ABSTRACT

LU, DI. Urban Greenway of Raleigh: The Evolution, Trail Use Correlations and Transportation Modes. (Under the direction of Professor Arthur Rice.)

Today’s urban environment is facing a challenge of lessened quantity and degraded quality of green space, as a result of the population growth pressure and other social, environmental and economic challenges. Loss of urban open space poses a threat to the health and sustainability of ecosystems, viability of natural resource dependent communities, and cultural character of urban communities. Greenways have evolved in America, as a strategic planning concept, over the past century as a response to dynamic populations and constantly changed landscapes. Unlike more remote national parks and other protected landscapes, greenways focus on linear open space and are located near population centers for a large number and a variety of users to access. The linear characteristics of greenways make them more attractive and resilient than traditional parks or green spaces in disrupted urban areas because greenways and linear parks make use of adjacent rivers, roadways, railways and pedestrian paths to help to create distinct economic, environmental, health and social benefits. However, few studies have explored the relationship between the use of the greenway and surrounding urban context. This dissertation: (1) explores the evolutionary relationship between open space systems (greenway networks) and urban form; (2) examines the associations between urban greenway trail characteristics and trail usage; and (3) investigates the modes of travel between recreation users and transportation users along the greenway trails.

Three issues are discussed in three Chapters. Chapter II explores the evolutionary relationship between open space systems (greenway networks) and urban form. This chapter indicates, as well as other North American cities, Raleigh possess a greenway system to achieve a comprehensive regional greenway network that joins inner cities to the suburban areas. Chapter II suggests that greenway be an evolutionary strategy that supports economic, ecological, and cultural sustainability.
Chapter III is a theoretical exploration of potential causal explanations for relationships between urban greenway trail characteristics and trail usage. It indicates that people intend to use urban greenway trails with low slope and good maintenance condition, proximate access, and mixed land-use in the surrounding area. The findings support evidence from planning theory that high population is associated with high efficiency in utilization of public facilities.

Also important to this study is an investigation into the modes of travel between recreation users and transportation users along the urban greenway trails in Raleigh. Chapter IV finds that in Raleigh purely recreational users tend to make longer, fewer visits than non-recreational users. Findings from this study show the surrounding land use is an important factor affecting how the greenway is used. Public transportation systems and urban bicycle routes are catalysts for greenway commuters.

The survey in this study indicates that the top reason people use greenway trails is because of the contact with the beauty of nature. A better understanding of the variables associated with human use of greenway will contribute to the future development and management. The dominant proportions of recreational users in this study indicate that greenways play an important role as recreation resources, but potential number of transportation users along greenways are encouraged.
Urban Greenway of Raleigh: The Evolution, Trail Use Correlations and Transportation Modes

by
Di Lu

A dissertation submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

Design

Raleigh, North Carolina

2014

APPROVED BY:

_________________________ _________________________
Myron Floyd Kofi Boone

_________________________ _________________________
Arthur Rice Jianxin Hu
Chair of Advisory Committee
DEDICATION

本文献给我的父母和妻子，你们的无限支持与爱保证我完成学业。

This dissertation is dedicated to my parents and my wife, I would not have done this without your love, support, and encouragement.
Di Lu was born in China. He received his bachelor degree of Landscape Architecture in 2008 from Nanjing Forestry University, China. Then he spent one year travelling and studying in Europe. He came to United States in 2009 and received his master degree of Environmental Design from Michigan State University in 2011. Di Lu spent the last three years at North Carolina State University to pursue his Ph.D. in Design. His research interests include sustainable site design, human use of greenway, planting design, GIS modeling for landscape planning and design. He is an accredited LEED professional in neighborhood development (LEED AP ND). He also acquired GIS Certification from NCSU.
ACKNOWLEDGEMENTS

First and foremost, I wish to acknowledge my deep gratitude to my committee chair: Professor Art Rice. Art is not only an advisor but also a model for me. The time we spent at the Global Village coffee shop was always very productive and efficient.

I would also thank my committee member Professor Myron Floyd and Professor Kofi Boone. Their questions and comments are always clear and inspiring for me to continue my research.

I would thank my committee member Professor Jianxin Hu for the help on my statistics.

I sincerely appreciate my parents. Thanks for all the unconditional love and financial support. Their physical and emotional supports keep me going forward.

I appreciate the help from Yang Li on my data collection.

I would like to express thanks to my friends and teachers who helped and supported me over the past three years studying at North Carolina State University.

