately 10,000 current residents of the BRRC (those living within 1.5 miles of the N.C. Museum of Art, at the center of the BRRC neighborhood) and estimated health benefits for the years 2028 (when health benefits are expected to begin accruing if the redesign is completed by 2023) through 2048 (the end of a typical 20-year planning horizon).

[1] City of Raleigh. (2012). Blue Ridge Road District Study. http://www.raleighnc.gov/content/PlanUrbanDesign/Documents/BlueRidge/BlueRidgeRoadDistrictStudyFinalReport.pdf

The project team used data collected from a survey of 386 randomly selected BRRC residents, previous studies quantifying the effect of neighborhood walkability on time spent walking for transportation, baseline health data from the N.C. State Center for Health Statistics, and World Health Organization (WHO) guidelines to construct a computer simulation model that predicts the increase in physical activity and the resulting health benefits that would come from increasing walkability throughout the corridor. The simulation model includes five major health outcomes: premature mortality, type 2 diabetes, coronary heart disease, stroke, and hypertension. In so doing, this HIA joined a small handful of other U.S. HIAs that have made use of quantitative analysis methods.

The results of the analysis indicate that implementing the small area plan will have significant health and economic benefits for BRRC residents. The simulation model predicts that increasing neighborhood walkability in the BRRC will increase the time that residents spend walking for transportation by 17 minutes per day, on average, for the 59% of residents who reported walking for transportation. No effects could be estimated for the 41% of residents who reported no walking, due to lack of available evidence. In turn, the model predicts that this increase in physical activity will decrease rates of premature mortality, diabetes, coronary heart disease (CHD), stroke, and hypertension. Table ES-1 shows the estimated total number of cases prevented over the time period 2028-2048 and the economic value (in today's dollars) of the avoided cases. In total, the economic value of the health benefits from a full build-out of the BRRC small area plan is more than $313 million.

**Table ES-1.** Estimated health benefits of BRRC small-area plan (full build-out)

| | Best estimate and plausible range of cases avoided, 2028-2048 | Fraction of all cases avoided | Total present value* |
|---|---|---|---|
| Deaths (premature) | 80 (30-120) | 7% (3-10%) | $294,000,000 |
| Diabetes (new cases) | 27 (1-79) | 2% (1-6%) | $3,740,000 |
| CHD (new cases) | 8 (2-15) | Females: 2.5% (0.6-4%)<br>Males: 0.5% (0-2%) | $1,110,000 |
| Stroke (new cases) | 17 (1-44) | 2% (0.06-4%) | $4,110,000 |
| Hypertension (new cases) | 91 (4-250) | 2% (0.2-3%) | $11,000,000 |

** Assumes 3.5% annual discount rate*

The estimates shown in Table ES-1 are restricted to current residents of the BRRC who already spend at least some time walking for transportation each week. Several potentially important populations are excluded due to lack of information, and hence these results in all likelihood underestimate the health benefits of the BRRC redesign. First, the estimates do not consider the additional population expected to move to the BRRC should the redesign go forward; the Raleigh Urban Design Center expects that the total population could increase by more than 70% under the redesign by the year 2040, compared with normal growth conditions. Second, the prediction excludes the more than 16,000 workers in the BRRC, many of whom do not live in the neighborhood but are likely to benefit from increased walkability near their workplaces. In addition, it does not account for the millions of annual visitors (a million annual visitors to the state fair and another 1.5 million visitors to PNC Arena) to the neighborhood. Furthermore, the team's conservative modeling approach assumes that time spent walking will increase only among those who are already active, since information was insufficient to predict the extent to which currently sedentary individuals will be induced to take up walking for transportation if the neighborhood is redesigned. Nonetheless, Table ES-1 represents the HIA team's best estimates of health benefits, given currently available information, for the population of current BRRC residents.

Based on the positive health impacts of the BRRC redesign, the HIA team collaborated with the project advisory board (see inside cover of this report) to craft recommendations intended to enhance the implementation of the small area plan and encourage people to walk. While the BRRC small area plan does not explicitly focus on health, the majority of the design changes proposed support the creation of an environment in which walking is safer and easier with a greater variety of places to which people can walk. The recommendations focus on two complementary and mutually reinforcing strategies: (1) increasing the quantity and quality of infrastructure for active transportation within the BRRC and (2) increasing the number of destinations that residents can walk to within the BRRC.

The top recommendations of the project team and advisory board are to:

- Provide more biking and walking infrastructure
- Take steps to make walking and bicycling safer and more pleasant (e.g., through intersection improvements, buffers between the road and bike lanes, traffic calming, signage, and other strategies)
- Increase connectivity of pedestrian and bicycle infrastructure throughout the district and beyond
- Improve transit connections throughout the corridor
- Require new developments to enhance walkability (e.g., through mixed land uses)
- Take active steps to attract development to the corridor
- Encourage BRRC residents to walk through programs such as Safe Routes to School, walking clubs or Meetup groups, media campaigns, and other strategies).

# 1. Background & Screening

## WHAT IS A HEALTH IMPACT ASSESSMENT?

>> A health impact assessment (HIA) is a process used by planners, health professionals, and decision-makers to identify the health impacts of proposed projects on a community. Health in this context is defined more broadly than simply the absence of disease, focusing instead on the broader physical, emotional, and social well-being of individuals. The goal of an HIA is produce recommendations for decision-makers outside of the public health field that allow them to recognize and maximize the positive health impacts of a program or project while mitigating any negative health impacts.

To date, more than 100 HIAs have been completed across the United States, examining the impacts of a diverse array of policies, programs, and projects on a variety of health outcomes. Of the 181 known completed HIAs in the U.S. in 2013, 36 have addressed the health effects of pedestrian and bicyclist transit infrastructure and programs[2] (Appendix A). These HIAs have predicted how increasing pedestrian and bicyclist transit infrastructure would increase or decrease health-related outcomes such as air and water quality, physical activity, noise, social capital, mental health, and social equity, but the magnitude of these effects was rarely estimated.[3] Only one, the Sacramento Safe Routes to School HIA, quantitatively predicted how changes in physical activity might affect body mass index among residents of the study area. The majority of HIAs based their analysis on some combination of literature and existing plan reviews, professional expertise, survey data and community input, while only a few HIAs used mathematical models or GIS mapping to estimate outcomes. Unlike most previous HIAs, this project quantitatively assesses the increase in walking due to changes in the built environment and estimates the resulting health and monetary benefits for this increase in physical activity. It is hoped that the results of this analysis might be more easily incorporated into the cost-benefit analyses that underlie many urban planning decisions and create a blueprint to facilitate the integration of public health considerations into urban planning.[4]

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[2] Health Impact Project. (2013). HIA in the United States. http://www.healthimpactproject.org/hia/us

[3] Dannenberg, A., Rayman, J., Ricklin, A., Kennedy, S., & Ross, C. (2011). Use of Health Impact Assessment to Improve Health Benefits of Transportation Projects and Policies in the United States, 2004-2011. Unpublished manuscript submitted for Transportation Research Board Annual Meeting.

This HIA follows six steps in accordance with recommendations in a recent, landmark report by the U.S. National Research Council on HIA[5]:

1. **Screening**: Determining whether the project or policy would benefit from an HIA and what resources are required.
2. **Scoping**: Narrowing the focus of the HIA to determine which health effects to study, who will be affected, and to identify key stakeholder concerns.
3. **Assessment**: Collecting and analyzing data.
4. **Recommendations**: Determining the strengths and weaknesses of the plan or policy from a health perspective and developing suggestions on how to decrease adverse health effects and improve health benefits.
5. **Reporting**: Writing a technical report to share findings and recommendations and ensuring the delivery of results to stakeholders.
6. **Monitoring and evaluation**: Developing a plan to track the process of the short- and long-term goals identified in the HIA. This is planned for future work and is not included in this report.

## OVERVIEW OF RALEIGH

>> Raleigh is North Carolina's capital and second-largest city, home to 423,179 residents who live in an area of 142.9 square miles. From 1900 to the present, Raleigh has been characterized by growth, adding population at a rate between 2.0 and 4.3 percent per year. In addition, city limits have expanded nearly every census year as a result of annexation. In 2011, the Raleigh-Cary metropolitan statistical area was the fifth fastest growing area in the United States. Raleigh's suburbanization after World War II led to rapid growth at the city's periphery, characterized by low-density, auto-dependent developments. Outside of the older core area, land-use patterns concentrate single- and multifamily housing on "loosely connected and cul-de-sac streets, […] which lack [the] street connectivity that helps facilitate walking, which in turn funnels all car trips to major thoroughfares even for local trips." As Raleigh planners look for ways to reduce traffic congestion and improve air quality and quality of life, understanding the relationship between land use patterns and residents' decisions whether to walk, bike, drive, or take public transportation has become increasingly important.

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[4] Singleton-Baldrey, L. (2012). The Impacts of Health Impact Assessment: A Review of 54 Health Impact Assessments, 2007-2012. University of North Carolina at Chapel Hill.
[5] National Research Council (NRC). (2011). Improving Health in the United States: The Role of Health Impact Assessment. Washington, D.C.: National Academies Press.
[6] U.S. Census Bureau (2013). North Carolina Quick Facts. http://quickfacts.census.gov/qfd/states/37/3755000.html
[7] City of Raleigh. (2009). 2030 Comprehensive Plan. Adopted October 7, 2009. p. 12 & 14.
[8] City of Raleigh. (2012). Raleigh Demographics. Accessed December 19, 2012 from http://www.raleighnc.gov/home/content/PlanLongRange/Articles/RaleighDemographics.html.
[9] City of Raleigh. (2009). 2030 Comprehensive Plan. Adopted October 7, 2009. p. 12.
[10] Ibid.

# OVERVIEW OF THE STUDY AREA

>> The Blue Ridge Road Corridor (BRRC), where this HIA was conducted, is located at the western edge of Raleigh (Figure 1). Blue Ridge Road is a major north-south thoroughfare that is used by area residents, employees, and visitors to access a number of area attractions, including the N.C. Museum of Art, Rex Healthcare Center, PNC Arena, the N.C. Fairgrounds, and the N.C. State University College of Veterinary Medicine Campus (Figure 2). At the outset of this HIA, 10,443 people were estimated to reside in the BRRC, representing 2.7% of Raleigh's total population. In spite of the substantial number of residents, employees, and visitors who travel within the BRRC, as well as the very large number of visitors to the BRRC each year, the area lacks pedestrian infrastructure (Figures 3 and 4), and, apart from the main attractions, has few residential areas and retailers. The limited local road network channels much of the traffic onto Blue Ridge Road.


**Figure 1.** Location of BRRC study area (orange circle) within Raleigh. The N.C. Museum of Art is represented by a star.

[11] U.S. Census Bureau (2010). American Community Survey 2006-2010(5-Year Estimates). T1. Total Population (Tract 515.02, Block Groups 1 & 2; Tract 524.01, Block Groups 1 & 2; Tract 525.03, Block Group 3; Tract 525.04, Block Groups 1 & 2; Wake County, North Carolina). Retrieved July 19, 2013 from http://www.socialexplorer.com.
[12] City of Raleigh. (2012). Blue Ridge Road District Study. http://www.raleighnc.gov/home/content/PlanUrbanDesign/Articles/BlueRidgeRoadDistrictStudy.html.

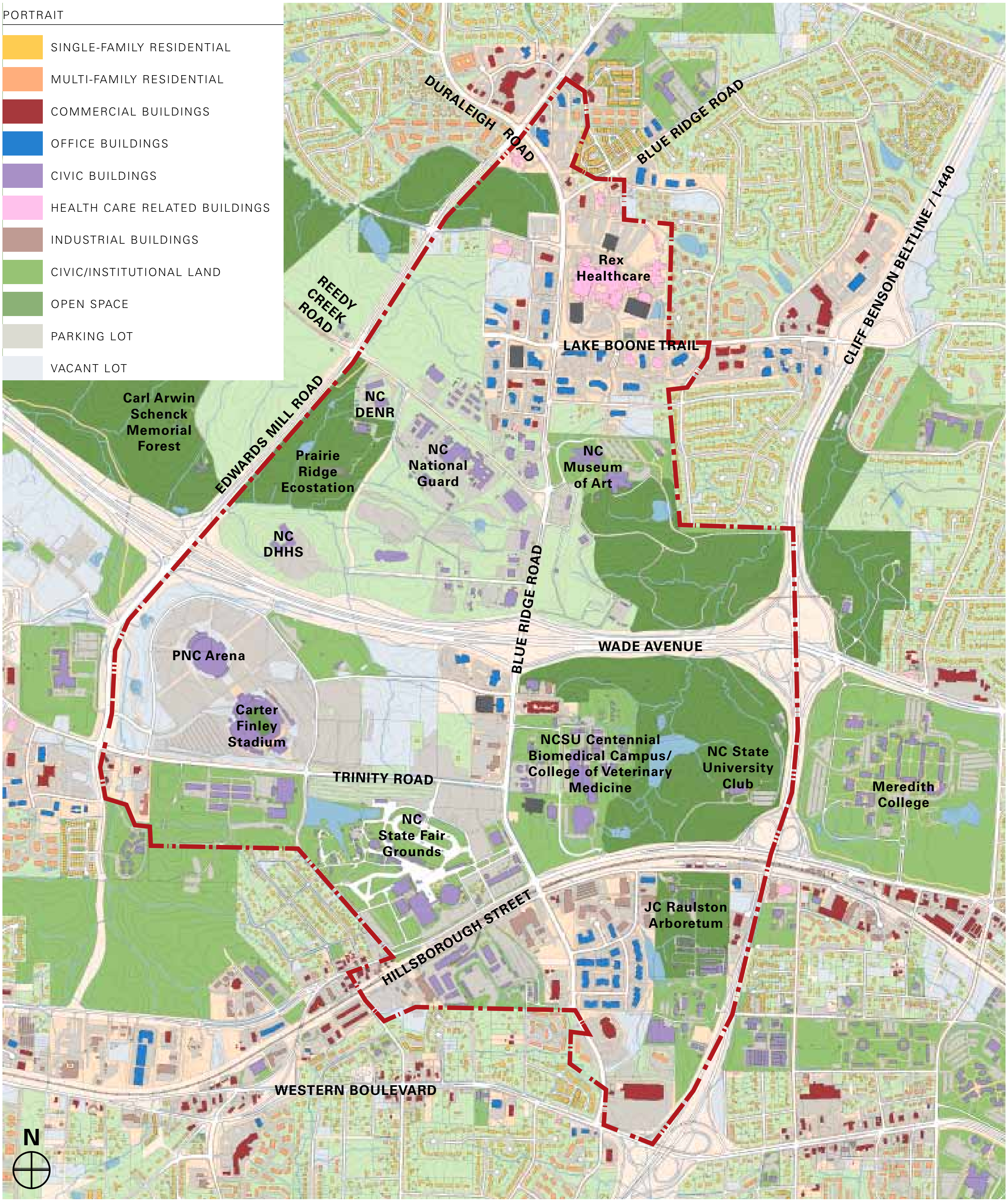


**Figure 2.** Location of streets and amenities within the Blue Ridge Road Corridor. The red dashed line shows the boundaries of the small area plan developed by the City of Raleigh Urban Design Center.[14]

[13] Ibid.

[14] City of Raleigh. (2012). Blue Ridge Road District Study. http://www.raleighnc.gov/content/PlanUrbanDesign/Documents/BlueRidge/BlueRidgeRoadDistrictStudyFinalReport.pdf

**Figures 3 (above) and 4 (right).** Current conditions in the BRRC are such that pedestrian and bicycle activity are discouraged. Pedestrian infrastructure such as sidewalks and crosswalks is lacking, as are retailers and/or residential areas that can be easily reached on foot, by bicycle, or by public transportation.

## ORIGINS OF THE PROJECT

>> The Interest in improving the overall transportation environment for motorists, pedestrians, bicyclists, and public transportation users led to the creation of the BRRC Work Group in 2008. Led by local physician Dr. Stuart Levin, the BRRC Work Group initially comprised members of the executive teams from Rex Healthcare and the N.C. Museum of Art. Over several years, the group grew to include representatives of other area stakeholder groups including N.C. State University, the N.C. State Fairgrounds, and the Centennial Authority in addition to state agencies with facilities in the corridor


**Figure 5.** **An excerpt from the BRRC small area plan, showing the current road network (left) and the proposed network of secondary streets (right, in orange) to increase connectivity between destinations within the corridor. All new and repaved streets would include sidewalks and bicycle facilities.**[16]

(including the N.C. Department of Transportation and Administration). The group met in 2011 under the auspices of the City of Raleigh Urban Design Center (in the Department of Planning and Economic Development) to develop strategies to promote wellness in the corridor, which led to two complementary efforts. The first was the creation of a new district plan (Figures 5, 6, and 7) for the BRRC to address a set of issues at a smaller geographic scale within the city. The contextual nature of district plans means that they can address the issues of an area through the proposal of tailored, specific solutions.[15] In the case of the BRRC, the new district plan was commissioned by the Raleigh Urban Design Center in 2011 and completed in 2012 after a series of public meetings encompassing the input of hundreds of stakeholders (including residents of areas adjacent to the corridor).

[15] http://www.denvergov.org/planning/HowWePlan/SmallAreaPlans/tabid/431849/Default.aspx
[16] City of Raleigh. (2012). Blue Ridge Road District Study. http://www.raleighnc.gov/content/PlanUrbanDesign/Documents/BlueRidge/BlueRidgeRoadDistrictStudyFinalReport.pdf

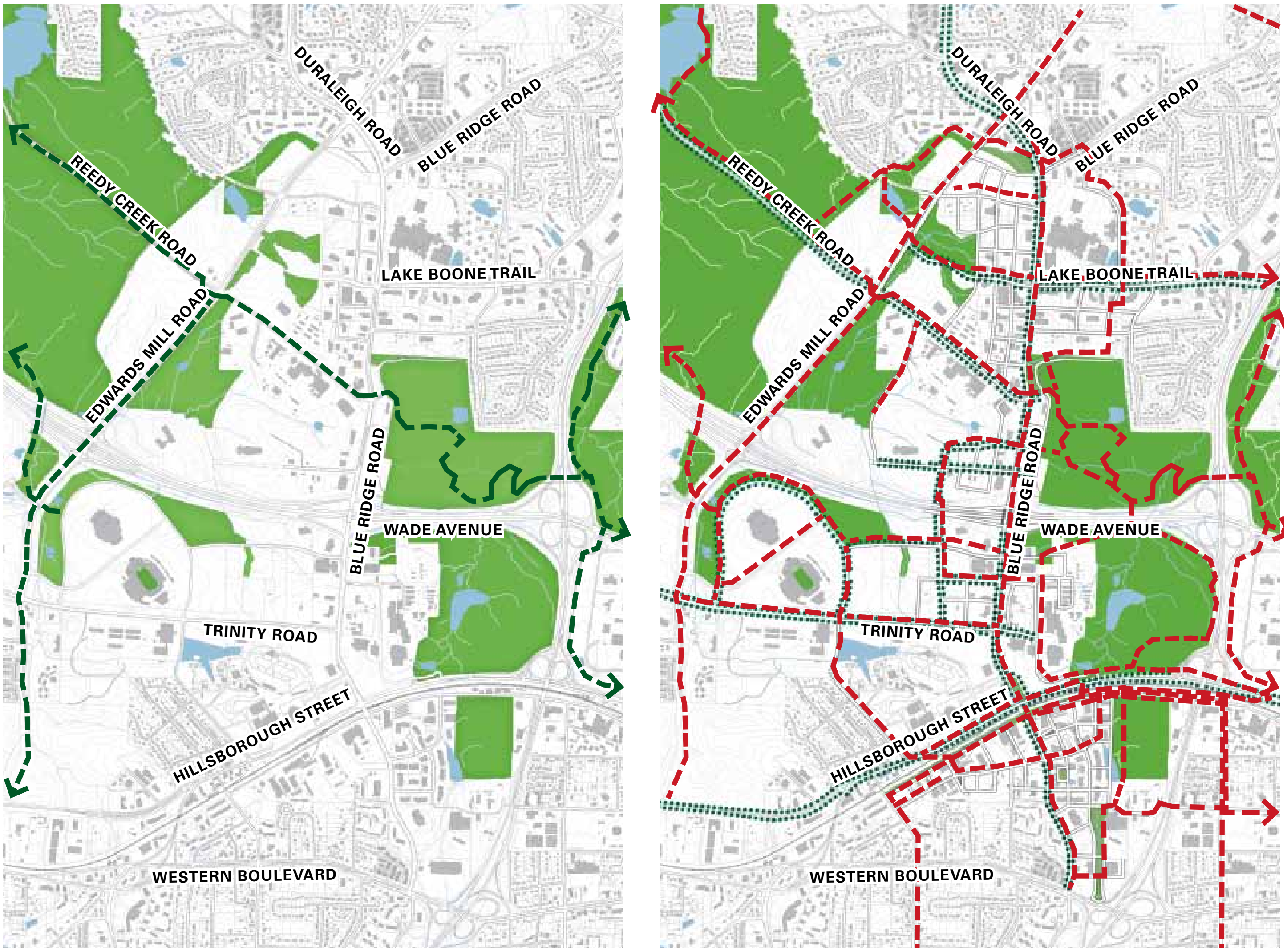


**Figure 6.** An excerpt from the BRRC small area plan, showing the current network of parks and greenways (left) and proposed new pedestrian connections (dashed red) to better link parks and greenways (right).[17]

Four main goals emerged from the planning process:

1. Improve circulation through adding new local connections, including streets, sidewalks, bike facilities, and greenway connections.
2. Create a sense of place through the identification of four smaller districts: Health and Wellness, Arts and Research, Entertainment and Education, and South of Hillsborough.
3. Use strategic building placement to create new destinations accessible by all modes of transportation (on foot, bike, or by public transportation, or car). Change zoning to allow for higher density, mixed-use development at points throughout the corridor.
4. Reinforce activity at destinations by providing more infrastructure for pedestrians, bicyclists, and transit.