Last but not least, I own a great deal to my wife Summer. Your moral and emotional support kept me going through the ups and downs during the journal in finishing my Terminal Degree.
# TABLE OF CONTENTS

LIST OF TABLES ........................................................................................................................................ ix

LIST OF FIGURES ......................................................................................................................................... xi

Chapter I

Introduction .................................................................................................................................................. 1

REFERENCES ............................................................................................................................................... 7

Chapter II

Retrofit the City: An Exploration of Evolutionary Relationship between Open Space Systems (Greenway Networks) and City Form ........................................................................................................ 10

Abstract .................................................................................................................................................. 10

1. Introduction .......................................................................................................................................... 11

2. Literature Review ................................................................................................................................ 12

   2.1 Greenway Evolution and Development at the Global Level......................................................... 12

   2.2 Greenway and Urban Form ........................................................................................................ 26

3. Methods ................................................................................................................................................ 30

   3.1 Method .......................................................................................................................................... 30

   3.2 Study Area .................................................................................................................................... 30

4. Results ................................................................................................................................................ 31

   4.1 The Formative Period (1792-1870s) ........................................................................................... 34

   4.2 The Olmsted Period (1870s-1940s) ......................................................................................... 35

   4.3 The Park System Period (1940s-1970s) .................................................................................. 37

   4.4 The Greenway Period (1970s-1980s) ..................................................................................... 39

   4.5 The Open Space Period (1980s-2000s) .................................................................................. 41

   4.6 The Collaborative Period (2000s-now) .................................................................................. 42

5. Discussions .......................................................................................................................................... 44

   5.1 Greenway Objectives for 2030 Comprehensive Plan ................................................................. 45
Chapter III

Urban Greenway Trail Characteristics as Correlates of Trail Usage

Abstract

1. Introduction

2. Literature Review
   2.1 The Built Environment and Physical Activity
   2.2 Mixed Land-Use as an Alternative Planning Strategy

3. Conceptual Framework
   3.1 Theoretical Perspective
   3.2 Conceptual Framework
   3.3 Research Questions

4. Methods
   4.1 Study Area and Sampling Strategy
   4.2 Data Collection
   4.3 Analysis Techniques

5. Results
   5.1 Descriptive Results
   5.2 Correlation Results
   5.3 Multiple Regression Results

6. Discussions
   6.1 Objective Measures of Trail Use
   6.2 Model for Trail Use
   6.3 Implication for Greenway Trail Planning and Design
   6.4 Limitation and Future Research
Chapter IV

Investigating the Modes of Travel between Recreation Users and Transportation Users along the Urban Greenway Trails

Abstract

1. Introduction

2. Literature Review
   2.1 Contemporary Urban Greenway Network
   2.2 Human Use of Greenway
   2.3 The Built Environment and Active Transportation

3. Methods
   3.1 Study Overview
   3.2 Study Area and Sampling Strategy
   3.3 Data Collection

4. Results
   4.1 Survey Respondent Characteristics
   4.2 Summary of Survey Responses
   4.3 Trail Use Pattern

5. Discussions
   5.1 Where Are Greenway Users from?
   5.2 Modes of Travel among Greenway Trail Use
   5.3 Greenway Trails and Surrounding Environment
   5.4 Understanding Greenway Users

6. Conclusion

REFERENCES
Chapter V

Conclusions ........................................................................................................................... 131

REFERENCES ..................................................................................................................... 135

APPENDIX ........................................................................................................................... 136

APPENDIX A - IRB Forms .............................................................................................. 137
LIST OF TABLES

Table 2.1  The Evolution of Open Space in Raleigh .......................................................... 33
Table 3.1  Description of Greenway Trail Sample ............................................................. 71
Table 3.2  Measurement of Greenway Characteristics ...................................................... 73
Table 3.3  Observe Schedule .......................................................................................... 78
Table 3.4  Measurement of Greenway Usage ................................................................... 79
Table 3.5  Summary of Kappa Statistics .......................................................................... 81
Table 3.6  Variables in Multiple Regression Model .......................................................... 82
Table 3.7  Usage of Greenway Trails by Gender, Age, Ethnicity, Group Size and Activity Type .......................................................................................................................... 84
Table 3.8  Demographic Characteristics of Raleigh ............................................................ 85
Table 3.9  Correlation Matrix (Spearman's Rho) of the Environmental Features Variables and the Trail Use Variables ........................................................................................................ 88
Table 3.10 Correlation Matrix (Spearman's Rho) of the Residential Proximity Variables and the Trail Use Variables ................................................................. 90
Table 3.11 Correlation Matrix (Spearman's Rho) of the Surrounding Land-Use Variables and the Trail Use Variable ...................................................................................................... 91
Table 3.12 Multiple Regression Model 1: Effect of Trail Features on Trail Use ............ 92
Table 3.13 Multiple Regression Model 2: Effect of Residential Proximity Variables on Trail Use .......................................................................................................................... 94
Table 3.14 Multiple Regression Model 3: Effect of the Surrounding Land-use Variables on Trail Use .......................................................................................................................... 95
Table 3.15 Multiple Regression Model 4: Effect of the Refined Variables on Trail Use .............................................................................................................................. 96
Table 4.1  Intercept Survey ............................................................................................ 115
Table 4.2  Characteristics of Survey Respondent by Gender, Age, Ethnicity, Group, and Activity ................................................................. 116