[16] City of Raleigh. (2012). Blue Ridge Road District Study. http://www.raleighnc.gov/content/PlanUrbanDesign/Documents/BlueRidge/BlueRidgeRoadDistrictStudyFinalReport.pdf

**Figure 7.** **Artist's rendering of one of the redesigned locations in the BRRC, featuring pedestrian-friendly, transit-oriented development anchored by a light-rail station.[17]**

At the same time that the district plan was being created, the BRRC Work Group looked for strategies that would provide support for the new plan. Although the BRRC Work Group and Raleigh Urban Design Center felt that the new plan offered measurable benefits in terms of transportation, health, and quality of life, the district plan would be competing for funding and prioritization against other plans and proposals in the Raleigh area. Additionally, the scope of the proposal required the coordination of different public and private agencies including state and municipal planning and transportation departments, area institutions and organizations, and local landowners and residents, whose cooperation would be needed to move the project towards implementation.

In order to increase support for the adoption of the plan, the BRRC Work Group decided to conduct an HIA in order to demonstrate the scope of the health benefits expected from the project. It was decided that the proposed HIA would predict the ways in which health would change for BRRC residents if the small area plan were to be adopted. In 2011, the BRRC Work Group partnered with professors from the University of North Carolina, Chapel Hill, to develop a proposal for funding for the project. That same year Jacqueline MacDonald Gibson of the UNC School of Public Health and Daniel Rodriguez of the UNC Department of City and Regional Planning and the UNC School of Public Health received grant funding from the BlueCross BlueShield of North Carolina Foundation to conduct a two-year, comprehensive HIA of the small area plan. Simultaneously, an advisory board consisting of representatives from local institutions and interest groups was convened to provide technical assistance, guidance, and oversight to the project team. The advisory board included representatives from key BRRC institutions such as the N.C. Museum of Art and Rex Healthcare, as well as state and local agencies such as the N.C. Department of Transportation, the City of Raleigh Urban Design Center, and the N.C. Department of Health and Human Services. A list of all advisory board members can be found at the beginning of this report.

In early 2012, the project team began work on the HIA. The project team was responsible for conducting the bulk of the HIA, including collecting all data, performing data analysis, interpreting results, and communicating findings. The team consisted of Gibson, an assistant professor in the Department of Environmental Sciences and Engineering in the Gillings School of Global Public Health at UNC, Rodriguez, a professor in the Department of City and Regional Planning in the College of Arts and Sciences and adjunct associate professor in the Department of Epidemiology in the Gillings School of Global Public Health at UNC, and Steve Bevington, the built environment coordinator at the N.C. Division of Public Health. Three students, Taylor Dennerlein, Jill Mead, and Evan Comen, assisted with data collection and analysis.

## PROJECT TIMELINE

- **2008:** Formation of the Blue Ridge Road Corridor (BRRC) Work Group
- **2011:** Commission of new small area plan by City of Raleigh Urban Design Center
- **2011:** Development of HIA proposal
- **2011:** Project team awarded grant funding for HIA
- **2012:** Beginning of work on HIA
- **FEB. 2012:** City of Raleigh's BRRC design charrette
- **FEB. 2012:** Focus group with BRRC stakeholders
- **MARCH 2012:** Four focus groups with BRRC stakeholders
- **JULY 2012:** Survey of area residents
- **AUG. 2012:** Publication of small area plan

## SIGNIFICANCE OF THE BRRC HIA

>> The project team conducted the HIA with three main goals in mind. The first was to understand and publicize the health impacts associated with the adoption and funding of the district plan. The second was to strengthen relationships and increase collaborations between public-health and nonpublic-health professionals beyond the scope of the HIA. This would lead to the third goal: to increase the consideration of health concerns in decisions being made in nonpublic-health fields such as city planning. At the time of the HIA proposal, the practice of conducting HIAs was uncommon in the state of North Carolina. To date, seven HIAs have been completed in North Carolina, while six (including this one) were under way as of August 2013.[18]

The HIA method proposed by the project team makes use of techniques to better quantify the health impacts of proposed projects. Most completed HIAs in the United States have predicted the direction (positive or negative) of health impacts but do not provide more detailed evidence about the magnitude of the impact.[19] Therefore, this HIA represents the one of the first efforts in the United States and the first in North Carolina to quantify, or produce numerical estimates of, the number of adverse health effects avoided by increasing physical activity. This HIA is also the first in the United States to use the World Health Organization's Health Economic Assessment Tool (HEAT) model as a framework for the analysis. Because the use of HIAs is still relatively new in the United States, it is hoped that this HIA will add to the toolkit of methods available to planning and public health practitioners designing and conducting their own HIAs. By demonstrating and providing a method for generating quantitative estimates of health impacts, HIA results can be incorporated more easily into the cost-benefit analyses typically employed by urban planners to rank and choose between different urban improvement and infrastructure projects.

[18] K. Hebert, personal communication, August 2013.
[19] Bhatia, R., & Seto, E. (2011). Quantitative estimation in health impact assessment: Opportunities and challenges. Environmental Impact Assessment Review, 31(3), 301-309.

# 2. Scoping

## GEOGRAPHY AND POPULATION

>> The geographical scope of an HIA is often determined by the reach of the proposed project or policy. In the case of the BRRC HIA, the project team focused on two main groups: (1) residents living within 1.5 miles of the N.C. Museum of Art who would be the most affected by BRRC redesign and (2) visitors to the trail network adjacent to the N.C. Museum of Art. While the project team collected information from both groups, only the residents' data were used at the basis of the health effects model.

Table 1 compares the demographics of the BRRC study area to those of the City of Raleigh. Compared to Raleigh, the BRRC has a lower under-18 population, a higher population of 18-24 year olds (reflecting the presence of Meredith College), and a higher percentage of residents over age 55. The BRRC has a higher proportion of white residents than Raleigh, as well as higher overall educational attainment. Average household income is higher than in Raleigh but consistent with the Wake County average, although lower median household income suggests that a higher proportion of BRRC residents earn lower wages than their counterparts in the rest of the city.

## HEALTH CONCERNS

>> In order to understand the health concerns of BRRC residents, employees, and visitors, the project team conducted five focus group discussions in February and March of 2012. Participants were recruited from citizens and officials who had attended the City of Raleigh's Blue Ridge Road Corridor design charrette in February 2012 and from contacts provided by the advisory committee. The discussions were hosted in convenient locations within the BRRC at both lunch and evening times so that all interested stakeholders could participate. Table 2 gives an overview of focus group discussion dates and participants.

**Table 1.** Blue Ridge Road Corridor neighborhood, City of Raleigh, Wake County, and North Carolina demographics (U.S. Census Bureau 2010a)

| Demographics | BRRC study area | City of Raleigh | Wake County | North Carolina |
|---|---|---|---|---|
| Total population[20] | 10,443 | 381,767 | 850,546 | 9,271,178 |
| **Gender** | | | | |
| Female | 51.8% | 51.6% | 51.2% | 51.3% |
| Male | 48.2% | 48.4% | 48.8% | 48.8% |
| **Income[21]** | | | | |
| Median household income (2010 $) | $48,913 | $52,116 | $63,770 | $45,570 |
| Average household income (2010 $) | $81,932 | $72,686 | $83,782 | $61,780 |
| **Age** | | | | |
| Under 18 years | 20.0% | 23.2% | 26.1% | 24.2% |
| 18 to 24 years | 19.3% | 13.9% | 9.6% | 9.8% |
| 25 to 34 years | 17.2% | 18.6% | 15.6% | 13.1% |
| 35 to 44 years | 12.9% | 15.5% | 16.7% | 14.4% |
| 45 to 54 years | 10.9% | 12.4% | 14.4% | 14.3% |
| 55 to 64 years | 10.0% | 8.5% | 9.4% | 11.5% |
| 65 to 74 years | 5.5% | 4.3% | 4.6% | 7.0% |
| 75 to 84 years | 3.0% | 2.6% | 2.6% | 4.1% |
| 85 years and over | 1.2% | 1.0% | 0.9% | 1.5% |
| **Race/ethnicity** | | | | |
| White | 66.4% | 58.9% | 67.9% | 69.6% |
| Black or African American | 18.6% | 29.6% | 20.5% | 21.4% |
| Hispanic (of any race) | 11.0% | 10.7% | 9.1% | 7.8% |
| American Indian and Alaska Native | 0.5% | 0.3% | 0.3% | 1.1% |
| Asian | 5.2% | 4.4% | 5.1% | 2.1% |
| Native Hawaiian | 0.0% | 0.0% | 0.0% | 0.1% |
| Other | 8.0% | 5.3% | 4.4% | 3.8% |
| Two or more | 1.2% | 1.5% | 1.8% | 1.9% |
| **Educational attainment[22]** | | | | |
| Less than high school | 6.8% | 9.6% | 8.4% | 16.4% |
| High school graduate | 10.9% | 17.3% | 17.6% | 28.2% |
| Some college | 28.2% | 26.5% | 26.6% | 29.2% |
| Bachelor's degree | 30.6% | 30.9% | 31.4% | 17.4% |
| Master's degree | 15.8% | 11.0% | 11.5% | 6.1% |
| Professional school degree | 3.7% | 2.7% | 2.4% | 1.5% |
| Doctorate degree | 4.1% | 2.1% | 2.1% | 1.1% |

[20] U.S. Census Bureau (2010). American Community Survey 2006-2010(5-Year Estimates). T1. Total Population (Tract 515.02, Block Groups 1 & 2; Tract 524.01, Block Groups 1 & 2; Tract 525.03, Block Group 3; Tract 525.04, Block Groups 1 & 2; Wake County, North Carolina). Retrieved July 19, 2013 from http://www.socialexplorer.com.

[21] U.S. Census Bureau (2010). American Community Survey 2006-2010 (5-Year Estimates). T57. Median Household Income (in 2012 Dollars) and T59. Average Household Income (in 2012 Dollars). (Tract 515.02, Block Groups 1 & 2; Tract 524.01, Block Groups 1 & 2; Tract 525.03, Block Group 3; Tract 525.04, Block Groups 1 & 2; Wake County, North Carolina). Retrieved July 22, 2013 from http://www.socialexplorer.com.

[22] U.S. Census Bureau (2010). American Community Survey 2006-2010(5-Year Estimates). T25. Educational Attainment For Population 25 Years and Over (Tract 515.02, Block Groups 1 & 2; Tract 524.01, Block Groups 1 & 2; Tract 525.03, Block Group 3; Tract 525.04, Block Groups 1 & 2; Wake County, North Carolina). Retrieved July 22, 2013 from http://www.socialexplorer.com.

**Table 2.** Focus group dates and attendees

| Date | No. attending | Stakeholder affiliations |
|---|---|---|
| 2/28/2012 | 6 | BRRC residents |
| 3/1/2012 | 9 | BRRC HIA advisory board |
| 3/6/2012 | 7 | BRRC residents and property owners |
| 3/8/2012 | 12 | Employees and volunteers of N.C. Museum of Art |
| 3/20/2012 | 6 | Local officials, employees, business owners, students |

**Table 3.** Top 12 recommended BRRC changes from focus group participants

| Top desired changes |
|---|
| Make it more aesthetically pleasing |
| Install sidewalks/crosswalks along and on major roads |
| Build more things to walk to |
| Provide bicycle lanes and racks |
| Create better connections with public transit |
| Create more educational opportunities |
| Provide better publicity, signage, maps, etc. |
| Build more walking trails |
| Improve access to walking trails/open space |
| Incentivize mixed-use development |
| Provide more water fountains and restrooms for walkers/runners |
| Incentivize increased density |

Project team members led 1.5-hour discussions guided by three main research questions:

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

The facilitators noted each response for each of the three main themes of the focus group discussions. Of the 12 changes mentioned in multiple focus groups, the majority were directly related to the ability to walk comfortably and safely within the corridor (Table 3).

Based on the concerns of stakeholders, the HIA advisory board and project team determined that the HIA would focus on walkability. Walkability is a term originally used by transportation professionals to describe the degree to which an environment supports walking for transportation reasons (for example, to a supermarket, work, school, or a park).[23] While the precise definition of walkability varies among sources, the most robust measurements use residential density, mixed land use (for example, residential neighborhoods that are close to or mixed with commercial uses like stores and restaurants), and connectivity (such as the presence of sidewalks and/or density of intersections).[24]

In the past 20 years, public health professionals have become increasingly interested in walkability as they study the environmental factors that influence whether individuals exercise sufficiently to achieve good health.[25] The Centers for Disease Control (CDC) recommends that adults ages 18-64 get at least 150 minutes a week of moderate-intensity physical activity (such as brisk walking) or 75 minutes a week of vigorous-intensity physical activity (such as jogging or running).[26] However, fewer than half (48%) of Americans meet these recommendations.[27] Adults in the South are the least likely to report physical activity compared to other regions in the United States.[28] In North Carolina, 46.8% of adults meet physical activity recommendations.[29]

Whether adults get sufficient physical activity is important because evidence shows that regular physical activity is effective at reducing the risk of obesity and several chronic diseases such as cardiovascular disease (CVD), diabetes, some types of cancer, hypertension, depression, and osteoporosis.[30] Studies have shown that increases in physical activity can reduce the risk of coronary heart disease by 35% and reduce the risk premature death by 55%.[31, 32] The social and economic costs of preventable chronic diseases and premature death have an enormous impact on individuals, families, and communities. Public health professionals promote walking as a low-impact, inexpensive, and nearly universally accessible method of reducing the risk of chronic disease. The CDC reports that people who walk are nearly three times as likely to meet overall physical activity recommendations as those who do not.[33]

However, the role the environment plays in facilitating or hindering walking is an important determinant of how much people walk. Multiple studies have shown that people who live in neighborhoods with higher walkability exercise more than those

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[23] Gauvin, L., Richard, L., Craig, C. L., Spivock, M., Riva, M., Forster, M., ... & Potvin, L. (2005). From walkability to active living potential: an "ecometric" validation study. American Journal of Preventive Medicine, 28(2), 126-133.
[24] Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. American Journal of Preventive Medicine, 28(2), 117-125.
[25] Gauvin, L., Richard, L., Craig, C. L., Spivock, M., Riva, M., Forster, M., ... & Potvin, L. (2005). From walkability to active living potential: an "ecometric" validation study. American Journal of Preventive Medicine, 28(2), 126-133.
[26] Centers for Disease Control and Prevention. (2013). How much physical activity do adults need? http://www.cdc.gov/physicalactivity/everyone/guidelines/adults.html
[27] Centers for Disease Control and Prevention. (2013).Facts about physical activity. http://www.cdc.gov/physicalactivity/data/facts.html
[28] Ibid.
[29] Eat Smart, Move More North Carolina. (2013). Physical Activity, Nutrition, and Obesity in North Carolina. http://www.eatsmartmovemorenc.com/Data/Texts/Quick%20Facts.pdf
[30] Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: the evidence. Canadian Medical Association Journal, 174(6), 801-809.
[31] Macera, C. A., & Powell, K. E. (2001). Population attributable risk: implications of physical activity dose. Medicine and science in sports and exercise, 33(6; SUPP), S635-S639.
[32] Myers, J., Kaykha, A., George, S., Abella, J., Zaheer, N., Lear, S., ... & Froelicher, V. (2004). Fitness versus physical activity patterns in predicting mortality in men. The American journal of medicine, 117(12), 912-918.
[33] Centers for Disease Control and Prevention. (2012). Vital Signs: Walking Among Adults—United States, 2005 and 2010. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6131a4.htm

who live in neighborhoods with lower walkability,[34, 35] and this effect has been observed in both high- and low-income neighborhoods.[36] Other key characteristics of the built environment associated with active transportation (walking and biking) include location relative to other community destinations, aesthetic qualities, and proximity to parks. The presence of sidewalks, well-lit streets, and separation from traffic are also associated with greater amounts of physical activity.[37] This indicates that living in an environment where walking is easy, enjoyable, feels safe, and allows people to get from their homes to places they want to go leads to a greater amount of walking than an environment where walking is difficult, feels unsafe, or there is nowhere to walk to.

Focus group discussions with BRRC stakeholders revealed that BRRC residents and employees want an environment where it is possible to walk from place to place safely and pleasantly and where there are a greater diversity of destinations than currently exist. Based on focus group feedback, BRRC stakeholders believe that changes in area infrastructure can have a positive impact on stress, injury prevention, mental health, cancer, asthma, hypertension, cholesterol, diabetes, arthritis, safety, and ability to participate in physical activity. Their opinions are backed by research that associates greater walkability with greater levels of physical activity, which in turn is related to fewer chronic diseases and lower incidence of premature death. The analysis that follows in this HIA attempts to estimate, based on current and predicted levels of walkability and physical activity, the number of cases of chronic disease and premature death among BRRC residents that could be prevented by neighborhood-level increases in walkability in the BRRC.

[34] Adams, M. A., Sallis, J. F., Kerr, J., Conway, T. L., Saelens, B. E., Frank, L. D., ... & Cain, K. L. (2011). Neighborhood environment profiles related to physical activity and weight status: A latent profile analysis. Preventive medicine, 52(5), 326-331.
[35] Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. American journal of preventive medicine, 28(2), 117-125.
[36] Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., ... & Kerr, J. (2009). Neighborhood built environment and income: examining multiple health outcomes. Social science & medicine, 68(7), 1285-1293.
[37] Ibid.

# 3. Assessment

In order to understand how the redesign of the BRRC would impact walkability, physical activity, and long-term health, the project team followed four main steps:

1. **Understanding current physical activity levels.** Collecting data about current physical activity levels from residents, including walking for recreation, walking for transportation, and bicycle use.
2. **Quantifying walkability.** Choosing a method to compare the walkability of the current BRRC built environment to the built environment proposed in the small area plan.
3. **Estimating changes in walking from increased walkability.** Deriving an estimation of the effect of the changes in the built environment on the time spent walking for transportation each day.
4. **Predicting the health effects of increased walking.** Modeling the long-term health effects of increased walking for residents of the BRRC neighborhood.

These four components were incorporated into a simulation model in order to estimate the impact of the new BRRC design on health. Each of the four steps is detailed below.

## UNDERSTANDING CURRENT PHYSICAL ACTIVITY LEVELS

>> Although the CDC collects data about physical activity levels on a continuous basis, only state-level data are available for North Carolina.[38] Therefore, in order to understand walking and physical activity behaviors at the level of the BRRC project area, it was necessary to collect data directly from BRRC residents.

Data were collected from BRRC residents in July 2012 through the administration of a survey mailed to households randomly selected from the 3,525 households living within 1.5 miles of the N.C. Museum of Art. To ensure an adequate number of responses, surveys were mailed to 1,650 randomly selected households. The neigh-

[38] North Carolina Center for Health Statistics. (2013). Behavioral Risk Factor Surveillance System. http://www.schs.state.nc.us/units/stat/brfss/

borhood survey was comprised of 27 questions about general health, physical activity and travel behavior, neighborhood environment, N.C. Museum of Art trail usage, and general demographics. The questions were adapted from multiple sources: the International Physical Activity Questionnaire,[39] the Neighborhood Environmental Walkability Score,[40] the Behavioral Risk Factor Surveillance System,[41] and the Census.[42] Residents had the option to mail the completed survey in a prepaid envelope or to complete an identical online survey prepared with Qualtrics software. A copy of this survey can be found in Appendix B.

## MEASURING WALKABILITY

>> The second component necessary to predict changes in walking was a method to compare the walkability of the current BRRC built environment with the built environment proposed in the small area plan. The project team conducted a comprehensive review of all peer-reviewed literature on the relationship between the built environment and physical activity. The project team retrieved all articles from the PubMed and Web of Science databases that combined the keywords "sidewalks," "trails," and/or "walkability" with "walking" and/or "physical activity." Inclusion criteria for this review included a general adult population in a North American setting, objective measures of the built environment (rather than self report), a publication date within the past 10 years, and one of two chosen outcome measures: either the amount of time spent on physical activity or the odds of walking greater than 150 minutes per week. This gave the project team a small set of articles that most closely approximated their research question. In total, 12 studies met the inclusion criteria. These 12 articles are summarized in Appendix C.

Of the 12 studies relevant to HIA conditions, six translated urban form characteristics into a walkability score or index—in essence a summary measure of a neighborhood's friendliness to walking.[43] The project team decided that a walkability score (rather than, for example, the total length of sidewalks in an area) would be the most appropriate measure of walkability for the purposes of the HIA because such scores represent a composite measurement of built environment characteristics useful for understanding the impact of a number of features, such as the presence of inter-

[39] IPAQ Group. (2002). Questionnaires. International Physical Activity Questionnaire. https://sites.google.com/site/theipaq/questionnaires

[40] Sallis, J. F. (2007). Neighborhood Environment Walkability Scale (NEWS) - Abbreviated. http://sallis.ucsd.edu/Documents/NEWS_A.pdf

[41] Centers for Disease Control and Prevention. (2011). Behavioral Risk Factor Surveillance System Questionnaire. http://www.cdc.gov/brfss/questionnaires/pdf-ques/2011brfss.pdf

[42] U.S. Census Bureau. 2000. United States Census 2000 Long Form Questionnaire. http://www.census.gov/dmd/www/pdf/d02p.pdf

[43] These are: Freeman et al. (2012); Adams et al. (2011); Sallis et al. (2009); Cao, Mokhtarian, and Handy (2009); Frank et al. (2006); and Frank et al. (2005). See Appendix E.

sections and walking destinations in addition to the presence/absence of sidewalks, simultaneously. Additionally, walkability indices have been applied in several urban contexts in the U.S., strengthening the case for using a walkability index. Most importantly, empirical research has validated an association between the walkability measure and time spent walking. The six articles were closely reviewed in order to choose the walkability measure that demonstrated the best fit with project objectives.

Ultimately, the team chose to employ a walkability index developed by a team led by Dr. Larry Frank, professor in the School of Community and Regional Planning and the School of Population and Public Health at the University of British Columbia, and Dr. James Sallis, Distinguished Professor of Family and Preventive Medicine at the University of California, San Diego. Frank, Sallis, and their colleagues describe the rationale for this index and how to compute it in a 2010 article entitled "The Development of a Walkability Index: Application to the Neighborhood Quality of Life Study," published in the British Journal of Sports Medicine.[44] The team selected this measure because it has been validated against observational data on walking behavior and is increasingly used in U.S. and international studies investigating the effects of urban form on physical activity.

The walkability index developed by Frank et al. uses four components to estimate walkability at the neighborhood level:

1. **Intersection density**: The number of intersections divided by land area, which is used to estimate the relative connectivity of the street network (and, for example, represents the ease for pedestrians of crossing from one side of a street to the other).
2. **Net residential density**: The number of units of housing divided by residential land area, which is used to understand the relative density of housing (with higher densities shown to be more conducive to walking due to shorter distances among residences).
3. **Retail floor area ratio (FAR)**: The square footage of retail buildings divided by the square footage of land devoted to retail use, which is used to compare the relative densities of retail use. A lower ratio indicates a higher proportion of area designated for parking and fewer destinations attractive to walkers.
4. **Land use mix**: A measurement ranging from 0 to 1 that measures the diversity of land use in an area. A score of 1 indicates that there is an even distribution of the five land uses considered in this measure: residential, retail, entertainment, office, and institutional. A score of 0 indicates a single use. This number is computed using an entropy equation developed by Cervero and Kockelman in 1997.[45]

[44] Frank, L.D., Sallis, J.F., Saelens, B.E., Leary, L., Cain, K., Conway, T.L., & Hess, P.M. (2010). The development of a walkability index: Application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44(13), 924-933.
[45] Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: density, diversity, and design. Transportation Research Part D: Transport and Environment, 2(3), 199-219.

Once a value for each of the four components is calculated at the neighborhood or census block group level, it is standardized using an established statistical technique (involving calculation of a *Z*-score).[46] The result is that the average of each standardized (*Z*-score) value across all neighborhoods is approximately zero, and the standard deviation is approximately one. For example, a value of 1.5 for a neighborhood means that the variable for that neighborhood is 1.5 standard deviations above the mean of all neighborhoods, so the area is more conducive to walking than the average neighborhood. The four standardized values for each component are combined according to the following equation:

**Walkability score = (2 x *Z*-intersection density) + (*Z*-net residential density) + (*Z*-retail floor area ratio) + (*Z*-land-use mix)**

The weighting factor of two for the intersection density score reflects the strong influence of the presence of multiple intersections on people's choice of whether to walk or drive, as determined in multiple previous studies.

As an illustration of differences in walkability, Figures 8 and 9 show pictures of two neighborhoods studied by Frank et al. as part of developing the walkability index. Figure 8 shows a low-walkability neighborhood. Especially notable is the lack of pedestrian-friendly intersections and lack of inviting street facades. Figure 9 shows a high-walkability neighborhood, with sidewalks, street-level businesses abutting the sidewalks, and residential units above the businesses.

Table 4 shows the values used to compute the *Z*-score of each component for the BRRC and the overall walkability score under the present and future scenarios.


**Figure 8.** **Example of a low-income neighborhood with a low walkability score. Several large state roads bifurcate the neighborhood, and businesses have large setbacks from the street. This example is the Kent East Hill community in King County, Wash., one of those studied by Frank and colleagues (see main text).**[47]

[46] To calculate the Z-score, the mean value of the variable (e.g., intersection density) for all neighborhoods in a region is subtracted from the value for the specific neighborhood. The resulting difference is divided by the standard deviation of the variable's value across all neighborhoods.
[47] Frank, L.D., Sallis, J.F., Saelens, B.E., Leary, L., Cain, K., Conway, T.L., & Hess, P.M. (2010). The development of a walkability index: Application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44(13), 924-933.


**Figure 9.** Example of a low-income neighborhood with a high walkability score. Ground-level stores front the sidewalks, and residential units are above the stores (an example of a mixed-use area from Frank et al.[47]).

**Table 4.** Blue Ridge Road Corridor existing and proposed land use characteristics (Urban Design Associates et al. 2012)

| | Existing | | Proposed | | | |
|---|---|---|---|---|---|---|
| Urban characteristics | 2012 BRRC (average) | Entire BRRC (average) | South of Hillsborough | Entertainment and Education | Arts and Research | Health and Wellness |
| Intersections | 47 | 85 | 40 | 9 | 12 | 24 |
| Total land area (acres) | 1,562 | 1,562 | 156 | 683 | 494 | 229 |
| *Intersection density* | *0.030* | *0.054* | *0.256* | *0.013* | *0.024* | *0.105* |
| ***Intersection density z-score*** | ***-1.25*** | ***-2.50*** | ***-2.49*** | ***-2.51*** | ***-2.49*** | ***-2.50*** |
| Residential units | 0 | 7,676 | 5,568 | 854 | 387 | 867 |
| Residential land use* | 0 | 124 | 88.94 | 12.42 | 8.46 | 13.87 |
| *Net residential density* | *-* | *62.06* | *62.60* | *68.77* | *45.73* | *62.50* |
| ***Net residential density z-score*** | ***-0.57*** | ***1.71*** | ***1.73*** | ***1.96*** | ***1.11*** | ***1.73*** |
| Retail and entertainment floor area* | 241,841 | 744,900 | 338,800 | 39,900 | 250,500 | 115,700 |
| Retail land (acres) | 16,186,957 | 16,186,957 | 7,585,254 | 6,086,617 | 2,451,599 | 63,487 |
| *Retail FAR* | *0.015* | *0.046* | *0.045* | *0.007* | *0.102* | *1.822* |
| ***Retail FAR z-score*** | ***-1.09*** | ***0.73*** | ***-0.98*** | ***-1.12*** | ***-0.76*** | ***5.78*** |
| Office floor area* | 2,971,407 | 6,048,600 | 1,244,600 | 708,000 | 1,431,000 | 2,665,000 |
| Mixed use offices floor area* | - | 1,752,800 | 438,400 | - | 851,600 | 462,800 |
| Institutional floor area* | 676,250 | 676,250 | - | 222,000 | 266,000 | 188,250 |
| Residential floor area* | - | 8,752,500 | 6,322,500 | 950,000 | 352,500 | 1,127,500 |
| Mixed use residential floor area* | - | 1,140,200 | 830,200 | 159,600 | 150,400 | - |
| Retail and entertainment floor area* | 241,841 | 744,900 | 338,800 | 39,900 | 250,500 | 115,700 |
| *Land use mix* | *0.492* | *0.686* | *0.452* | *0.733* | *0.678* | *0.598* |
| ***Land use mix z-score*** | ***0.54*** | ***1.10*** | ***0.37*** | ***1.62*** | ***1.37*** | ***1.02*** |
| ***Walkability index score*** | ***-3.61*** | ***0.96*** | ***-1.37*** | ***-0.05*** | ***-0.77*** | ***6.03*** |

** Measured in square feet*

The data in Table 4 were provided by the Raleigh Urban Design Center. *Z*-scores are shown for the BRRC as a whole and for each of the four planned subdistricts: South of Hillsborough, Entertainment and Education, Arts and Research, and Health and Wellness. As detailed in the table, the increase in density, diversification of land use, and enhancement of connectivity proposed in the small area plan is expected to lead to a significant increase in the overall walkability of the BRRC. The existing walkability score for the entire neighborhood is -3.61, which places the BRRC at the lowest 0.02% of walkability, in comparison with the neighborhoods used to develop the walkability index. Under the new BRRC design, the walkability score for the entire corridor improves in all urban characteristics except for intersection density. The overall walkability score of the redesigned BRRC is 0.96, which would elevate the BRRC to the top 17% of neighborhoods used to develop the walkability index.

## PREDICTING CHANGES IN WALKING FROM INCREASED WALKABILITY

>> The six previous studies (selected from the research review described in the previous section) that translated urban form into a walkability score also assessed the physical activity patterns of residents of each neighborhood studied. The most recent of these studies was conducted by Sallis et al., and it used the same International Physical Activity Questionnaire items that the research team used in the BRRC to characterize time spent walking.[48] Sallis et al. surveyed 2,199 residents of 32 neighborhoods in the Baltimore-Washington, D.C., and Seattle metropolitan areas about how much time they usually spent walking for transportation purposes; the neighborhoods illustrated in Figures 8 and 9 were among those surveyed. Sallis et al. divided the 32 neighborhoods into two income categories: high and low. Seattle neighborhoods with median household incomes less than $62,000 were classified as low-income; Baltimore neighborhoods with median incomes less than $58,500 were considered low income. They also divided respondents according to whether their home was in a high-walkability (positive walkability score) or low-walkability (negative walkability score) neighborhood.

In comparing walkability scores for the 32 neighborhoods to the amount of time spent walking for transportation, the researchers found a relationship between higher walkability and more walking by neighborhood residents, regardless of whether the neighborhood was high- or low-income. Results of Sallis et al.'s analysis showed that while minutes of physical activity per day and minutes of leisure walking per week

[48] Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., ... & Kerr, J. (2009). Neighborhood built environment and income: Examining multiple health outcomes. Social Science & Medicine, 68(7), 1285-1293.

were slightly higher in high-walkability neighborhoods than in low-walkability neighborhoods, the differences for transportation walking were substantial. In low-income, high-walkability neighborhoods, the number of minutes spent walking for transportation per week was more than twice as high as in low-income, low-walkability neighborhoods. In high-income, high-walkability neighborhoods, people walked for transportation three times as much as in high-income, low-walkability neighborhoods (Table 5).

**Table 5.** Differences in physical activity in neighborhoods with low and high walkability[48]

| | Low income | | High income | |
|---|---|---|---|---|
| **Activity** | **Low walkability** | **High walkability** | **Low walkability** | **High walkability** |
| Transportation walking, min/week: mean (standard deviation) | 15.6 (1.2) | 36.2 (1.2) | 13.2 (1.2) | 41.3 (1.2) |
| Leisure walking, min/week: mean (standard deviation) | 13.3 (1.1) | 16.4 (1.1) | 15.0 (1.1) | 21.1 (1.1) |
| Moderate-to-vigorous physical activity, min/day: mean (standard deviation) | 28.5 (1.6) | 33.4 (1.6) | 29.0 (1.6) | 16.4 (1.1) |

The research team used the differences in walking for transportation between low-income, high- and low-walkability neighborhoods observed in the Sallis study to predict how walking for transportation might change if the BRRC is rebuilt. In other words, the team assumed that if the BRRC were made more walkable, its residents would change their walking behavior so that it would be similar to that observed in the low-income, high-walkability neighborhoods studied by Sallis et al. Because the median per capita income in the BRRC ($48,913 in 2010) fell closer to the low-income levels in the Sallis et al. analysis, the project team used the observed transportation walking differences between low- and high-walkability neighborhoods observed in the low-income areas that Sallis et al. studied.

In addition to observational data from previous studies showing differences in walking behavior by walkability score, predicting walking behavior in the redesigned BRRC required an estimate of the time that members of the BRRC population currently spend walking for transportation. Data about walking for transportation in the Sallis and BRRC residential questionnaires came from the same questions, which were borrowed by both sets of researchers from the International Physical Activity Questionnaire:

1. During the last seven days, on how many days did you walk for at least 10 minutes at a time to go from place to place?
2. How much time did you usually spend on one of those days walking from place to place?

Respondent answers to these questions were multiplied together and then divided by seven to obtain the average minutes per day spent walking for transportation under the current BRRC design.

To predict how current walking behavior (revealed in the BRRC resident survey) would change under a redesigned BRRC, the project team developed a computer simulation model using *Analytica* software (available from Lumina Decision Systems, Los Gatos, Calif.). *Analytica* enables a process known as Monte Carlo simulation, which allowed the project team to explore the effects of variability in individual walking behavior and how individuals might respond differently to changes in the built environment. The simulation model incorporates both the residential survey data and data from the Sallis et al. study, revealing observed differences in walking for transportation between low-walkability and high-walkability neighborhoods. Appendix E describes details of the simulation model. In brief, the model first randomly selects an individual BRRC resident and assigns that individual a walking behavior profile selected at random from the residential survey responses. Next, the model randomly selects two individuals from the population included in the Sallis study: one in a low-income, low-walkability neighborhood and the other in a low-income, high-walkability neighborhood. The model assigns each of these two individuals a walking behavior profile selected at random from the results of the surveys administered by the Sallis et al. team. Next, the model computes the percentage difference in walking time between these latter two individuals. Finally, it applies this percentage change to the randomly selected BRRC resident to predict the individual's walking behavior under a redesigned BRRC. For example, if the randomly sampled individual from the low-walkability neighborhood in the Sallis et al. study spends 17.5 minutes a week walking for transportation and the corresponding individual in the high-walkability neighborhood walks 35 minutes a week for transportation, then the simulation computes that the randomly selected BRRC resident will change his/her walking behavior under a redesigned BRRC by the same proportionate amount: 35 minutes/17.5 minutes = 200%. So, if the randomly selected individual currently spends 4 minutes a day walking for transportation, then under the redesign he or she would be predicted to spend 8 minutes a day walking for transportation. This simulation process is repeated thousands of times to characterize the variability in walking behavior under current and future BRRC conditions across the entire BRRC residential population.

A limitation of this approach is that individuals who currently do not walk anywhere for transportation are assumed to spend no time walking for transportation in the redesigned BRRC. In other words, the model predicts increases in walking for transportation only for those who already walk from place to place in the neighborhood. As a result, the estimates of population changes in walking behavior under the redesigned BRRC are likely to be conservative (i.e., to underpredict increases in physical activity and resulting health benefits). Unfortunately, the data available at this time did not allow the project team to assess the potential for those who currently rely exclusively on motorized transportation to change their behavior.

## PREDICTING THE HEALTH EFFECTS OF INCREASED WALKING

>> The fourth and final necessity was a method that would allow the project team to move from an estimation of increased walking to an estimation of the long-term health impacts of more walking. As a starting point for the model, the project team

consulted the World Health Organization's (WHO) Health Economic Assessment Tool (HEAT) model. The HEAT model is a free online spreadsheet-based tool for estimating the economic impact of decreased premature death due to increases in active transportation (walking and bicycling).[49] The project team used the HEAT model as the starting point because it represents the state-of-the-art approach for quantifying the health impacts of walking and cycling for transportation. The model was developed by the WHO with support by international experts in the relationships between physical activity and health. The project team extended the model in two important ways. First, the HEAT model estimates benefits only in terms of reduced cases of premature mortality. Based on a review of prior epidemiologic studies estimating the relationships between walking and nonfatal adverse health effects, the project team added the capability to estimate reductions in four chronic diseases known to be affected by physical activity: type 2 diabetes, coronary heart disease (CHD), stroke, and hypertension. In addition, the project team added the capability to calculate variability and uncertainty in the estimated benefits. The HEAT model operates in a spreadsheet and produces a fixed estimate of the number of deaths avoided by increases in walking for transportation. However, many of the factors used to make these predictions can involve a large degree of variability (representing differences in individual behaviors, for example) and uncertainty (for example, in the increase in walking time expected under the redesign). Hence, the project team rebuilt the HEAT model using *Analytica* software (available from Lumina Decision Systems, Los Gatos, Calif.), which automates the process of estimating variability and uncertainty in computations. This allowed the project team to report a "best guess" of health benefits along with a plausible range. Appendix E describes further details of this process.

## Data Requirements

In order to use the rebuilt HEAT model, the project team needed to collect data from primary and secondary sources  and literature.[50] The necessary data included:

1. **Baseline population and health data.** Baseline population and health data came from the U.S. Census, the survey of BRRC residents, and the N.C. State Center for Health Statistics. The project team used census data to estimate the number of people living in the BRRC and the age, gender, and race of residents. Information about death rates came from the N.C. State Center for Health Statistics and was adjusted to the neighborhood level based on the demographic characteristics of the BRRC. Information on the prevalence of type 2 diabetes, CHD, stroke, and hypertension was downloaded from the Centers for Disease

[49] http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Transport-and-health/activities/promotion-of-safe-walking-and-cycling-in-urban-areas/quantifying-the-positive-health-effects-of-cycling-and-walking/health-economic-assessment-tool-heat-for-cycling-and-walking

[50] Primary data refers to information collected directly from sources, such as surveys and interviews. Secondary data refers to data collected by another trusted source, such as health information collected by the N.C. Department of Health.

Control Behavioral Risk Factor Surveillance System (using data for Wake County adjusted to reflect the BRRC's demographics).

2. **Projections of future population growth.** The project team's analysis assumed that the redesign of the BRRC would be completed by 2023, although lack of dedicated funding could delay completion beyond that year. The manual for the use of the HEAT model suggests that at least five years are necessary for the benefits of increased regular walking to accrue. The project team estimated health benefits for 20 years beginning in 2028, since 20 years is a typical time horizon for planning capital expenditure projects, and therefore fits well into a typical cost-benefit analysis. To project the future size of the BRRC population, the project team assumed the area would continue to grow at 3.1% annually, the same current growth rate as in the city of Raleigh.[51]
3. **Baseline walking behavior.** Baseline walking behavior (time spent per day walking for transportation) was estimated from the residential survey described earlier in this section.
4. **Prediction of walking behavior following BRRC redesign.** The prediction of the increase in walking expected following the redesign came from the *Analytica* simulation described in the previous section.
5. **Information on how walking decreases the risk of premature death, diabetes, coronary heart disease, cardiovascular disease, and hypertension.** The project team conducted a comprehensive literature review to understand the relationship between regular walking and these five health conditions, choosing relative risk information based on rigorous reviews or meta-analyses of numerous studies.

   ***Premature death.*** Data about the effect of regular walking on premature death risk came from the original HEAT model.[52] Their comprehensive meta-analysis indicated that the risk of premature mortality from any cause can be estimated directly as a function of minutes per day spent walking:[53]

$$RR=0.78^{\text{walking time}/29}$$

For example, an individual who walks for exactly 29 minutes a day has a relative risk of premature death from any cause of 0.78, meaning he/she is 22% less likely to die prematurely compared with someone who does not walk at all.

***Diabetes.*** Data about the effect of regular walking on diabetes risk came from a 2012 study of 9,933 adults conducted by Furie and Desai. They found the risk of diabetes could be predicted by the amount of time study participants spent in active transportation. For example, those reporting more than 21 minutes of active transportation (walking or cycling) daily had a 31% lower risk of developing type 2 diabetes than those who reported no active transportation.[54]

[51] City of Raleigh. 2012. "Raleigh Demographics." City of Raleigh. December 19. http://www.raleighnc.gov/home/content/PlanLongRange/Articles/RaleighDemographics.html

***Coronary heart disease.*** Data about the effect of regular walking on coronary heart disease risk came from a 2007 study by Hu et al. of 47,840 Finnish adults aged 25-64. The study found that men who walked or cycled to and from work for 1-29 minutes a day had an 8% lower risk of CHD than men who did not and that those who spent 30 or more minutes a day walking or cycling to work reduced their CHD risk by 11%. Among women the effects were even stronger: walking or cycling to work for 1-29 or more than 29 minutes daily decreased CHD risk by 17% and 34%, respectively.[55]

***Stroke.*** Data about the effect of regular walking on the risk of having a stroke came from a 2005 study by Hu et al. This study followed the same group used to estimate the effects of physical activity on CHD. The researchers found that active commuting for 1-29 minutes daily reduced stroke risk by 8% and that 30 or more daily minutes of active commuting decreased stroke risk by 14%.[56]

***Hypertension.*** Data about the effect of regular walking on the risk of developing hypertension came from the same 2012 study by Furie and Desai as was used to estimate effects of walking on diabetes. They found that participants who reported spending 1-21 minutes a day in active transportation (walking or cycling) had a 19% lower risk of developing hypertension than participants who reported no active transportation; those who spent more than 21 minutes a day in active transportation reduced their risk by an additional 5%.[57]

6. **An estimation of the economic value of avoided death and chronic disease.** In keeping with the transportation focus of the HIA, the project team used the same value used by the U.S. Department of Transportation to estimate the value of an avoided death: $9.1 million.[58] For the other health outcomes (CHD, stroke, hypertension, and diabetes), the team used North Carolina-specific estimates from the Milken Institute.[59] These values, used in the HIA analysis to calculate the monetary value of avoiding these health outcomes, are shown in Table 6. The reported values (as estimated by the Milken Institute) are for the year 2023. For each estimation year (2028-2048), these estimates were escalated from 2023 values by the annual percentages indicated in Table 6 to reflect inflation in the costs of medical care and lost productivity.

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[52] World Health Organization. (2011). Health Economic Assessment Tools (HEAT) for Walking and for Cycling: Methodology and User Guide.
[53] Ibid.
[54] Furie, G. L., & Desai, M. M. (2012). Active Transportation and cardiovascular disease risk factors in US Adults. American journal of preventive medicine, 43(6), 621-628.
[55] Hu, G., Jousilahti, P., Borodulin, K., Barengo, N. C., Lakka, T. A., Nissinen, A., & Tuomilehto, J. (2007). Occupational, commuting and leisure-time physical activity in relation to coronary heart disease among middle-aged Finnish men and women. Atherosclerosis, 194(2), 490-497.
[56] Hu, G., Sarti, C., Jousilahti, P., Silventoinen, K., Barengo, N. C., & Tuomilehto, J. (2005). Leisure time, occupational, and commuting physical activity and the risk of stroke. Stroke, 36(9), 1994-1999.
[57] Furie, G. L., & Desai, M. M. (2012). Active Transportation and cardiovascular disease risk factors in US Adults. American journal of preventive medicine, 43(6), 621-628.
[58] U.S. Department of Transportation. (2013). Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses. http://www.dot.gov/regulations/economic-values-used-in-analysis
[59] DeVol, R., Bedroussian, A., Charuworn, A., Chatterjee, A., Kim, I., Kim, S., & Klowden, K. (2007). An unhealthy America: The economic burden of chronic disease. Santa Monica, Calif.: Milken Institute.