Table 4.3  Summary of Survey Responses ................................................................. 118
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure 2.1</th>
<th>Map of Emerald Necklace</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2.2</td>
<td>Highline Park In New York City</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>The 1943-1944 London Open Space Plan Proposed A Vast Web of Interconnected Open Space</td>
<td>20</td>
</tr>
<tr>
<td>Figure 2.4</td>
<td>Promenade Plantée Offers A Unique View of the City for Locals and Tourists</td>
<td>21</td>
</tr>
<tr>
<td>Figure 2.5</td>
<td>New Town Greenway Network in Tsukuba, Japan</td>
<td>22</td>
</tr>
<tr>
<td>Figure 2.6</td>
<td>Park Connector Network Concept Plan 2002 in Singapore</td>
<td>23</td>
</tr>
<tr>
<td>Figure 2.7</td>
<td>Pearl River Delta Comprehensive Greenway Network in China</td>
<td>24</td>
</tr>
<tr>
<td>Figure 2.8</td>
<td>An Aerial View of the Rose Fitzgerald Kennedy Greenway in Downtown Boston</td>
<td>26</td>
</tr>
<tr>
<td>Figure 2.9</td>
<td>Five Green Wedges Are Proposed at the Metropolitan Level for Nanjing, China</td>
<td>29</td>
</tr>
<tr>
<td>Figure 2.10</td>
<td>Goals and Functions of Parks Eras of the Last 150 Years in the United States</td>
<td>32</td>
</tr>
<tr>
<td>Figure 2.11</td>
<td>1972 Plan for Platting Raleigh by William Christmas</td>
<td>35</td>
</tr>
<tr>
<td>Figure 2.12</td>
<td>1872 Map of Raleigh, North Carolina</td>
<td>36</td>
</tr>
<tr>
<td>Figure 2.13</td>
<td>1974 City-Wide Greenway System Plan</td>
<td>40</td>
</tr>
<tr>
<td>Figure 2.14</td>
<td>2013 Raleigh Greenway System Plan</td>
<td>44</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>The Ecological Model of Physical Activity</td>
<td>63</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>Conceptual Framework</td>
<td>65</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>Location of Greenway Segment Sample within Raleigh Metropolitan Region</td>
<td>70</td>
</tr>
</tbody>
</table>
Figure 3.4  Greenway Segment 1 ................................................................. 71
Figure 3.5  Pedestrian Proximity Analysis ............................................. 75
Figure 3.6  Use Comparisons between Weekday and Weekend ............ 85
Figure 3.7  Uses by Time of Weekday .................................................... 86
Figure 4.1  Location of Greenway Segment Sample within Raleigh Metropolitan Region ................................................................. 113
Figure 4.2  Characteristics between Respondents and All Users........... 117
Figure 4.3  Summary of Trail Use Duration ......................................... 119
Figure 4.4  Summary of Trail Use Frequency ....................................... 119
Figure 4.5  Trip Purpose for All Respondents and Three Individual Segments .......... 121
Figure 4.6  Context Map of Greenway Segment 1 ............................ 123
Figure 4.7  Context Map of Greenway Segment 4 ............................. 123
Figure 4.8  Context Map of Greenway Segment 15 ........................... 124
Figure 4.9  Map of Raleigh Bicycle Route ......................................... 126
Chapter I

Introduction

Definition of Key Terms

Greenway - a linear open space established along a natural corridor, such as river, creek, stream, rail-trail, or other routes for recreation or alternative transportation purpose. It is also defined as “networks of lands that are planned, designed, and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use” (Ahern, 2002).

Trail - "a designated route or path on land or water with public access for recreation or transportation purposes such as walking, jogging, motorcycling, hiking, bicycling, horseback riding, mountain biking, canoeing, kayaking, and backpacking" (Jim, 2001).

Urban Resilience - "the capability of the system to prepare for, respond to, and recover from change or disturbance with minimum damage to public safety and health, the economy and security within a given urban area" (Walker and Salt, 2006).

Sustainability - as a part of the concept of sustainable development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987).