**Table 6.** Dollar value of an avoided adverse health outcome (in the year 2023)[60]

| Health outcome | Direct health-care expenditures | Lost productivity | Total costs | Annual rate of increase* |
|---|---|---|---|---|
| Diabetes | $4,328 | $16,672 | $21,000 | 3.4% |
| CHD | $8,083 | $11,805 | $19,889 | 3.7% |
| Stroke | $14,788 | $19,604 | $34,392 | 3.8% |
| Hypertension | $2,141 | $16,402 | $18,543 | 3.3% |

****Cost estimates shown are for the year 2023. Costs are increased at the rates shown in this column for each year considered in the study (2028-2048).***

## Model Construction

The project team used the data explained in the previous section as the basis for constructing a model to simulate how the health of BRRC residents may change after the planned new design for the neighborhood is fully implemented. In essence, *Analytica* selects at random a hypothetical individual resident of the BRRC. This selection includes identifying the individual's age and gender. The probability that this individual will be a 35- to 44-year-old female, for example, is based on the proportion of the current BRRC population having those characteristics, as determined by the U.S. Census. Using the survey data collected for this research, the model randomly assigns (as described above) the amount of time the selected individual walks for transportation on any given day. For example, about 25% of those surveyed said they spent 1-10 minutes a day walking for transportation, so in the simulation, the hypothetical individual's chance of walking 1-10 minutes daily is 25%. Then, the simulation selects the expected increase in the time this individual will spend walking in the future, after the BRRC redesign. This selection is carried out as previously described. Then, the model uses this new time spent walking to calculate the reduced risk of each health outcome for this hypothetical individual, using the results of the previously described studies of the health benefits of increased walking. The model then repeats this random selection and calculation process thousands of times, in effect simulating the entire BRRC population and how the redesign will change behavior and health. After generating preliminary results, the project team also conducted sensitivity and uncertainty analyses to identify which of the model input variables had the most influence on the predicted health effects of the new BRRC design as well as those which contributed the most to uncertainty in the results. The computational details of the application of this model can be found in Appendix E.

[60] DeVol, R., Bedroussian, A., Charuworn, A., Chatterjee, A., Kim, I., Kim, S., & Klowden, K. (2007). An unhealthy America: The economic burden of chronic disease. Santa Monica, Calif.: Milken Institute.

# 4. Findings

## SURVEY FINDINGS

>> The survey of residents provided the project team with a wealth of information on the physical activity levels and health of BRRC residents that allowed them to understand the current health profile of residents and estimate the health impacts of the small area plan. In total, 386 residents completed the neighborhood resident survey, representing 3.7% of BRRC study area residents.

### Current Health Concerns

As seen in Table 7, the health profile of BRRC resident survey respondents differs somewhat from the health profile of the Raleigh-Cary metropolitan statistical area. BRRC survey respondents were more likely to report a body mass index within the recommended range, as well as lower prevalence of diabetes, heart attack, asthma, and chronic obstructive pulmonary disease. However, BRRC residents were more likely to report high blood pressure, angina, stroke, and cancer than were residents of the larger metropolitan area. A possible explanation is the older average age of survey respondents compared with residents of the Raleigh-Cary metropolitan statistical area, since the development of chronic disease is associated with older age.

### Current Physical Activity

The survey of residents showed that more than 40% of residents do not engage in the recommended amount of physical activity per week. Figure 10 shows how the proportion of residents who meet physical activity recommendations compares with figures from the Raleigh-Cary metropolitan area and the state of North Carolina collected by the N.C. Division of Public Health as part of the annual Behavioral Risk Factor Surveillance System developed by the CDC.[61, 63] Sufficient physical activity is determined by the CDC, which recommends at least 150 minutes a week of moderate-intensity physical activity (such as brisk walking) or 75 minutes a week of vigorous-intensity physical activity (such as jogging or running) for adults ages 18-64.[64]

Figure 11 shows the amount of time that BRRC residents walk each day for trans-

**Table 7.** Blue Ridge Road Corridor residential survey respondent health profile (n=386)

| | Survey respondents (2012) | Raleigh-Cary[61] (2011) | North Carolina[62] (2012) |
|---|---|---|---|
| **Body mass index** | | | |
| Underweight | 3.2% | ---% | 1.8% |
| Recommended range | 52.1% | 33.6% | 32.4% |
| Overweight | 35.0% | 34.3% | 36.2% |
| Obese | 9.6% | 30.6% | 29.6% |
| **Health conditions** | | | |
| Hypertension | 27.5% | 26.2% | 32.4% |
| Borderline | 6.0% | N/A | 1.4% |
| Pregnancy-related | 0.5% | N/A | 0.7% |
| Diabetes | 7.0% | 7.9% | 10.4% |
| Borderline | 3.6% | N/A | 8.8% |
| Pregnancy-related | 1.0% | N/A | N/A |
| Heart attack | 2.1% | 2.4% | 4.6% |
| Angina | 6.0% | 3.6% | 4.4% |
| Stroke | 3.1% | 2.7% | 3.2% |
| Asthma | 6.7% | 11.5% | 11.7% |
| Chronic obstructive pulmonary disease | 2.3% | 4.5% | 6.8% |
| Cancer | 15.5% | 11.1% | 13.4% |

portation according to the survey results. The median time spent walking for transportation was about 4 minutes per person per day, meaning that 50% of residents walk less than and 50% more than 4 minutes a day for transportation. Notably, 41% of surveyed residents did not report any walking for transportation. This is consistent with findings from the 2010 National Health Interview Survey conducted by the CDC, which found that 38% of Americans reported no walking.[65] Under current conditions, 16% of residents walk for at least 29 minutes every day, and, in doing so, meet both CDC and WHO recommendations for minutes of daily physical activity through transportation walking alone.

## Current Walkability Concerns

Another component of the residential survey was a series of questions about the current built environment in the BRRC neighborhood. These questions were taken from the Neighborhood Environmental Walkability Score questionnaire, which mea-

[61] Centers for Disease Control and Prevention (2011). SMART: BRFSS City and County Data. Raleigh-Cary Metropolitan Statistical Area. http://apps.nccd.cdc.gov/BRFSS-SMART

[62] North Carolina Center for Health Statistics. (2013). 2012 BRFSS Survey Results: North Carolina. Accessed October 11, 2013 from http://www.schs.state.nc.us/schs/brfss/2012/nc/all/topics.html

[63] Eat Smart, Move More North Carolina. (2013). Physical Activity, Nutrition, and Obesity in North Carolina. Accessed October 11, 2013 from http://www.eatsmartmovemorenc.com/Data/Texts/Quick%20Facts.pdf

[64] http://www.cdc.gov/physicalactivity/everyone/guidelines/adults.html

[65] Centers for Disease Control and Prevention. (2012). Vital Signs: Walking Among Adults—United States, 2005 and 2010. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6131a4.htm

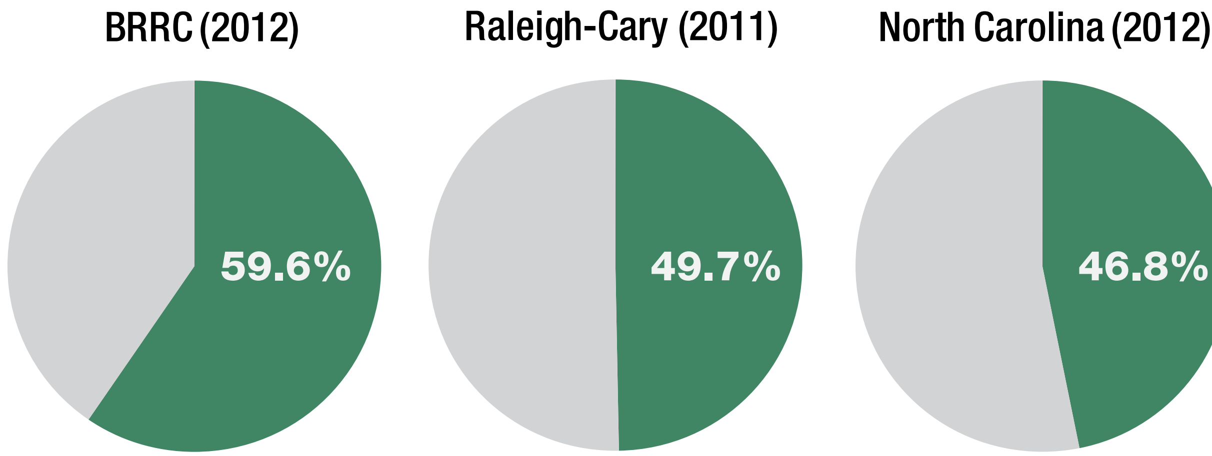


**Figure 10.** Percentage of survey respondents meeting aerobic physical activity recommendations.

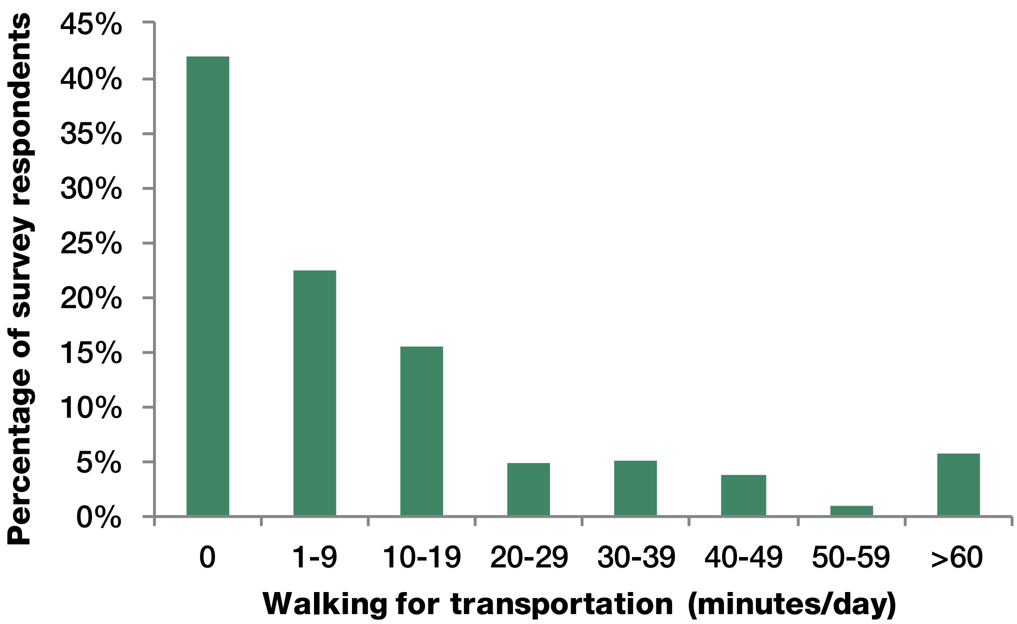


**Figure 11.** Number of minutes spent walking for transportation per day by percentage of respondents.

sures residents' perception of neighborhood design features.[66] Respondents were asked how much they agreed or disagreed with the statements listed in Table 8. Responses to these questions indicated which factors related to walkability were of the most and least concern to neighborhood residents. Top concerns included high speeds on nearby streets, heavy traffic that impedes walking, and the lack of adequate lighting on streets at night. The areas of least concern were litter, a lack of trees, and the ease of finding one's way around the neighborhood.

[66] Saelens, B.E., Sallis, J.F., Black, J.B., and Chen, D. (2003). Neighborhood-based differences in physical activity: An environment scale evaluation. American Journal of Public Health, 93, 1552-1558.

**Table 8.** Responses to neighborhood walkability issues, in order of concern

| | Neighborhood walkability issue | Agree | Disagree |
|---|---|---|---|
| 1. | The speed of traffic on most nearby streets is usually slow (30 mph or less). | 30.5% | 69.5% |
| 2. | There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in the BRRC neighborhood. | 61.1% | 38.9% |
| 3. | The BRRC neighborhood streets are well-lit at night. | 65.2% | 34.8% |
| 4. | There are crosswalks and pedestrian signals to help walkers cross busy streets in the BRRC neighborhood. | 65.8% | 34.2% |
| 5. | There are many interesting things to look at while walking in the BRRC neighbor-hood. | 68.3% | 31.7% |
| 6. | There are many attractive natural sites in the BRRC neighborhood. | 69.1% | 30.9% |
| 7. | There are sidewalks on most of the streets in the BRRC neighborhood. | 72.2% | 27.8% |
| 8. | Sidewalks are separated from the road/traffic in the BRRC neighborhood. | 74.7% | 26.3% |
| 9. | Most drivers exceed the posted speed limits while driving in the BRRC. | 79.9% | 20.1% |
| 10. | There are attractive buildings/homes in the BRRC neighborhood. | 81.8% | 18.9% |
| 11. | The BRR neighborhood is generally free from litter. | 84.7% | 15.3% |
| 12. | There are trees along the streets in the BRRC neighborhood. | 86.9% | 13.1% |
| 13. | It is easy to find my way around the BRRC neighborhood when walking or biking. | 92.0% | 8.0% |

## CHANGES IN WALKING FROM INCREASED WALKABILITY

>> In order to predict changes in walking for transportation as a result of increased walkability, the project team built a simulation model as detailed in Section 3 and Appendix E. Figure 12 shows how the distribution of minutes of walking behavior per person is predicted to change following BRRC redesign. The median number of minutes that residents walk daily is expected to increase from 4 minutes under current conditions to 9 minutes under the redesign. The average daily walking time is expected to increase from 13 to 30 minutes. Another positive finding was that the percentage of people who participate in 29 minutes of daily physical activity through transportation walking alone is expected to increase from 16% under current conditions to 29% following redesign. If the redesign has the predicted effects, nearly a third of residents will receive the health benefits of sufficient physical activity just by walking from place to place.

## HOW WILL THE PROPOSED PLAN AFFECT HEALTH?

>> The computer simulation model constructed for this project predicts that the implementation of the small area plan will have significant health and economic benefits

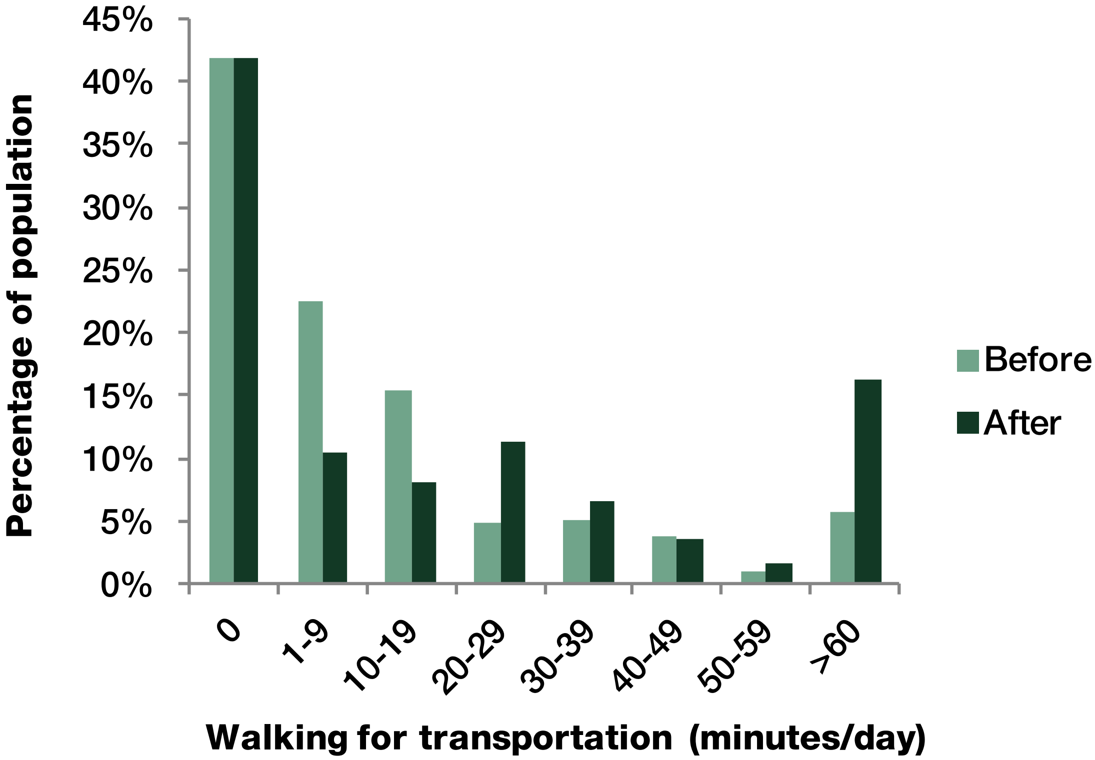


**Figure 12.** Number of minutes of walking per day before and after the redesign.

for current and future residents of the BRRC. Table 9 shows the predicted number of cases of premature death and nonfatal cases of diabetes, CHD, stroke, and hypertension that could be avoided in the BRRC population in total over the time span 2028 to 2048 if the new BRRC design were to be implemented and walking for transportation were to increase as predicted. In total, the model predicts that increasing the walkability of the BRRC will lead to 80 fewer avoidable premature deaths (a decrease of 7%) in the resident population by 2048. Increasing walkability in the corridor is predicted to lead to a decrease of 27 cases of diabetes (a 2% decrease), 8 cases of CHD (a 1.5% decrease), 17 cases of stroke (a 2% decrease), and 92 cases of hypertension (a 1% decrease) in total between 2028 and 2048.

In addition to showing the best estimate of the number of cases avoided, Table 9 also shows the plausible range of cases. These numbers are upper and lower bounds of the 95% confidence intervals from the computer simulation model. For example, the lower bound reflects what would happen if the BRRC redesign had a small effect on walking behavior and/or the protective effect of walking is at the low range of plausible values. The opposite is true for the upper bound value, which reflects a large increase in walking across the population and/or a large protective benefit. As such, the lower bound represents a pessimistic estimate of benefits, while the upper bound reflects an optimistic estimate. Showing the plausible ranges is important because the combination of variability in behavior and baseline health from one individual to another and uncertainty in the relationships among urban design, walking behavior, and

**Table 9.** Estimated health benefits of BRRC small-area plan (full build-out)

| | Best estimate and plausible range of cases avoided, 2028-2048 | Fraction of all cases avoided | Total present value* |
|---|---|---|---|
| Deaths (premature) | 80 (30-120) | 7% (3-10%) | $294,000,000 |
| Diabetes (new cases) | 27 (1-79) | 2% (1-6%) | $3,740,000 |
| CHD (new cases) | 8 (2-15) | Females: 2.5% (0.6-4%)<br>Males: 0.5% (0-2%) | $1,110,000 |
| Stroke (new cases) | 17 (1-44) | 2% (0.06-4%) | $4,110,000 |
| Hypertension (new cases) | 91 (4-250) | 2% (0.2-3%) | $11,000,000 |

** Assumes 3.5% annual discount rate*

health mean that providing a single predicted value is misleading. However, the actual effects are 95% likely to occur within the bounds of the indicated plausible ranges.

The total health benefits summarized in Table 9 accrue gradually throughout the 20 years of the study period. Figures 13-17 show the benefits realized during each future year considered as a fraction of the total cases of each adverse health outcome expected in the population. For example, Figure 13 shows that in the year 2028, the BRRC redesign is predicted to lead to a decrease in premature deaths from an expected value of 38 without the redesign to 35 if the redesign is fully implemented. Worth noting in Figures 14-17 is that the benefits of chronic disease prevention accumulate over time. For example, one new case of diabetes is prevented in 2028 and another is prevented in 2029, so in total two fewer people in the population will suffer from diabetes in the year 2029 if the redesign is implemented.

The decreases in premature mortality and disease amount to an estimated financial benefit of $313 million in total over for the 20 years of the analysis (2028-2048) (Table 9). The estimates in Table 9 assume a discount rate of 3.5% per year in keeping with the discount rate used by the N.C. Department of Transportation. Discount rates are used in cost-benefit analysis in order to compare amounts of money at different points in time, based on the assumption that money is worth more to its owner in the present than in the future. However, total estimates of benefits are highly sensitive to the choice of discount rate. Some economists argue that health benefits accruing to future generations should be discounted at rates closer to 0%, while others argue for using rates consistent with the return on investment in financial markets. Table 10 shows the sensitivity of the predicted health benefits to alternative choices of discount rate. As shown, for all reasonable choices of the discount rate, the health benefits of the BRRC redesign are expected to exceed $130 million.

**Table 10.** Sensitivity of estimated economic benefits (mean value) to discount rate

| | Discount rate | | | | |
|---|---|---|---|---|---|
| Health outcome | 0.0% | 2.0% | 3.5% | 5.0% | 7.0% |
| Deaths | $730,000,000 | $430,000,000 | $294,000,000 | $203,000,000 | $127,000,000 |
| Diabetes | $10,500,000 | $5,790,000 | $3,740,000 | $2,440,000 | $1,410,000 |
| CHD | $3,140,000 | $1,720,000 | $1,110,000 | $726,000 | $419,000 |
| Stroke | $11,600,000 | $6,370,000 | $4,110,000 | $2,680,000 | $1,550,000 |
| Hypertension | $30,900,000 | $17,000,000 | $11,000,000 | $7,180,000 | $4,150,000 |
| **Total** | **$786,000,000** | **$461,000,000** | **$313,000,000** | **$216,000,000** | **$134,000,000** |

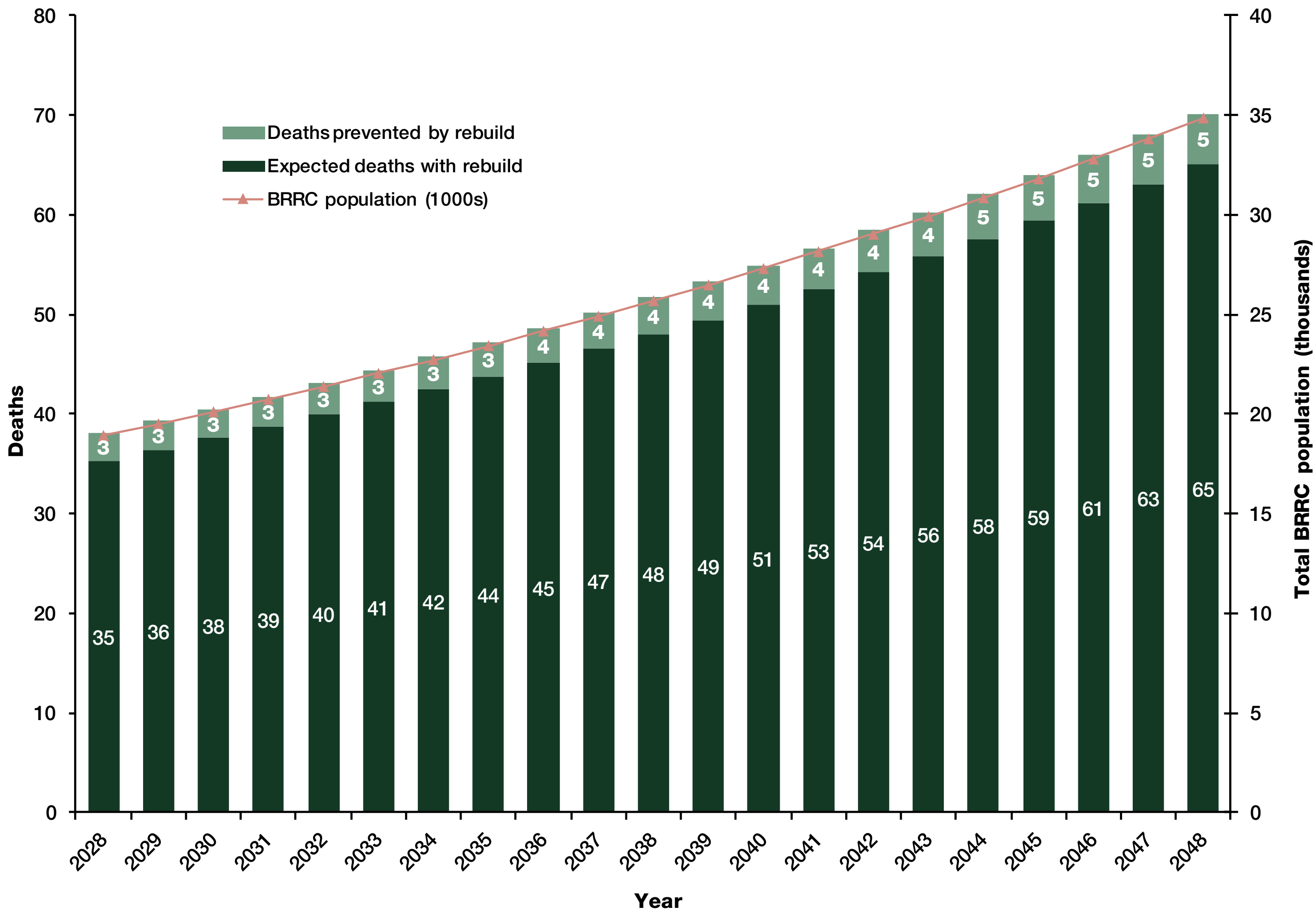


**Figure 13.** Number of premature deaths expected per year in the BRRC resident population after the neighborhood is rebuilt, along with the number of deaths prevented by increasing walkability. (The sum of these two values gives the number of deaths expected per year if the rebuild does not occur.) Also shown is the expected BRRC resident population (right axis) under a growth rate of 3.1% per year, consistent with the growth rate of Raleigh in recent years.

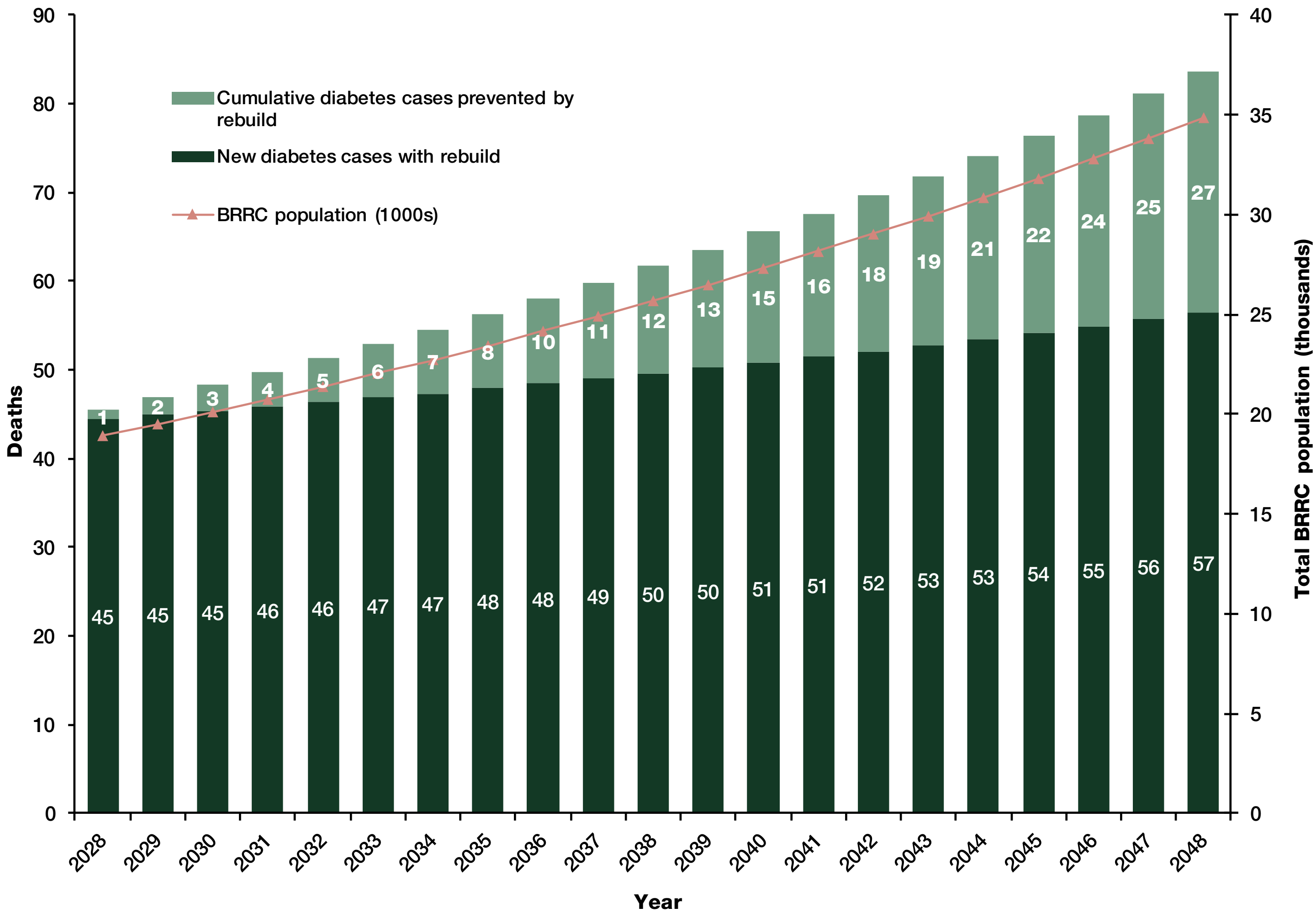


**Figure 14.** Diabetes cases preventable by increasing walkability in the BRRC. The lower part of the bar for each year shows the total expected cases of diabetes assuming increased walkability, and the upper part shows the cases prevented by the urban improvements. Without the improvements, the expected number of cases would be the sum of the two portions of each bar.

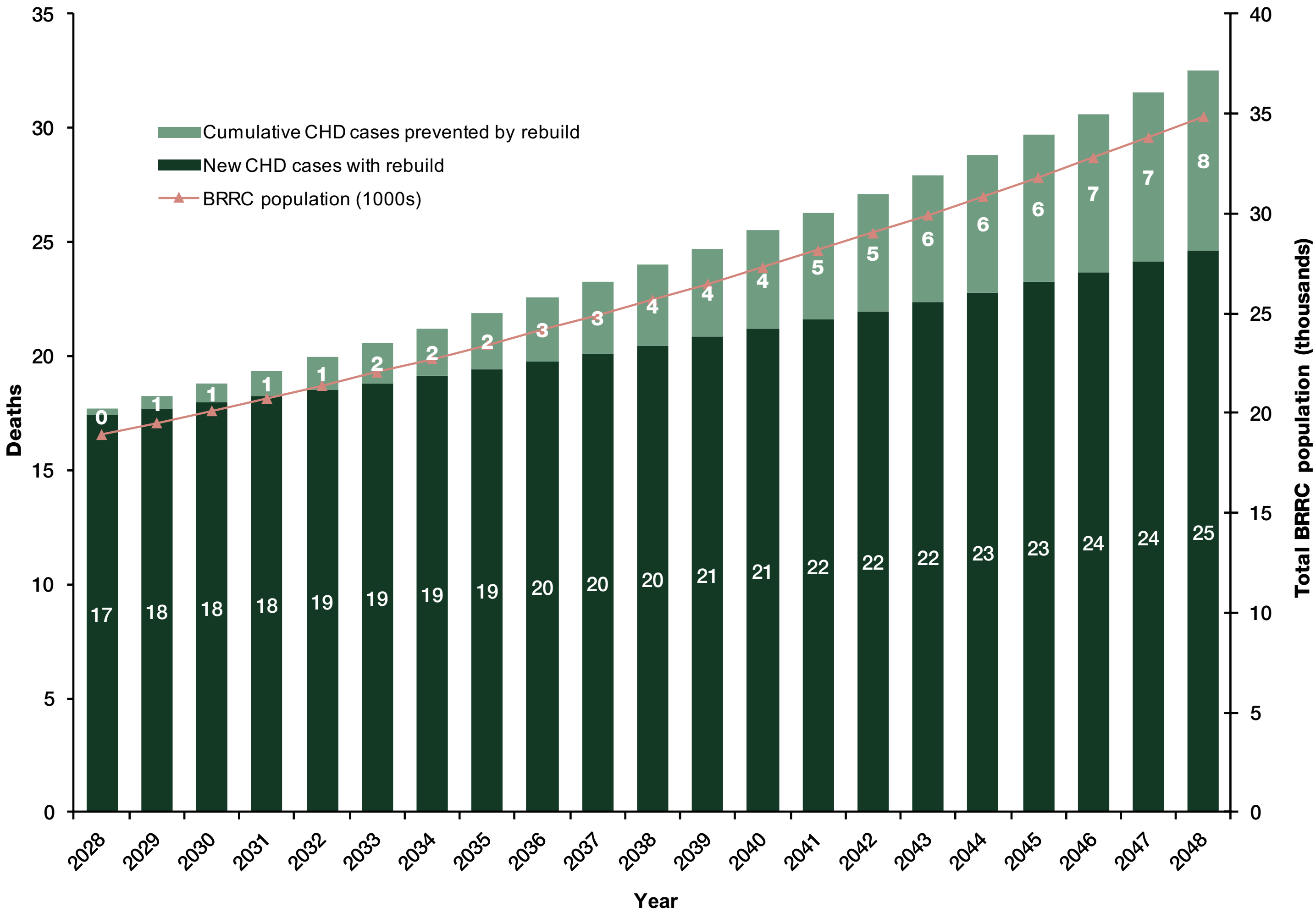


**Figure 15.** CHD cases preventable by increasing walkability in the BRRC. The lower part of the bar for each year shows the total expected cases of CHD assuming increased walkability, and the upper part shows the cases prevented by the urban improvements. Without the improvements, the expected number of cases would be the sum of the two portions of each bar.

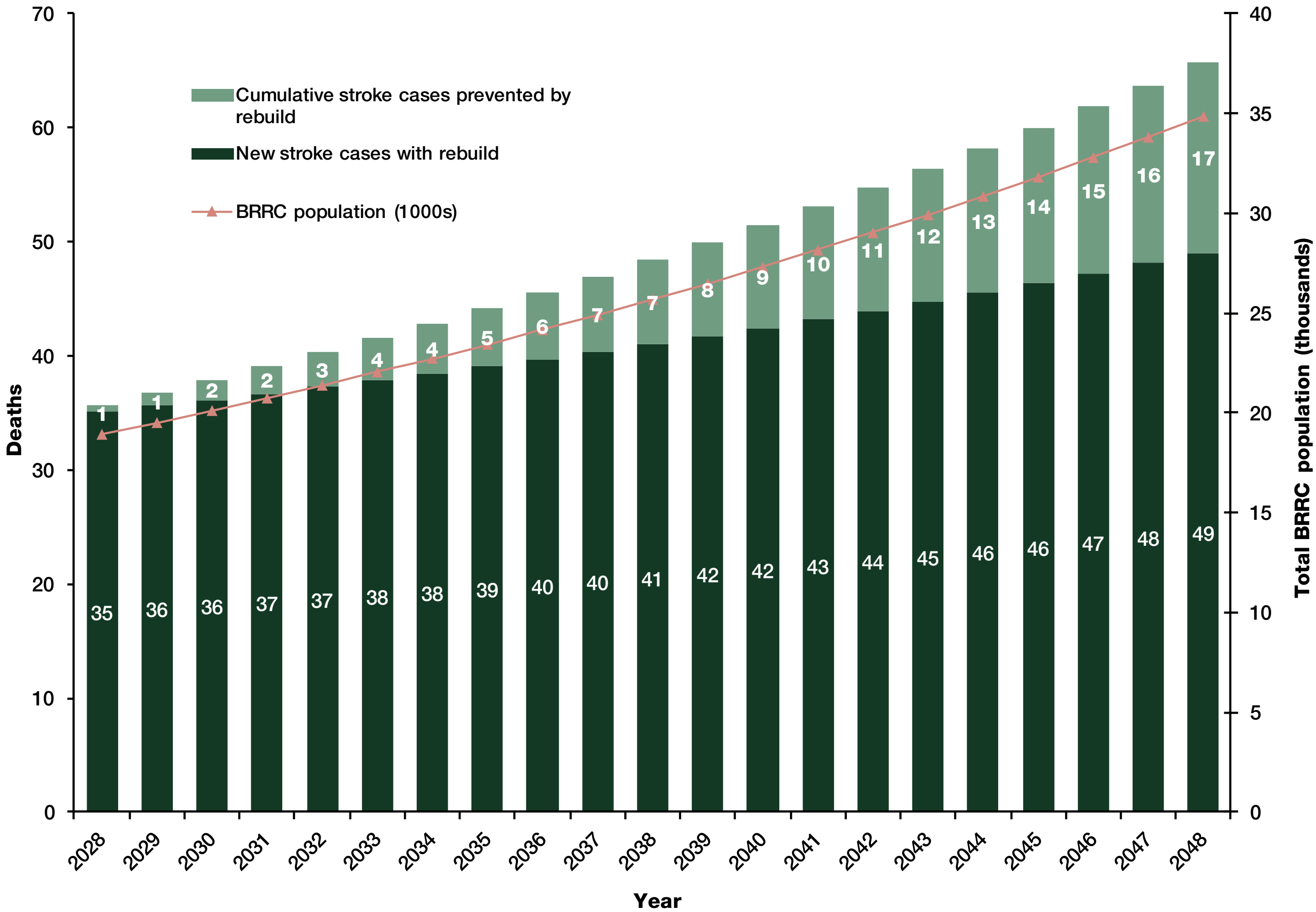


**Figure 16.** Stroke cases preventable by increasing walkability in the BRRC. The lower part of the bar for each year shows the total expected number of people who will have previously had a stroke assuming increased walkability, and the upper part shows the cases prevented by the urban improvements. Without the improvements, the expected number of cases would be the sum of the two portions of each bar.

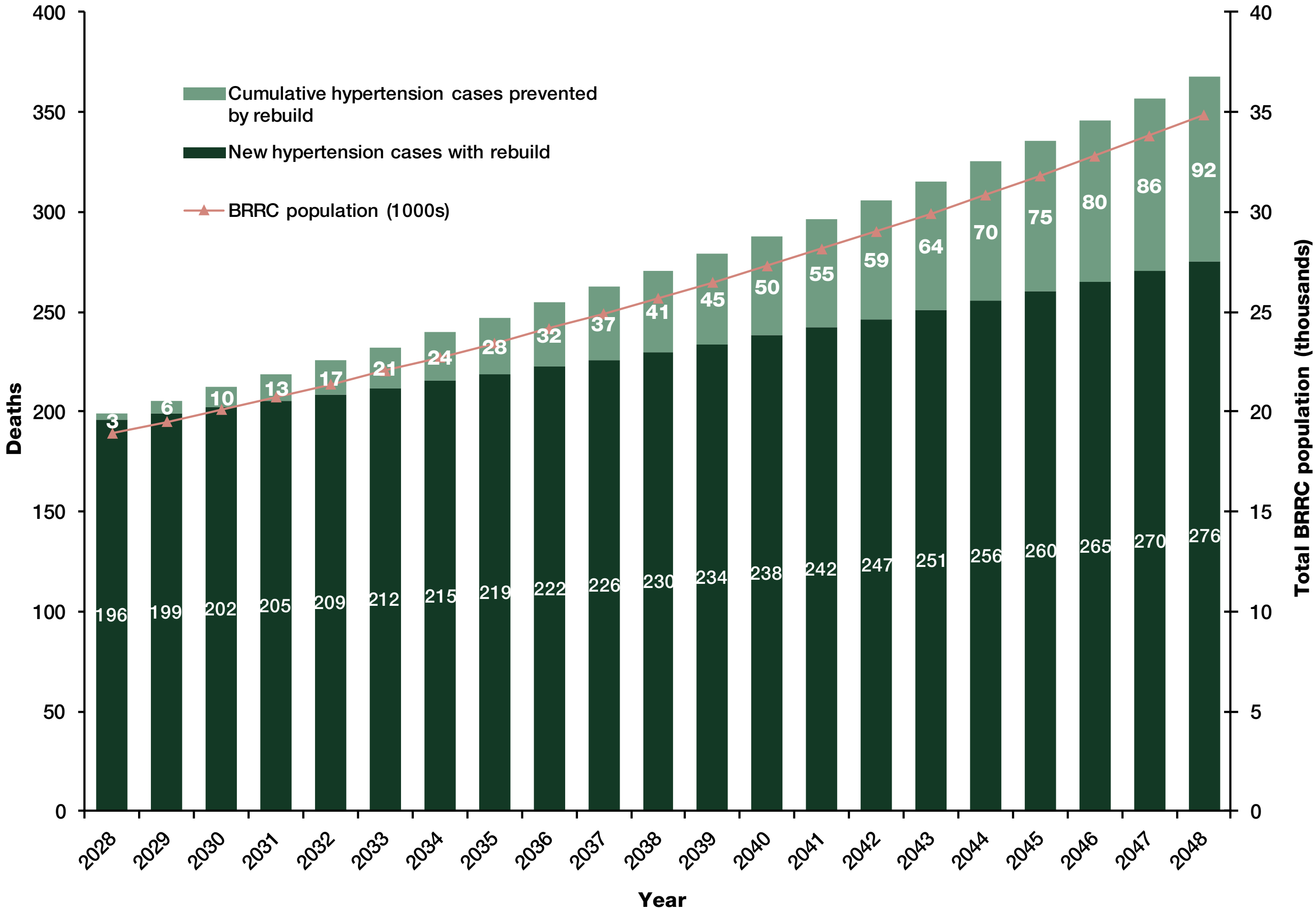


**Figure 17.** Hypertension cases preventable by increasing walkability in the BRRC. The lower part of the bar for each year shows the total expected cases of hypertension assuming increased walkability, and the upper part shows the cases prevented by the urban improvements. Without the improvements, the expected number of cases would be the sum of the two portions of each bar.

## LIMITATIONS

>> The estimates of health benefits presented in this report are restricted to current residents of the BRRC who already spend at least some time walking for transportation each week. Several potentially important populations are excluded due to lack of information, and hence these results in all likelihood underestimate the health benefits of the BRRC redesign.

First, the estimates do not consider the additional population expected to move to the BRRC should the redesign go forward; the Raleigh Urban Design Center expects that the total population could increase by more than 70% by the year 2040, compared with normal growth conditions, under the redesign. Second, the predictions exclude the more than 16,000 workers in the BRRC, many of whom do not live in the neighborhood but are likely to benefit from increased walkability near their workplaces. In addition, the estimates do not account for the millions of annual visitors to the neighborhood (1 million visitors to the state fair and 1.5 million visitors to PNC Arena alone). Furthermore, the team's conservative modeling approach assumes that time spent walking will increase only among those who are already active, since information was insufficient to predict the extent to which currently sedentary individuals would be induced to take up walking for transportation if the neighborhood were redesigned. Nonetheless, these results represent the HIA team's best estimates of health benefits, given currently available information, for the population of current BRRC residents.

# 5. Recommendations

Throughout the course of the HIA, the project team met regularly with the advisory board to share results and invite their input for planning next steps. In June 2013, a complete draft report of major findings was shared with advisory board members in order to begin the process of collectively generating recommendations based on HIA findings.

The main recommendations focused on how to increase walkability and enhance the built environments that support walkability within the BRRC in order to create an environment supportive of physical activity, and, consequently, residents' health. The project team focused on two complementary and mutually-reinforcing strategies: (1) increasing the quantity and quality of infrastructure for active transportation within the BRRC, and (2) increasing the number of destinations that residents can walk to within the BRRC. While the BRRC small area plan does not explicitly focus on health, the majority of the design changes proposed by the small area plan support the creation of an environment in which walking is safer and easier with a greater variety of places to walk to. After reviewing the small area plan and Raleigh's Unified Development Ordinance, Comprehensive Pedestrian Plan, and other policies and efforts, the project team identified actions that will enhance the implementation of the small area plan and support people's decision to walk. After identifying key recommendations, the project team met with advisory board members in order to generate specific strategies to achieve the goals laid out in the recommendations.

## #1: PROVIDE MORE BIKING AND WALKING INFRASTRUCTURE

>> The presence of sidewalks is fundamental to the decision of whether to walk. A number of studies have found that greater availability of sidewalks is associated with greater amounts of walking for transportation,[67] walking in general,[68, 69] or meeting rec-

[67] McCormack, G. R., Shiell, A., Giles-Corti, B., Begg, S., Veerman, J. L., Geelhoed, E., ... & Emery, J. H. (2012). The association between sidewalk length and walking for different purposes in established neighborhoods. International journal of behavioral nutrition and physical activity, 9(1), 92.
[68] Addy, C. L., Wilson, D. K., Kirtland, K. A., Ainsworth, B. E., Sharpe, P., & Kimsey, D. (2004). Associations of perceived social and physical environmental supports with physical activity and walking behavior. Journal Information, 94(3).
[69] Royal, D., & Miller-Steiger, D. (2008). National Survey of Bicyclist and Pedestrian Attitudes and Behavior. US Department of Transportation, National Highway Traffic Safety Administration.

ommended levels of physical activity.[70] Similarly, bicyclist facilities have been shown to increase the safety of pedestrians for reasons discussed in Recommendation #2 and therefore also support walking behavior. However, the Blue Ridge Road District Study characterizes the pedestrian and bicycle environment in the BRRC as "very poor."[71] With the exception of the area around the Rex Healthcare complex, sidewalks are "severely limited," with large portions of Blue Ridge Road lacking any sidewalks at all.[72] Therefore, the project team and advisory board recommend that both public and private institutions in the BRRC work to provide sidewalks, walkways, and bicycle facilities along both sides of all streets within the BRRC. Specifically:

- **Ensure continuity of sidewalks and bicycle facilities through the districts.** Provide sidewalks on both sides of the street, with wider sidewalks along Blue Ridge Road and where higher volumes of foot traffic are expected, such as around the fairgrounds, N.C. State vet campus, hospital, museum, and PNC Arena.
- **Provide on-street bike lanes where it is safe to do so** along smaller side streets. Consider separate bike facilities (such as bike paths and cycle tracks) along high-volume roads where the average speed of vehicles exceeds 30 mph, such as Blue Ridge Road. For facilities owned by the N.C. Department of Transportation, the City of Raleigh should work with N.C. DOT to provide and connect bicycle facilities.
- **Provide places to walk within large, privately operated campuses** such as the Rex medical complex, the Centennial Biomedical Campus, and new developments on large parcels. Connect with greenway or area sidewalks for accessing other destinations.
- **Add pedestrian and bike facilities to the Wade Avenue Bridge.** This will allow pedestrians and bicyclists to cross travel north or south on Blue Ridge Road to cross Wade Avenue.
- **Institutionalize pedestrian-friendly practices as the development norm.**

## #2: TAKE STEPS TO MAKE BICYCLING AND WALKING SAFER AND MORE PLEASANT

>> Safety is an important consideration in the decision whether to walk or bike. Two types of safety are recognized in public health: (1) actual safety, that is, safety which can be measured (e.g., the number of pedestrian-vehicle crashes per mile walked),

[70] Reed, J. A., Wilson, D. K., Ainsworth, B. E., Bowles, H., & Mixon, G. (2006). Perceptions of neighborhood sidewalks on walking and physical activity patterns in a southeastern community in the US. Journal of Physical Activity & Health, 3(2), 243.
[71] City of Raleigh. (2012). Blue Ridge Road District Study. p. 12 http://www.raleighnc.gov/content/PlanUrbanDesign/Documents/BlueRidge/BlueRidgeRoadDistrictStudyFinalReport.pdf
[72] Ibid.

and (2) perceived safety, which is the subjective feeling of safety while in a particular place or engaged in an activity.[73] Both have important relationships to health. Increasing the actual safety of a location prevent injuries and fatalities, while increased levels of perceived safety are associated with more walking and biking.[74]

Increasing the amount and quality of pedestrian and bicyclist infrastructure can increase both actual and perceived safety. Along the roadway, pedestrians and bicyclists feel safer when they are separated from traffic.[75] Bicycle facilities can increase perceived safety for pedestrians by increasing separation from the road while providing increases in actual safety for bicycle users.[76] At intersection locations, high-visibility crosswalks, signals, curb extensions, and medians can reduce conflicts between pedestrians and motorists, increase pedestrian visibility and ease of crossing, and remind motorists to watch for pedestrians, which increases actual and perceived safety alike.[77]

It has been shown that increasing the number of bicyclists and pedestrians in and of itself increases safety for those road users. Studies have revealed that the more pedestrians and bicyclists use the road, the less likely it is for each person to be involved in a collision.[78] Busier sidewalks and bike lanes can increase perceived safety by increasing the number of eyes on the road, especially when other pedestrians and bicyclists have familiar faces. Our specific recommendations are to:

- **Enhance intersection locations with pedestrian and bicyclist infrastructure** such as median islands, curb extensions, etc., where appropriate.
- **Improve the walking and biking environment along Blue Ridge Road and other roadway segments.** Provide on-street parking or a similar buffer between pedestrians, bikes, and the road to reduce feelings of exposure to fast-moving cars.
- Measure motorist speeds along Blue Ridge Road and neighborhood roads to **determine whether traffic calming may be necessary**. Segments of the road are wide and could be calmed, as suggested in the small area plan. Consider lowering speed limits or using strategies that naturally slow down drivers, such as narrowing traffic lanes.
- **Provide wayfinding** for destinations accessible by foot and bicycle within the BRRC.
- **Add landscaping and employ placemaking strategies to increase visual interest.**
- **Provide adequate lighting at night** along public pedestrian and bicyclist facilities.

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73 Cho, G., Rodríguez, D. A., & Khattak, A. J. (2009). The role of the built environment in explaining relationships between perceived and actual pedestrian and bicyclist safety. Accident Analysis & Prevention, 41(4), 692-702.
74 Ibid.
75 McLeod, D. (2010). Multimodal Level of Service Analysis in the 2010 Highway Capacity Manual. http://trbperformance.org/node/444
76 Teschke, K., Harris, M. A., Reynolds, C. C., Winters, M., Babul, S., Chipman, M., ... & Cripton, P. A. (2012). Route infrastructure and the risk of injuries to bicyclists: A case-crossover study. American journal of public health, 102(12), 2336-2343.
77 Chen, L., Chen, C., Ewing, R., McKnight, C. E., Srinivasan, R., & Roe, M. (2013). Safety countermeasures and crash reduction in New York City—Experience and lessons learned. Accident Analysis & Prevention, 50, 312-322.
78 Jacobsen, P. L. (2003). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Injury Prevention, 9(3), 205-209.

- **Encourage bicycle facilities**—such as secured bicycle racks, personal lockers, and showers—**for new and existing office developments** to encourage bicycling as an alternative work commute.
- **Improve intersection geometry for pedestrians and bicyclists where necessary.** Even with sidewalks on all streets, large intersections and interchanges can be difficult for pedestrians to navigate.
- **Ensure that existing sidewalk facilities are in good condition and navigable for people of all abilities.**
- **Ensure that traffic light timing is appropriate for the crossing needs of pedestrians.**

## #3: INCREASE CONNECTIVITY OF PEDESTRIAN AND BICYCLING INFRASTRUCTURE

» The connectivity of walking and bicycle infrastructure is associated with both increased walking[79] and increased transportation walking.[80, 81] Connectivity refers to the number of blocks and intersections, as well as the presence of walking/biking infrastructure linking different destinations, namely because they help to provide more direct routes for accessing locations. Increasing the connectivity of the street network is an important component of the small area plan, as well as an important component of the validated walkability index used for the purposes of this HIA.

Greenway connectivity also has an important effect on how much people walk for recreation. The City of Raleigh has an extensive and valuable greenway network that passes through the BRRC study area. At the request of the advisory board, the project team conducted a series of trail user surveys and counts on the trail network adjacent to the N.C. Museum of Art. The visitor survey allowed the advisory board and project team to characterize trail users and understand the impact of the opening of the 3-mile House Creek Greenway in summer 2012. The greenway opening increased connectivity between the Reedy Creek Greenway that passes through the project area and the Crabtree Creek Greenway to the north. Visitor counts conducted before and after the opening of the House Creek Greenway showed that pedestrians increased by 3.8% and bicyclists increased by 14.5% following the completion of the trail. For this reason, the project team recommends continuing to increase the connectivity of greenways in addition to increasing the connectivity of sidewalks and walkways. Specifically:

[79] Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Annals of behavioral medicine, 25(2), 80-91.
[80] Berrigan, D., Pickle, L. W., & Dill, J. (2010). Associations between street connectivity and active transportation. International journal of health geographics, 9(1), 20.
[81] Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K., & Donovan, R. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. Social science & medicine, 56(8), 1693-1703.

- **Continue to link up existing greenways.** Connect the existing trails north around the Rex Hospital expansion and west to Schenk Forest. Connect the greenway at the N.C. Museum of Art under Wade Avenue to the N.C. State vet campus.
- **Create and provide districtwide maps** to help residents and visitors navigate the district on foot.
- New development and redevelopment should **provide pedestrian and vehicular connectivity between individual development sites** to provide alternative means of access along corridors.
- **Connect the N.C. State University campus to the facilities across Blue Ridge Road via a new east/west pedestrian connection.**
- **Treat the Capital Area Greenway Trail system as part of the city's transportation network** for bicycles and pedestrians and plan system connections accordingly.
- **Ensure that safe pedestrian walkways or multiuse paths** that provide direct links between roadways and major destinations such as transit stops, schools, parks, and shopping centers **are included in any new subdivision or development.**
- Increase street connectivity throughout the corridor to **create greater intersection density**, decreasing distances between destinations and providing diverse routes for pedestrians and bicyclists.

## #4: IMPROVE TRANSIT CONNECTIONS THROUGHOUT THE CORRIDOR

>> Although at first glance transit may not appear related to walking, one study found that 29% of people who use transit get 30 minutes a day of physical activity through walking to transit alone,[82] making public transportation an important supporter of regular physical activity. Also, because public transportation is better supported through greater density of users and land uses, the types of development that complement and maximize public transportation investments also favor greater numbers of trips by walking and biking. Our specific recommendations are to:

- **Create a light rail connection at Hillsborough and Blue Ridge roads.** Plan for pedestrian and bicyclist access to encourage fewer trips by car.
- **Strengthen the presence of public transportation in the corridor.** Fill in the "transit gap" and strengthen regional transit by connecting Triangle Transit to CATA service. Increase frequencies for service.
- **Support transit connections through the use of transit oriented development.** Develop or redevelop sites around bus and light rail stops to include residential, mixed-use, commercial, and office development.

[82] Besser, L. M., & Dannenberg, A. L. (2005). Walking to public transit: steps to help meet physical activity recommendations. American Journal of Preventive Medicine, 29(4), 273-280.

# #5: REQUIRE NEW DEVELOPMENTS TO ENHANCE WALKABILITY

>> The placement and proximity of destinations is one of the most important factors in determining how much people walk for transportation.[83] The presence and convenience of utilitarian destinations has been associated with walking for transportation, especially destinations such as grocery stores, restaurants, post offices, and banks.[84, 85, 86] A national survey of more than 12,000 adults found that the most common purpose of walking trips (38%) was for personal errands, such as going to the grocery store.[87] Another important factor is the density of housing, which can increase the number of people who can live within a short distance (generally ¼ to ½ mile) of commercial, retail, school, work, or transit-stop destinations. Higher density at the parcel level has been associated with odds of walking frequently for transportation.[88] Creating the conditions for such land use within the BRRC will require coordination between public and private agencies over many years but is supported by recent policies adopted as part of Raleigh's Unified Development Ordinance in 2013. Our specific recommendations are to:

- **Allow zoning/rezoning that facilitates mixed-use development along corridor.** Modify or adopt the Future Land Use plan as laid out in the 2030 Comp Plan.
- **Incentivize mixed-use development along Blue Ridge Road.** Work with private developers to provide incentives (bonuses, streamlined approvals) for mixed-use and compact development.
- Eliminate minimum parking zoning requirements. **Consider alternative parking provision strategies in light of the various facilities with ample parking (fairgrounds, N.C. State vet campus, hospital, museum, and PNC Arena) in the corridor**, and shared parking arrangements that take advantage of existing capacity, especially for a light-rail park-and-ride lot.
- **Redevelop unattractive or underutilized sites** to increase activity and make the area more attractive for new residents and development.
- **Follow development and redevelopment practices that support walking, biking, and transit use.**

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[83] Ewing, R., & Cervero, R. (2001). Travel and the built environment: a synthesis. Transportation Research Record: Journal of the Transportation Research Board, 1780(1), 87-114.
[84] Lee, C., & Moudon, A. V. (2006). Correlates of walking for transportation or recreation purposes. Journal of Physical Activity & Health, 3, S77.
[85] Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K., & Donovan, R. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. Social science & medicine, 56(8), 1693-1703.
[86] Owen, N., Humpel, N., Leslie, E., Bauman, A., & Sallis, J. F. (2004). Understanding environmental influences on walking: review and research agenda. American journal of preventive medicine, 27(1), 67-76.
[87] Royal, D., & Miller-Steiger, D. (2008). National Survey of Bicyclist and Pedestrian Attitudes and Behavior. US Department of Transportation, National Highway Traffic Safety Administration.
[88] Lee, C., & Moudon, A. V. (2006). Correlates of walking for transportation or recreation purposes. Journal of Physical Activity & Health, 3, S77.

- **Prioritize development that gives residents places to walk to.** Disincentivize new developments such as gas stations and drive-throughs.

## #6: TAKE ACTIVE STEPS TO ATTRACT DEVELOPMENT TO THE CORRIDOR

>> Given that North Carolina state agencies own many of the parcels along the corridor, development along the corridor will take time to materialize. The city needs to take active steps to engage land owners in conversations about the future of the corridor in order to attract development proposals that are consistent with the small area plan. Some of the strategies discussed above regarding rezoning and mixed development are conditional on the clearing of potential hurdles that exist among land owners. We recommend these specific short-term strategies to attract development to the corridor:

- **Create a 501(c)(3) to advocate for the implementation of the small area plan and ensure that walking- and biking-friendly projects are considered.** Involve BRRC residents to advocate for prioritization and funding of projects. Provide guidance for residents interested in reaching out to planners, developers, and elected officials as funding and projects are being decided.
- **Support the creation of an interagency state group for coordinating land-use issues in the BRRC.**
- **Prioritize the BRRC improvements identified in the city's Pedestrian Plan and other planning documents.** These planning documents were developed before the Blue Ridge Corridor Study. The study now provides a stronger case for prioritizing corridor improvements relative to other parts of the city. Thus, plan priorities should reflect the heightened importance of needed corridor improvements.
- **Examine potential infrastructure capacity issues along the corridor.** If necessary, follow up with a fiscal impact assessment of the districts in the small area plan to determine the potential cost to the city of upgrading existing water and sewer infrastructure in the corridor.
- **Explore financing options for the building of roads within the study area.** The planned widening of Blue Ridge Road partly funded through the recently passed $75 million city bond provides an opportunity to implement pedestrian and bicycle facilities and crossings (particularly over Wade Avenue). Some of the extra cost of enhancing the sorely needed street connectivity in the corridor will come from developers. However, the need appears so great that additional city funding may be required. Consider financing options for such infrastructure, including tax increment financing and a special assessment district.

## #7: ENCOURAGE BRRC RESIDENTS TO WALK

>> Studies have shown that an individual's attitude toward walking can be as much of a barrier as the built environment.[89] Although the project team believes it is important to first address many of the built environment factors that create a poor quality walking environment in the BRRC, we also believe it is important to consider strategies to promote walking at the individual level. Example programs include Safe Routes to School for school-age children and related programs such as walking school buses and bike trains, walking clubs or Meetup groups organized by the BRRC Work Group or local institutions, messaging or social media campaigns that promote walking as fun and/or important to long-term health, easy cruiser rides for bicyclists of all experience levels and abilities, and partnerships between public health professionals and area institutions to promote walking among area employees and/or residents (such as nature walks or geocaching events at the N.C. Museum of Art trails, free shoe fittings for walkers, pedometer giveaways, and lunchtime walks).

## SUPPORTIVE STRATEGIES

>> Create greater awareness of role of pedestrian/bike infrastructure in people's decisions to walk among residents of BRRC, area institutions, and the public.

>> Pursue local, state, or federal funding that will allow the city to prioritize the building of sidewalks. Seek grants from public health organizations, community development organizations, and economic development organizations. Would residents be willing to fund a local improvements fund for filling in sidewalks throughout the whole city? Given the short and long term health benefits we've laid out here, the City of Raleigh should consider creating or dedicating a funding stream for retrofitting all Raleigh streets with sidewalks.

>> Conduct a walkability audit with neighborhood residents to catalog existing infrastructure and identify priority areas for basis of advocacy efforts.

>> Conduct mental mapping exercises with neighborhood residents to understand which features of the neighborhood are desired or undesired. This project can give some inspiration: http://iwishthiswas.cc/

>> Reach out to Raleigh residents to garner support for changes to regional destinations, such as the museum and fairgrounds.

[89] Joh, K., Nguyen, M. T., & Boarnet, M. G. (2012). Can built and social environmental factors encourage walking among individuals with negative walking attitudes? Journal of Planning Education and Research, 32(2), 219-236.

>> Reach out to other advocacy groups that support walking, biking, transit-oriented development, and walkable development to enlist support for objectives.

>> Support N.C. Department of transportation efforts to make Blue Ridge Road a Complete Street.

>> Create excitement around the idea of making the Blue Ridge Road a demonstration project for walkability.

# 6. Appendices

## APPENDIX A:
## Active Transportation Health Impact Assessments in the United States

| HIA Name; Location; Year | Methods | Scoping | Assessment | Recommendations |
|---|---|---|---|---|
| Western SOMA Community Plan; San Francisco, CA; 2009 | Review of area plan; focus groups; Healthy Development Measurement Tool (HDMT); professional expertise | Traffic safety, pedestrian and bicycle environment, air quality, noise, housing, local economy, retail services and public transit services | Measured 30 community health objectives using the HDMT. Based on the area plans, evaluated whether or not the development targets met the benchmark, a minimum standard, does not meet any standard, or if there was insufficient information. | Support greater access to open space, child care and infrastructure to make it safer and easier for people to walk and bike. |
| Eastern Neighborhoods Rezoning and Area Plans[1]; San Francisco, CA; 2007 | Analysis of health effects associated with change in environment outcomes documented in an EIR; developed and used predictive model of vehicle pedestrian collisions | Roadway air pollutant emissions; noise related land use conflicts; pedestrian safety | 134,000 existing and 44,000 future neighborhood residents in area with land use conflicts among residential, industrial, and transportation uses; local health disparities related to area of residence, ethnicity, and measures of SES. Quantitative: Predict 20 additional pedestrian collisions per year. Qualitative: Mortality and respiratory morbidity for new residents near busy roadways; noise-related sleep disturbance | Exposure modeling and mechanical ventilation to mitigate land use–air quality conflicts; noise mitigation measures; traffic calming; intersection countermeasures; circulation changes and traffic demand reduction |
| East Bay Greenway[2]; Alameda County, CA; 2007 | Dialogue among area residents, neighborhood organizations, and health experts; literature review; expert review of scope; secondary data analysis | Physical activity; social cohesion; greening the landscape; motor vehicle use and air pollutants; safety concerns | Affected population mostly low SES and minority with high rates of obesity and chronic diseases. Quantitative: None. Qualitative: Reduced obesity, diabetes, heart disease, pedestrian and bicycle injuries, and osteoporosis; improved mental health and life expectancy | Optimize design to reduce pedestrian and bicyclist injury risks; incorporate public safety measures to reduce risk of crime |

[1] Dannenberg, A. L., Bhatia, R., Cole, B. L., Heaton, S. K., Feldman, J. D., & Rutt, C. D. (2008). Use of health impact assessment in the U.S.: 27 case studies, 1999–2007. American Journal of Preventive Medicine, 34(3), 241-256.

[2] Dannenberg, A., Rayman, J., Ricklin, A., Kennedy, S., Ross, C. (2011). Use of Health Impact Assessment to Improve Health Benefits of Transportation Projects and Policies in the United States, 2004-2011. Unpublished manuscript submitted for Transportation Research Board Annual Meeting.

[3] UCLA (2009). Still/Lyell Freeway Channel/Excelsior District. Health Impact Assessment Clearinghouse Learning & Information Center. http://www.hiaguide.org/hia/stilllyell-freeway-channelexcelsior-district.

[4] Humboldt County Public Health Branch, Humboldt Partnership for Active Living, and Human Impact Partners. (2008). Humboldt County General Plan Update Health Impact Assessment. http://www.healthimpactproject.org/resources/document/humboldt-county-general-plan-update.pdf

| HIA Name; Location; Year | Methods | Scoping | Assessment | Recommendations |
|---|---|---|---|---|
| Executive Park Sub Area Plan[1]; San Francisco, CA; 2007 | Application of HDMT to area plan for 71 acre mixed-use residential development; assessed 84 community-level indicators for area | Structured evaluation of existing conditions and development outcomes using HDMT | 2,800 units of new residential housing in area with inadequate neighborhood infrastructure; local health disparities related to area of residence, ethnicity, and measures of SES. Quantitative: None. Qualitative: Stakeholder interviews; evaluated land-use plan content against 87 HDMT development criteria | Increase specificity of plan's implementing actions; reduce area's isolation by improving transportation systems and access to goods and services; coordinate with other local development; 135 specific recommendations for area plan and planning process |
| Still/Lyell Freeway Channel in Excelsior District[3]; San Francisco, CA; 2009 | Door-to-door community surveys, traffic counts, outdoor air quality and noise modeling, outdoor air quality and noise exposure assessment, pedestrian environmental quality evaluation, historical document review, publicly available data from sources including hospitalization data, U.S. Census data, and traffic-related injury data | Traffic, air quality, environmental noise, pedestrian hazards, the community, community health outcomes, and community solutions | Entire study area exposed to a greater amount of $PM_{2.5}$ than the threshold they picked. HIA links unavailable | Retroactive HIA |
| Humboldt County General Plan Update[4]; Humboldt County, CA; 2008 | Assessed 35 health indicators for three different community plan alternatives using HDMT | Physical activity; cost of housing, services, transportation; air, water, noise quality; climate change; jobs; stress; access to goods, services, jobs, education; nutritional habits; crime; social cohesion | Plan A would increase affordable housing, decreased reliance on cars, increased access to goods, services, and emergency services, increase social connections, and develop the least amount of open space. | Recommended the community plan which provides for focused or concentrated growth. |
| MacArthur BART[1]; Oakland, CA; 2007 | Review of literature and planning documents; field visits; interviews with key stake-holders, content experts, area residents, and business people; secondary data analysis; quantitative health-effects forecasting tools | Affordable housing, employment opportunities, transportation access, physical activity, access to parks and green space, pedestrian safety, noise, air quality, social cohesion | 600 households who rent or buy housing units; Oakland residents including many of low SES Quantitative: 17% of residents near rail line will have disturbed sleep; increased cancer risk from freeway emissions; one extra pedestrian injury or death per 3.25 years; increased rental-housing supply for low income families Qualitative: Increased social interaction, facilitates routine physical activity for residents | Unbundle parking from housing unit sales; add bicycle parking; connect project to local bike network; recruit full-service grocery store; add pedestrian safety improvements; use building materials and ventilation systems to reduce allergens and toxic exposures |
| Oak to Ninth Avenue Project[1]; Oakland, CA, 2006 | Review of development proposal, EIA data, and literature; public input and interviews with key stakeholders; GIS mapping; quantitative forecasting; planning process provided minimal public involvement | Pedestrian safety, air quality, open space, environmental noise, housing affordability, public school capacity, social cohesion | 411,000 existing and 7500 future neighborhood residents, 19% area poverty rate; high housing costs; health disparities related to area of residence and SES. Quantitative: Loss of 15 acres of open space; pedestrian injuries; sleep disturbed by ambient noise; unmet housing and school needs; health effects of particulate matter. Qualitative: Open space adequacy and accessibility; social cohesion | Incorporate new public routes to waterfront park; add traffic-calming, lower speed limits, and other pedestrian safety measures; notify potential buyers of air quality risks |

[5] Human Impact Partners (2008) Pittsburg Railroad Avenue Specific Plan Health Impact Assessment. Oakland, California. http://www.healthimpactproject.org/resources/document/pittsburg-railroad-avenue-transit-oriented-development.pdf

[6] San Francisco Department of Public Health. (2008). Impacts on the Community Health of Area Plans for the Mission, East SoMa, and Potrero Hill/Showplace Square.

[7] St. Louis County Public Health & Human Services. (2011). Health Impact Assessment: Duluth, Minnesota's Complete Street Resolution, Mobility in the Hillside Neighborhoods and the Schematic Redesign of Sisth Avenue East. http://www.healthimpactproject.org/hia/us/hia-report/HIA-Sixth-Avenue-East-Final-Report-1.pdf

[8] Slotterback, C., Forsyth, A., Krizek, K., Johnson, A., & Pennucci, A. (2010). Testing Three Health Impact Assessment Tools in Planning: A Process Evaluation. Environmental Impact Assessment Review.

[9] City of Ramsey. (2008) City of Ramsey Health Impact Assessment. http://www.healthimpactproject.org/resources/document/city-of-ramsey.pdf

| HIA Name; Location; Year | Methods | Scoping | Assessment | Recommendations |
|---|---|---|---|---|
| Pittsburg Railroad Avenue Transit-Oriented Development[5]; Contra Costa, CA; 2008 | Review of the literature; mapping of existing retail services; field visits and site observations; interviews of residents, city officials, and involved stakeholders; assessment of pedestrian quality; mathematical models of air quality and noise impacts; analysis of project trip generation | Access to affordable housing, jobs and livelihood, transportation, retail and services, air quality, noise, asthma, injury, and physical and mental health | Increased use of BART, leading to increased physical activity; increased pedestrian collisions; increased vehicle trips | Implementing transportation strategies (parking, bus routes to BART, etc.) to encourage use of BART and decreased use of cars; install traffic calming measures; install bike lanes and bike support areas (bike racks, etc.) |
| South of Market, Mission, and Potrero/Showplace Square Area Plans[6]; San Francisco, CA; 2008 | Review of area plan; focus groups; HDMT; professional expertise | Environmental quality; housing; economy and industry; transportation; public infrastructure | Measured 27 community health objectives using the HDMT. Based on the area plans, evaluated whether or not the development targets met the benchmark, a minimum standard, does not meet any standard, or if there was insufficient information. | Numerous recommendations for revising the area plans |
| Sacramento Safe Routes to School[2]; Sacramento, CA; 2004 | Developed logic model to forecast outcomes; used data from National Household Transportation Survey, California Healthy Kids Survey, and literature; reviewed existing programs; consulted project coordinator | Physical activity, obesity, air pollution, pedestrian safety, neighborhood safety and crime | 1,186 elementary school students and their guardians; low-income population with high ethnic diversity. Quantitative: Students achieving 30 min/day of physical activity would increase from 13% to 21%; overweight students would reduce body mass index 0.09kg/$m^2$/year. Qualitative: Reduced air pollution exposure; small decrease in pedestrian injuries; enhanced social capital; reduced neighborhood crime | Encourage walk-to-school programs as one opportunity for children to be active; also encourage physical education classes and other active after-school programs and activities |
| Jack London Gateway senior housing project[1]; Oakland, CA; 2006 | Facilitated structured participant dialogue among area residents, neighborhood organizations, and environmental health experts; literature review; secondary data analysis | Outdoor and indoor air quality; access to retail services; environmental noise; pedestrian safety; community violence | Low-income and minority elderly; health disparities related to elderly minority populations. Quantitative: Increase housing affordability. Qualitative: Adverse impacts on respiratory illness, sleep disturbance, injury, physical activity, and fear of crime; potential benefits from retail services | Incorporate design features to improve indoor air quality; use noise-insulating features; make building nonsmoking; increase private security; add walkability amenities and traffic-calming measures; allow pets; provide transport to services |
| Treasure Island Transportation Plan[2]; San Francisco, CA; 2009 | Application of the Healthy Development Measurement Tool using all ten community level health objectives within only one of the six healthy city vision elements: Sustainable and Safe Transportation | Physical activity, air quality, safety/injury, access to multimodal transportation | People living and visiting Treasure Island; no health disparities identified. Quantitative findings: None. Qualitative findings: Current density/development targets will increase physical activity and decrease vehicle pollution; proposed traffic demand management will promote more trips by bike, foot, or transit; traffic calming measures will decrease vehicle collisions and pedestrian injuries | Eliminate parking requirements; specify parking maximums; create pedestrian/bike/traffic calming improvements map for plan; address economic barriers to public transit use; prioritize pedestrian improvements at high risk locations |
| Derby Redevelopment[1]; Commerce City, CO; 2007 | Literature review; input from community and local business association; walkability assessment; GIS mapping Photovoice project; recommendations from walkability and transportation planning and public policy consultants | Physical activity, nutrition | 27,000 residents of historic Commerce City; groups at high risk for physical inactivity include children and teens, elderly, low-income individuals and Hispanic and black residents. Quantitative: None. Qualitative: Increased bicyclist and pedestrian physical activity and safety; possible decrease in crime and fear of crime; favorable environment for expanding healthy food options | Take action to spur redevelopment plan; fund traffic calming, parks and open space; prepare bicycle and pedestrian plan; add affordable housing and universal design features; create a "Clean and Safe" Program of property maintenance and code enforcement for junk, weeds, and trash; police and community surveillance |

[10] Buescher, B., Harker, L., Kaur, H., & Mote, K. (2011). Aberdeen Pedestrian Transportation Plan Health Impact Assessment.

| HIA Name; Location; Year | Methods | Scoping | Assessment | Recommendations |
|---|---|---|---|---|
| Atlanta Beltline[2]; Atlanta, GA; 2007 | Expert and stakeholder opinions; community survey; literature review; HIA was conducted in parallel with multiple city-initiated planning processes | Built environment and land use patterns; transit access; pedestrian safety; physical activity; social capital; quality of life; air and water quality; noise | 200,000 current and 50,000 future area residents and 230,000 area workers; project may improve health disparities associated with low SES. Quantitative: Increase in physical activity and in access to green space and transit; little impact on air quality. Qualitative: Increase social equity and quality of life, decrease injury and crime | Encourage faster progress than current 25-year schedule to obtain earlier health benefits; add health professional to advisory board; add more parks to underserved area; assure adequate affordable housing is built |
| Buford Highway Redevelopment[2]; Decatur, GA; 2004 | Expert opinion, literature review and modeling | Built environment, pedestrian safety; physical activity; air pollution | 14,000 people in highway corridor area; project designed to reduce injuries and other health disparities in low-income immigrant population. Quantitative: Estimated 6.1 fewer injuries and 1.6 fewer fatalities to pedestrians, 73.8 fewer motor vehicle injuries per year; 73 minutes per week more physical activity; no change in air pollution. Qualitative: Increased safety and social capital | Use incremental approach for redeveloping the area, increase housing density, assure mixed-income housing including affordable housing |
| City of Decatur Community Transportation Plan[2]; Decatur, GA, 2007 | Rapid HIA; input from community leaders and local health and planning experts; literature review | Physical activity; access to health-promoting goods and services; safety; social capital | 20,000 residents and numerous people who work in or visit Decatur; increased health risks associated with age, income and disabilities. Quantitative: None. Qualitative: Improved bicyclist and pedestrian safety; improved access; increased opportunities for physical activity and building social capital | Prioritize safety issues and connectivity to promote active travel for commuting and recreation; improve intersections for users of all abilities; assign staff person to coordinate the City's Active Living initiatives |
| 6th Avenue East Duluth HIA[7]; Duluth, MN; 2011 | Redesign study, public outreach and workshops, master list of health indicators from SFDPH | Accessibility and safety; physical activity; livability | Qualitative assessment using mainly anecdotal evidence (residents mentioned that decreasing the number of bus stops by half would make it difficult for elderly and disabled) | Additional bus stops, additional traffic signals, official bike route, develop plan to clear snow from pedestrian medians, provide safe crosswalks, encourage mixed use development |
| Apple Valley[8]; Dakota County, MN; 2010 | Rapid HIA; No stakeholder involvement, primarily run by the planning department | Information not publicly available | Information not publicly available | Used to inform Comprehensive Plan update |
| City of Ramsey HIA[9]; Ramsey, MN; 2008 | Threshold Analysis developed by Design for Health | Accessibility; air quality; environmental and housing quality; food; mental health; physical activity; safety; social capital; water quality | Using threshold analysis, points were awarded to each category. Awarded a total 32 points out of 100: 0 in accessibility as mostly rural development with no transit, 0 in proximity to fruit and vegetables, and 0 in access to parks, open space, and trails | Ensure that when the city is fully developed, at least 50% of residents live within a 600m walking buffer of an active park space and a trail, enforce complete streets |
| Lowry Corridor Project[2]; Minneapolis, MN; 2007 | Rapid desktop HIA; literature review; secondary data analysis of planning documents, census data and injury data | Social capital, employment opportunities, pedestrian safety, physical activity | 18,000 residents in neighborhoods affected by project; health disparities associated with concentrated poverty and unemployment. Quantitative: None. Qualitative: Increase social supports; decreased fear of crime; increased physical activity and access to transit; increased mobility for people with disabilities | Install pedestrian-level lighting; driver-feedback speed limit signs in pedestrian and school areas; 'Share the Road' signs; increased public signage and maps for public transit routes |
| Xcel Energy Corridor[2]; Bloomington, MN; 2008 | Community involvement exercise: Brainstorming broad health impacts; expert opinion | Access to trails for physical activity | City population ~86,000; >11% non-white. Little information available on assessment step | Implement plan to connect walk/bike trails through the Xcel Energy Corridor |

[11] BicycleHaywoodNC, and Haywood County. (2011). Haywood County Comprehensive Bicycle Plan Health Impact Assessment. http://www.healthimpactproject.org/resources/document/Haywood-County-NC-Comprehensive-Bike-Plan-HIA.pdf
[12] Madrigal, Therese, Kate Wells, and Kim Curley. (2010). Healthy Tumalo Community Plan. http://www.healthimpactproject.org/resources/document/Tumalo-Community-Plan.pdf
[13] Nashville Area MPO. (2010). 2035 Regional Transportation Plan. http://www.healthimpactproject.org/resources/document/nashville-northwest-corridor-transit.pdf

| HIA Name; Location; Year | Methods | Scoping | Assessment | Recommendations |
|---|---|---|---|---|
| The Impact of Highway 550 Design on and Safety[2]; Cuba, NM, 2011 | Rapid HIA based on existing data and published literature; walkability workshop for community members and federal, state and local partners | Pedestrian-vehicle related crashes; pedestrian safety; opportunities for physical activity; social capital; economic vitality | Rural low income community of 8,800 people; 36% Hispanic, 36% Native American; Quantitative: High rates of obesity and diabetes; Qualitative: Social capital, economic vitality | Add or upgrade sidewalks; upgrade driveway and road crossing ramps to ADA standards; buffer between vehicular traffic and sidewalk; provide pedestrian-scale lighting, shade and benches; use median islands spaced to accommodate pedestrian destinations; explore traffic calming |
| Aberdeen Pedestrian Transportation Plan HIA[10]; Aberdeen, NC; 2011 | Peer-reviewed literature; observational data; mapped children's activity spaces using ArcGIS; stakeholder input interviews and survey data. | Children's physical activity; including recreation and active transportation to school | Children between the ages of 4 and 15 living in Aberdeen, NC; Quantitative: none; Qualitative: increased walking and physical activity, more students walking to school, decrease in unsafe crossings | Encourage public information campaigns, safe routes to school, crossing guards, and patrol officers |
| Haywood County Comprehensive Bicycle Plan HIA[11]; Haywood, NC; 2011 | Peer-reviewed literature; review of existing plans | Physical activity | Out of 28 goals and objectives, 15 had strong evidence from the literature to support increased physical activity, 9 had moderate evidence, and only 4 had little evidence | Unknown |
| Interstate 75 Focus Area Study[2]; Cincinnati, OH; 2010 | Literature review; review of existing plans | Air quality, motor vehicle traffic, community displacement | Low income neighborhoods with unfavorable health indicators. Quantitative: Proposed pre-, during-, post-construction air quality study. Qualitative: Increase physical activity, decrease cardiovascular disease, diabetes, obesity, osteoporosis; "root shock" to residents displaced from homes | Maintain community cohesion and access during displacement; promote landscaping and green space; create safe, walkable streets; install bike and pedestrian facilities; improve connectivity; create affordable housing opportunity; include HIA recommendations in construction contracts; install traffic calming devices; reduce construction noise; monitor air quality during and after construction |
| Sellwood Bridge HIA[2]; Portland, OR; 2011 | Review of Draft Environmental Impact Statement and Locally Preferred Alternative; literature review | Pedestrian and bicyclist safety; air quality during construction; noise levels during construction | Bicycle and pedestrian users of bridge; construction workers; area residents and park users; health risks due to air pollution and noise during construction; Quantitative: Bicycle and foot traffic on bridge estimated to increase 1,600% to 1,700% by 2036; Qualitative: "Safety in numbers" may improve safety for pedestrian and bike users | Use signage and lane markings on shared use paths; consider visual and physical barriers between the motor vehicle and on-road bike lanes; continue to seek design input from Bicycle/ Pedestrian Working Group; promote use of clean diesel technology and practices from contractors; monitor project-related air quality during construction; adjust construction schedule to allow quiet for residents |
| Tumalo Community Plan[12]; Tumalo, Oregon; 2010 | Advisory committee; listening sessions; literature review | Physical activity; traffic safety; "rural livability," which often speaks to social capital/cohesion; access to goods and services; and frequency of recreation | Nothing quantitative, primarily based off of literature | Improving the safety and accessibility of the major highway that runs through town; creating new parks and other necessary infrastructure to maximize the safe and healthy use of riverfront property as a recreational facility; and building trails or other connections between existing recreational facilities and downtown, local schools and businesses |

[14] Public Health - Seattle and King County, and Puget Sound Clean Air Agency. (2008). "SR 520 Health Impact Assessment." http://www.healthimpactproject.org/resources/document/State-Route-520-Bridge.pdf

| HIA Name; Location; Year | Methods | Scoping | Assessment | Recommendations |
|---|---|---|---|---|
| I-5 Columbia River Crossing[2]; Portland, OR; 2008 | Formed inter-agency workgroup; literature review; expert opinion; HIA submitted as part of public comment period for DEIS | Access to transportation options; safety; air quality; noise; environmental justice issues | High proportion of non-white, low-income residents relative to other areas in region; population reports high exposure to noise and poor air; Quantitative: None; Qualitative: Improved access to walk/bike and transit; improved mobility for vulnerable populations; increased noise; increased air pollution | Maintain community cohesion while improving access; improve road safety; provide bike and pedestrian facilities; establish health-based standards for project; conduct further analysis on: traffic projections beyond 2030, air quality and noise impacts, widening bike/pedestrian paths, local street access |
| Nashville Northwest Corridor Transit[13]; Nashville, TN; 2010 | Used Regional Bicycle and Pedestrian Study; public and stakeholder comments | Information not publicly available | Information not publicly available | Informed one TOD site: senior housing; community gardens; walking paths; a community gathering space; and public art |
| Clark County Bicycle and Pedestrian Master Plan[2]; Clark County, WA; 2010 | Literature review; analysis of census data and local data on health indicators; Advisory Committee including public health, planning, transportation, parks, and area resident representatives | Physical activity; pedestrian and bicyclist injuries | People living in Clark County; high rates of overweight and obesity; special attention on low income population, youth, and unincorporated areas; Quantitative: Access to sidewalks and bike trails; pedestrian and bicyclist injury rates | Geographic focus on moderate-high density disadvantaged areas; implement a variety of bikeway facility types; add parking management program; create policies to increase bike/pedestrian access to nutritious food; design for inexperienced cyclists; include health and equity in project evaluation criteria |
| Clark County Highway 99 Sub-Area Plan[2]; Vancouver, WA; 2008 | Community input; analysis of state and local health data; literature review | Health equity, access to public transit, affordable housing, living wage jobs, air quality, noise, access to healthy foods, physical activity, pedestrian access, motor vehicle injury | Area population projected to grow 1.7% and 35% expected to be 50+ by 2025; 20% high school students have asthma; 66% youth and 45% adults do not get enough physical activity. Quantitative: None. Qualitative: With best aspects of project: improved health equity, physical activity, social cohesion, decreased obesity and homelessness; Without project: increased poverty/crowding, violence | Create mixed-used/ mixed-income community with new zoning rules; increase access to public transit; improve housing conditions for low income residents; plant trees and form parks; encourage locating grocery stores in neighborhoods; make the area bicycle and pedestrian friendly |
| State Route 520 Bridge[14]; Seattle and King County, WA; 2008 | DEIS analysis; literature review; public and stakeholder comments | Air quality, water quality, green space, physical activity, noise, mental well-being, safety, social connections, and emergency medical services | Assesses three different alternatives for the SR 520 Bridge; Quantitative: None. Qualitative: reduced greenhouse gas emissions and other air pollutants through the use of alternatives to single-occupant vehicles, increased opportunities for physical activity, and improved social connections. | Increase and improve transit service to meet increased demand, attract more riders, and reduce air pollution; Install connected walking and bicycling facilities throughout the corridor; Create a common way finding system |
| King Street Station Multimodal Hub: Health Impact Assessment[2]; Seattle, WA; 2011 | Review of literature, existing data, and comments from public meetings; interviews with relevant agencies; site visits; Google Maps | Health equity; safety and injury; air and noise pollution; social capital and mental health; physical activity and obesity | Transit hub users; residents of surrounding neighborhoods who are more racially diverse, older, and less affluent than rest of city; Quantitative: None. Qualitative: Potential of infrastructure changes to improve safety and security of local residents and of bicycle, pedestrian and automobile users; potential of improved way finding and place making to increase social capital and mental health of surrounding neighborhoods; potential of infrastructure changes to encourage transit use, biking and walking as well as use of green space | Conduct air quality and noise monitoring and mitigation during construction; close bus stops only when absolutely necessary; pursue lidding of railroads to reclaim space for pedestrians and green space; transform street reroute into green, public space and use programming; implement human-scale, iconic design features to unite disparate transit stations; install canopies, benches, way finding tools, and street lighting; establish methods to monitor progress toward recommendations |

# APPENDIX B:
# BRRC Resident Survey

### *SECTION 1: GENERAL HEALTH*

1) Would you say that in general your health status is: (Please circle one)
   - ❑ Excellent
   - ❑ Very good
   - ❑ Good
   - ❑ Fair
   - ❑ Poor
   - ❑ Don't know/not sure
   - ❑ Refuse to say

2) Have you ever been told by a doctor, nurse, or other health professional that you have or have had the following health conditions?

| | | Yes | No | Yes, female told only during pregnancy | Told borderline | Don't know | Prefer not to say |
|---|---|---|---|---|---|---|---|
| a. | High blood pressure? | ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |
| b. | Diabetes? | ❑ | ❑ | ❑ | ❑ | ❑ | ❑ |

| | | Yes | No | Don't know | Prefer not to say |
|---|---|---|---|---|---|
| c. | Heart attack? | ❑ | ❑ | ❑ | ❑ |
| d. | Angina or coronary heart disease? | ❑ | ❑ | ❑ | ❑ |
| e. | Stroke? | ❑ | ❑ | ❑ | ❑ |
| f. | Asthma? | ❑ | ❑ | ❑ | ❑ |
| g. | COPD, emphysema or chronic bronchitis? | ❑ | ❑ | ❑ | ❑ |
| h. | Cancer? | ❑ | ❑ | ❑ | ❑ |

### *SECTION 2: PHYSICAL ACTIVITY AND TRAVEL BEHAVIOR*

3) How many times a week do you usually do 20 minutes or more of vigorous-intensity physical activity? This is activity that causes large increases in breathing or heart rate, such as heavy lifting, heavy yard work, jogging, aerobics, or fast bicycling.
   ❑ 3 or more times a week ❑ 1 or 2 times a week ❑ None

4) How many times a week do you usually do 30 minutes or more of moderate-intensity physical activity? This is activity that causes small increases in breather or heart rate, such as walking, carrying light loads, bicycling at a regular pace, or vacuuming (Note: This does not include vigorous-intensity activity).
   ❑ 5 or more times a week ❑ 3 to 4 times a week ❑ 1 or 2 times a week ❑ None

The following questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

5) During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram? If zero, please skip to question 7.
   _____ **days per week**

6) How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?
   _____ **minutes per day**

7) During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**? If zero, please skip to question 9.
   _____ **days per week**

8) How much time did you usually spend on one of those days to **bicycle** from place to place?
   _____ **minutes per day**

9) During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**? If zero, please skip to question 11.
_____ **days per week**

10) How much time did you usually spend on one of those days **walking** from place to place?
_____ **minutes per day**

11) In the past week, how frequently did you travel to other places within the Blue Ridge Road neighborhood, like a grocery store, museum, workplace, or gas station?
_____ **trips**

12) Of those trips reported in question 11, how many trips were taken by the following modes of transportation?

| | | |
|---|---|---|
| _____ car | _____ bicycle | _____ walking |
| _____ taxi | _____ public bus | _____ other |

13) Do you own a car? ❑ Yes ❑ No

### *SECTION 3: NEIGHBORHOOD ENVIRONMENT*

14) For this question, please indicate your agreement level with the statements below by checking the appropriate box. When we refer to the Blue Ridge Road neighborhood, we mean the area along Blue Ridge Road, bounded to the north by Edwards Mill Road, to the south by Hillsborough Street, to the west by Edwards Mill Road, and to the east by I-440.

| | | Strongly disagree | Somewhat disagree | Somewhat agree | Strongly agree |
|---|---|---|---|---|---|
| a. | There are sidewalks on most of the streets in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| b. | Sidewalks are separated from the road/traffic in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| c. | The Blue Ridge Road neighborhood streets are well lit at night. | ❑ | ❑ | ❑ | ❑ |
| d. | There are crosswalks and pedestrian signals to help walkers cross busy streets in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| e. | There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| f. | The speed of traffic on most nearby streets is usually slow (30 mph or less). | ❑ | ❑ | ❑ | ❑ |
| g. | Most drivers exceed the posted speed limits while driving in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| h. | It is easy to find my way around the Blue Ridge Road neighborhood when walking or biking. | ❑ | ❑ | ❑ | ❑ |
| i. | There are trees along the streets in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| j. | There are many interesting things to look at while walking in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| k. | The Blue Ridge Road neighborhood is generally free from litter. | ❑ | ❑ | ❑ | ❑ |
| l. | There are many attractive natural sites in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |
| m. | There are attractive buildings/homes in the Blue Ridge Road neighborhood. | ❑ | ❑ | ❑ | ❑ |

## *SECTION 4: NC MUSEUM OF ART TRAIL USAGE*

15) On average, how often do you use the trails behind the NC Museum of Art?
- ❑ Daily
- ❑ 3-5 times a week
- ❑ 1-2 times a week
- ❑ A couple of times in the month
- ❑ Once a month
- ❑ A few times a year
- ❑ Once a year or less
- ❑ Never
- ❑ Don't know

16) How easy is it to find your way on the trails behind the NC Museum of Art?
- ❑ Very easy
- ❑ Somewhat easy
- ❑ Average
- ❑ Somewhat difficult
- ❑ Very difficult
- ❑ Don't Know

## *SECTION 5: ABOUT YOU*

17) Do you work outside the home? ❑ Yes ❑ No

18) If you work outside the home, what is the nearest street intersection to your current place of work? (Please list 2 streets)

______________________________________________________________________

19) Sex ❑ Male ❑ Female

20) What is your age?
- ❑ 18-24
- ❑ 25-34
- ❑ 35-44
- ❑ 45-54
- ❑ 55-64
- ❑ 65-74
- ❑ 75-84
- ❑ 85+

21) Are you of Hispanic, Latino, or Spanish origin? ❑ Yes ❑ No

22) What is your race?
- ❑ White
- ❑ Black
- ❑ American Indian or Alaska Native
- ❑ Asian
- ❑ Other
- ❑ Two or more races

23) What is your marital status?
- ❑ Married
- ❑ Widowed
- ❑ Divorced
- ❑ Separated
- ❑ Never married

24) What is the highest degree or level of school you have COMPLETED?
- ❑ Some high school
- ❑ High school graduate – high school diploma or equivalent
- ❑ Some college, but no degree
- ❑ Associate degree
- ❑ Bachelor's degree
- ❑ Master's degree
- ❑ Professional degree
- ❑ Doctorate degree

25) Which of these categories best describes your annual household income?
- ❑ Less than $10,000
- ❑ $10,000 to $14,999
- ❑ $15,000 to $19,999
- ❑ $20,000 to $24,999
- ❑ $25,000 to $29,999
- ❑ $30,000 to $34,999
- ❑ $35,000 to $39,999
- ❑ $40,000 to $44,999
- ❑ $45,000 to $49,999
- ❑ $50,000 to $59,999
- ❑ $60,000 to $74,999
- ❑ $75,000 to $99,999
- ❑ $100,000 to $124,999
- ❑ $125,000 to $149,999
- ❑ $150,000 or $199,999
- ❑ $200,000 or More

26) About how much do you weigh without shoes? __ __ __ lbs

27) About how tall are you without shoes? __ __/__ __ ft/in

# APPENDIX C:
# Articles Included in Walkability Literature Review

| | Independent variable | Dependent variable/ outcome measure |
|---|---|---|
| Saelens, B. E., Sallis, J. F., Frank, L. D., Cain, K. L., Conway, T. L., Chapman, J. E., ... & Kerr, J. (2012). Neighborhood environment and psychosocial correlates of adults' physical activity. Med Sci Sports Exerc, 44(4), 637-646. | Walkability characteristics<br>Household income | Accelerometer-measured MVPA, self-reported transportation walking, and self-reported leisure walking |
| Freeman, L., Neckerman, K., Schwartz-Soicher, O., Quinn, J., Richards, C., Bader, M. D., ... & Rundle, A. G. (2012). Neighborhood Walkability and Active Travel (Walking and Cycling) in New York City. Journal of Urban Health, 1-11. | A neighborhood walkability scale that measured residential, intersection, and subway stop density; land use mix; and the ratio of retail building floor area to retail land area | Number of episodes of active travel (walking and cycling), also measured proportion of those who reported no active travel. |
| Sehatzadeh, B., Noland, R. B., & Weiner, M. D. (2011). Walking frequency, cars, dogs, and the built environment. Transportation research part A: policy and practice, 45(8), 741-754. | Walkability index | Frequency of walking |
| Adams, M. A., Sallis, J. F., Kerr, J., Conway, T. L., Saelens, B. E., Frank, L. D., ... & Cain, K. L. (2011). Neighborhood environment profiles related to physical activity and weight status: A latent profile analysis. Preventive medicine, 52(5), 326-331. | Walkability, four categories: Low walkability/transit and recreational sparsity, low walkability and recreational sparsity, moderate walkability and recreational density, and high walkability and recreational density | Minutes of moderate to vigorous physical activity (MVPA) per day<br>Minutes of transport walking per week<br>Minutes of leisure walking per week |
| Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., ... & Kerr, J. (2009). Neighborhood built environment and income: examining multiple health outcomes. Social science & medicine, 68(7), 1285-1293. | Walkability of neighborhood (low or high) divided into two income measures (low or high) to create four quadrants | Minutes per day of moderate-to-vigorous physical activity<br>Minutes per week of transport walking<br>Minutes per week of leisure walking |
| Wells, N. M., & Yang, Y. (2008). Neighborhood design and walking: a quasi-experimental longitudinal study. American Journal of Preventive Medicine, 34(4), 313-319. | Characterization of neighborhood design: Neo-traditional compared or conventional suburban | Walking: Steps per week calculate by pedometer |
| Lovasi, G., Moudon, A., Pearson, A., Hurvitz, P., Larson, E., Siscovick, D., ... & Psaty, B. (2008). Using built environment characteristics to predict walking for exercise. International Journal of Health Geographics, 7(1), 10. | Walkability | Walking for exercise |
| Frank, L. D., Saelens, B. E., Powell, K. E., & Chapman, J. E. (2007). Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity?. Social science & medicine, 65(9), 1898-1914. | A walkability index composed of measures of retail floor area, land use mix, net residential density, and intersection density. This study added a "neighborhood preference" factor as well | Percent of survey respondents taking walking trips |
| Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use to health: associations between neighborhood walkability and active transportation, body mass index, and air quality. Journal of the American Planning Association, 72(1), 75-87. | Walkability within a 1 km buffer, composed of net residential density, street connectivity, land use mix, and retail floor area | Time spent in active travel, measured using IPAQ |
| Rodríguez, D. A., Khattak, A. J., & Evenson, K. R. (2006). Can new Urbanism encourage physical activity?: Comparing a new Urbanist neighborhood with conventional suburbs. Journal of the American Planning Association, 72(1), 43-54. | Neighborhood type: New Urbanist or conventional suburban | Physical activity |
| Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. American journal of preventive medicine, 28(2), 117-125. | A walkability score consisting of objective measures of land-use mix, residential density and intersection density. | Minutes per day of moderate intensity physical activity<br>Meets recommendation of ≥30 minutes of moderate-intensity physical activity on ≥1 study days |
| Cao, X. J., Mokhtarian, P. L., & Handy, S. L. (2009). The relationship between the built environment and nonwork travel: A case study of Northern California. Transportation Research Part A: Policy and Practice, 43(5), 548-559. | Neighborhood design: Traditional or suburban | Walk trips |

# APPENDIX D: Demographic Characteristics of BRRC Survey Respondents

| Demographics | Survey respondents | BRRC study area |
|---|---|---|
| Total population | 386 | 10,443 |
| **Gender** | | |
| Female | 62.9% | 51.8% |
| Male | 37.1% | 48.2% |
| **Household income** | | |
| Less than $10,000 | 1.4% | 5.8% |
| $10,000 to $19,999 | 3.1% | 9.1% |
| $20,000 to $29,999 | 5.2% | 12.1% |
| $30,000 to $39,999 | 5.5% | 13.9% |
| $40,000 to $49,999 | 6.4% | 10.8% |
| $50,000 to $74,999 | 16.1% | 14.8% |
| $75,000 to $99,999 | 16.8% | 7.9% |
| $100,000 to $124,999 | 13.9% | 9.1% |
| $125,000 to $149,999 | 6.6% | 4.5% |
| $150,000 to $199,999 | 11.3% | 4.2% |
| $200,000 or more | 13.6% | 7.9% |
| **Age** | | |
| Under 18 years* | --- | 20.0% |
| 18 to 24 years | 2.9% | 19.3% |
| 25 to 34 years | 9.8% | 17.2% |
| 35 to 44 years | 15.0% | 12.9% |
| 45 to 54 years | 16.4% | 10.9% |
| 55 to 64 years | 22.4% | 10.0% |
| 65 to 74 years | 16.9% | 5.5% |
| 75 to 84 years | 10.6% | 3.0% |
| 85 years and over | 6.1% | 1.2% |
| **Race/ethnicity** | | |
| White | 91.3% | 66.4% |
| Black or African American | 5.0% | 18.6% |
| Hispanic (of any race) | 1.7% | 11.0% |
| American Indian and Alaska Native | 0.0% | 0.5% |
| Asian | 1.3% | 5.2% |
| Native Hawaiian | -- | 0.0% |
| Other | 0.5% | 8.0% |
| Two or more | 1.8% | 1.2% |
| **Educational attainment** | | |
| Less than high school | 0.3% | 6.8% |
| High school graduate | 4.5% | 10.9% |
| Some college | 18.2% | 28.2% |
| Bachelor's degree | 37.1% | 30.6% |
| Master's degree | 23.2% | 15.8% |
| Professional school degree | 3.9% | 3.7% |
| Doctorate degree | 12.9% | 4.1% |

* Data not collected from respondents younger than 18.

# APPENDIX E: Method for Calculating Health Benefits

This appendix describes the equations used to estimate the health benefits attributable to increased walking for transportation that might occur among BRRC residents if the neighborhood is redesigned. We present the method stepwise. For each step, key assumptions are highlighted. In addition, we highlight new research that could be carried out to increase the certainty in the estimates presented in this HIA.

In all of these calculations, we assume that the build-out of the redesigned BRRC will be completed by 2023. We then assume that benefits first begin to accrue five years later, in 2028. We estimate benefits accruing over the subsequent 20 years, through the year 2048, since a 20-year horizon is common in planning capital investments. We estimate cases of each health event avoided in each year between 2028 and 2048. We then estimate the economic value, in today's dollars, of the sum total of all the benefits.

**Step 1:** Estimate the minutes per day that current BRRC residents spend walking for transportation. (As discussed in the main text, BRRC employees are not included in the analysis. Because of this, our figures are likely to underestimate the health benefits.)

The main text describes the survey used to estimate the amount of time (in minutes per day) that current BRRC residents spend walking for transportation. In the equations below, we denote this random variable as $w_{current}$.

*Key assumptions:* Survey respondents accurately reported their walking behavior; the survey sample is representative of the BRRC resident population.

*Research needs:* Epidemiologic study of BRRC current residents, using pedometers, to estimate current walking behavior.

**Step 2:** Estimate the minutes per day that BRRC residents of the future would spend walking if the small-area plan were completely built out.

In a large study quantifying the relationship between the built environment and walking behavior, Sallis et al. observed that among residents of 16 low-income neighborhoods in Baltimore, those living in neighborhoods with walkability scores below 0.03 spent on average 15.6 (SD=1.2) minutes per week walking for transportation.[15] In contrast, those in low-income neighborhoods with walkability scores greater than or equal to 0.03 averaged 36.2 (SD=1.2) minutes per week of walking for transportation. (The main text explains the meaning of the walkability score.)

[15] Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., ... & Kerr, J. (2009). Neighborhood built environment and income: examining multiple health outcomes. Social science & medicine, 68(7), 1285-1293.

We assumed that the proportionate change in time spent walking for transportation in the Blue Ridge Road Corridor would be the same as Sallis et al. observed in Baltimore: that is, on average, residents in a redesigned BRRC would spend on average 36.2/15.6 = 2.3 times as long walking per day as under current conditions. Therefore, in the newly designed BRRC, the amount of time spent walking for transportation is given by

$$W_{new} = \frac{Baltimore_{high}}{Baltimore_{low}} W_{current} \tag{1}$$

where $Baltimore_{high}$ and $Baltimore_{low}$ are assumed to be normally distributed random variables with mean=36.2 (SD=1.2) and mean=15.6 (SD=1.2) minutes per week, respectively.

*Key assumption:* The amount of time spent walking for transportation will change in a redesigned BRRC proportionately by the same amount as Sallis et al. observed in a previous study in low-income neighborhoods in Baltimore.

*Future research needs:* The effect of redesigning the BRRC on walking behavior could be estimated with much greater confidence if an epidemiologic study similar to that carried out by Sallis et al. could be performed in the Raleigh metropolitan area, provided that environments similar to the current and proposed BRRC were included.

**Step 3:** Estimate the fraction of deaths and chronic diseases that could be avoided each year in the BRRC if walking increases as predicted in a redesigned BRRC.

This step involves calculated a quantity known as the "attributable fraction" (*AF)* for each health endpoint (mortality, coronary heart disease, stroke, diabetes, and hypertension). The *AF* is a fundamental concept in public health. Rothman and Greenland (1998[16], cited in Hanley 2001[17]) define *AF* as "the fraction of all cases (exposed and unexposed) that would not have occurred if exposure had not occurred." Since walking is a beneficial or protective behavior (in more conventional public health applications, such as analysis of smoking effects on population health, the exposure is detrimental), the *AF* also is known as the prevented fraction. We calculate the number of cases that could be prevented if BRRC residents were "exposed" to an environment that enables them to walk more. The *AF* is calculated as follows (see Hanley 2001 for a derivation):

$$AF = \frac{\int_{w=0}^{\infty} (1 - RR(w)) f(w) dw}{1 + \int_{w=0}^{\infty} (1 - RR(w)) f(w) dw} \tag{2}$$

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[16] Hanley, J. A. (2001). A heuristic approach to the formulas for population attributable fraction. Journal of Epidemiology and Community Health, 55(7), 508–14.
[17] Rothman, K. J., & Greenland, S. (1998). Modern Epidemiology. Lippincott, Williams & Wilkins.

where $w$ is the number of minutes spent walking for transportation per day; $RR(w)$ is the risk of the adverse health outcome occurring in an individual who spends $w$ minutes per day walking for transportation, as compared to an individual who spends no time walking for transportation; and $f(w)$ is the probability distribution of time spent walking for transportation.

To estimate the benefits of rebuilding the BRRC as planned, we subtract the fraction of deaths avoided due to walking for transportation in the redesigned BRRC from that already avoided due to the current walking behavior of residents:

$$AF_{new} = \frac{\int_{w=0}^{\infty}(1-RR(w))f_{new}(w)dw - \int_{w=0}^{\infty}(1-RR(w))f_{current}(w)dw}{1+\int_{w=0}^{\infty}(1-RR(w))f_{current}(w)dw} \quad (3)$$

To use the above basic equation therefore requires specification of $f(w)$ and $RR(w)$. Further, $f(w)$ must be estimated for the conditions before and after the BRRC redesign, and a separate functional form $RR(w)$ is needed for each health outcome. The neighborhood survey in step 1 provides the basis for estimating fcurrent(w) (the baseline condition); $f_{current}(w)$ is the histogram of time spent walking under current conditions shown in the main text. To estimate $f_{new}(w)$ for the redesigned BRRC, we employed equation 1, substituting $f_{current}(w)$ for $w_{current}$.

The functions $RR(w)$ were drawn from the WHO HEAT model (for mortality) and from a survey of relevant epidemiologic literature for the other health outcomes.[18] All functions are based on meta-analyses that focused on the health benefits of walking for transportation. Table A summarizes the relative risk functions used in this analysis and the publications from which these functions were derived.

*Key assumptions:* The relative risk functions shown in Table A accurately describe the health effects in the BRRC of increased walking.

*Research needs:* Epidemiologic studies in populations comparable to those in Wake County are needed to confirm the functions describing the relationship between time spent walking and health status.

**Step 4:** Estimate the total deaths avoided by redesigning the BRRC.

From basic principles of public health epidemiology, the number of cases of each health outcome that could be avoided due to increased walking is estimated from the following equation:

$$\text{Avoided cases} = AF_{new} \times H_0 \quad (4)$$

where $AF_{new}$ is calculated from equation 3 and $H_0$ is the baseline rate of the health outcome among BRRC residents. The main text explains our sources for baseline health

[18] Kahlmeier, S., et al. (2011). Health economic assessment tools (HEAT) for walking and for cycling. Copenhagen, Denmark: WHO Regional Office for Europe.

**Table A.** Relative risk functions employed in this study

| Health Outcome | Relative Risk Function | Reference |
|---|---|---|
| Premature mortality | $RR(w) = RR_{ref}^{w/29\text{ minutes/day}}$ <br> $RR_{ref} \sim \text{Normal}(\text{mean} = 0.78,\ \text{sd} = 0.096)$ | WHO HEAT model |
| CHD | $RR(w) \sim \begin{matrix} \text{Normal}(0.92,\ 0.035) \text{ for males and } w \in [1,30) \\ \text{Normal}(0.83,\ 0.05) \text{ for females and } w \in [1,30) \\ \text{Normal}(0.89,\ 0.04) \text{ for males and } w \in [30,\infty) \\ \text{Normal}(0.66,\ 0.04) \text{ for females and } w \in [30,\infty) \end{matrix}$ | Hu et al. 2007,[19] Table 3, (multivariate HR1 model) |
| Stroke | $RR(w) \sim \begin{matrix} \text{Normal}(0.92,\ 0.04) \text{ for } w \in [1,30) \\ \text{Normal } (0.89,\ 0.045) \text{ for } w \in [30,\infty) \end{matrix}$ | Hu et al. 2005 [20] |
| Hypertension | $RR(w) = \dfrac{AOR(w)}{1 - H_0 + H_0 * AOR(w)}$ where <br> $H_0 =$ Baseline hypertension prevalence <br> $AOR(w) \sim \begin{matrix} \text{Lognormal}(\text{med} = 0.757,\ \text{gsd} = 1.12) \text{ if } w \in [1,\ 21.3] \\ \text{Lognormal}(\text{med} = 0.695,\ \text{gsd} = 1.10) \text{ if } w \in [21.3,\ \infty] \end{matrix}$ | Furie and Desai 2012,[21] Table 2 |
| Diabetes | $RR(w) = \dfrac{AOR(w)}{1 - H_0 + H_0 * AOR(w)}$ where <br> $H_0 =$ Baseline hypertension prevalence <br> $AOR(w) \sim \begin{matrix} \text{Lognormal}(\text{med} = 0.769,\ \text{gsd} = 1.16) \text{ if } w \in [1,\ 21.3] \\ \text{Lognormal}(\text{med} = 0.689,\ \text{gsd} = 1.13) \text{ if } w \in [1,\ \infty] \end{matrix}$ | Furie and Desai 2012, Table 2 |

**NOTES: The parameters given for normally distributed variables are the mean and standard deviation.**

data (the Wake County Department of Public Health and the N.C. Center for Health Statistics).

**Step 5:** Estimate the economic benefits of deaths avoided.

For total benefits, we consider all cases avoided between the year 2028, when the design is assumed to be complete and walking behavior has changed, through the year 2048 (the last year of the City of Raleigh's current planning horizon). We estimate benefits using several different economic discount rates, denoted as *r*, in order to

[19] Hu, G., Jousilahti, P., Borodulin, K., Barengo, N. C., Lakka, T. A., Nissinen, A., & Tuomilehto, J. (2007). Occupational, commuting and leisure-time physical activity in relation to coronary heart disease among middle-aged Finnish men and women. Atherosclerosis, 194(2), 490–7. doi:10.1016/j.atherosclerosis.2006.08.051

[20] Hu, G., Sarti, C., Jousilahti, P., Silventoinen, K., Barengo, N. C., & Tuomilehto, J. (2005). Leisure time, occupational, and commuting physical activity and the risk of stroke. Stroke: A journal of cerebral circulation, 36(9), 1994–9. doi:10.1161/01.STR.0000177868.89946.0c

[21] Furie, G. L., & Desai, M. M. (2012). Active transportation and cardiovascular disease risk factors in U.S. adults. American Journal of Preventive Medicine, 43(6), 621–8. doi:10.1016/j.amepre.2012.06.034

convert this future stream of benefits into present value. The equation for calculating the benefits is:

$$\text{Total benefits} = \sum_{i=2028}^{2048} \frac{B_i}{(1+r)^{(i-2013)}} \tag{5}$$

where $r$ is the discount rate and $B_i$ is the total dollar value of all cases avoided in year $i$.

*Key assumptions:* The dollar values in Table 6 (main text) accurately represent the cost of an adverse health outcome in Wake County and the value that Wake County residents place on an avoided premature death.