Green Infrastructure - a new and evolving term to combine with traditional "grey" infrastructure at the local level to achieve greater urban sustainability and resilience. Green infrastructure is also defined as "the interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, forest preserves and native plant vegetation that naturally manages stormwater, reduces flooding risk and improves water quality" (Benedict & McMahon, 2006).

Land Use - "the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it" (FAO, 1999). It is usually classified as agricultural, industrial, residential, recreational, mixed, or other use.
**Urban Form** - the general pattern of building height and development intensity, and the structural elements that define the city physically, such as natural features, transportation corridors, open space, public facilities, as well as activity centers (Morris, 1994).

The origin of cities, was as the central place for trading to the benefit of its citizens. In 1900, just 13% of the world population lived in cities; by 2000, the proportion rose to 47%, and continued growing. According to latest UN prediction, urban population will reach 60%, or 5 billion by 2030 (United Nations, 2012). The major function of cities is to provide places for people to trade, produce, communicate, and live (Bairoch, 1988). The urban environment needs to provide an agreeable place to live while minimizing or balancing negative side effects. The quality of city life relies on a range of components such as social equity, healthy environment, and dynamic economy (European Environment Agency, 2010). The environmental elements of good quality of life include good air quality, low noise levels, clean and sufficient water, good urban design with sufficient and high-quality public and green spaces, and multiple transportation approaches and pedestrian friendly opportunities (Miller, 1997; Burgess et al., 1988). By providing ecological, social, and recreational services, green spaces are essential for good urban environment and living.

Green spaces in cities exist mainly as urban forest, semi-natural areas, parks and gardens, incidental locations and linear open space, supplemented by scattered vegetated pockets associated with roads (Jim & Chen, 2003). Since the garden city idea advocated by Howard (1898) in the UK and the urban park movement pushed by Olmsted in the US during the 19th century, urban green space has become a crucial part of the urban environment that supports physical, social, and mental health of the entire region. As highly human-dominated systems, cities are habitats for humans, which are distinct from natural ecosystems. Therefore, urban green space is the only natural area that citizens can access on a daily basis. However, today’s urban environment is facing challenges in terms of lessened quantity and degraded quality of green space resulting from the population growth pressure, and social, environmental and economic challenges. Loss of urban open space poses a threat to the
health and sustainability of ecosystems, viability of natural resource-dependent communities, and cultural character of urban communities. Unfortunately, in some cities, drug dealers, criminals, and the homeless have taken over green spaces. Rather than providing relaxed or recreational places, these green spaces are negative to people’s daily life (Jacobs, 1993). Greenery does not automatically lead to positive physical or social activity, and the positioning of parkland can be a driving factor in the perception and use of the green space (Putnam & Quinn, 2007). Therefore, creating innovative ways to protect and enhance the quality of urban green space is not only for recreation purpose but also as sustainable responses to environmental challenges and social inequalities in cities.

The book that inspired this research is Charles Little's *Greenways for America* (1990), which is concerned with the development of new solutions to meet environmental challenges. Through outlining the history of the movement and describing different kinds of greenways, Little illustrates how greenways contribute to lives and environments of communities and cities. Unlike more remote national parks and other protected landscapes, greenways focus on linear open space and are located near population centers for large and multiple uses to access (Ahern, 2002).

Greenways represent a distinct strategic approach to landscape planning by supporting combinations of spatially and functionally compatible land uses within a network (Ahern, 2002). Greenways, as a strategic planning concept, has evolved over the past century in America as a response to dynamic populations and constantly changed landscapes. The narrow shape of greenways makes them more attractive and resilient than traditional parks or green spaces in the urban area because greenways can serve more areas than traditional parks without taking up many developable lands. Ideally, by providing sustainable transportation infrastructure, greenway network can create a citywide network of landscape boulevards, greenway streets, and linear parks, which connect neighborhoods to one another and to public transit hubs. Therefore, greenway networks can be a substantial contributor to the quality of life due in part to the multiple purposes and functions they can provide.
There are tremendous ecological benefits or ecosystem services that greenways contribute: including flood hazard avoidance, water quality and quantity maintenance, creation of riparian greenway corridors, air pollutant removal, balancing atmospheric oxygen and carbon dioxide contents, and wildlife habitat (Miller, 1997; Smardon, 1988; Arendt, 1994). Greenways are a connected network or matrix of patches and corridors (Forman, 1995); or large-scale ecological area of landscape linkages or mega corridors (Thorne, 1993); or that managed for nature protection, recreation, agriculture, and cultural landscape protection (Ahern, 2002).

In addition, greenways contribute to economic growth (Conine et al., 2004). As natural public open space, greenways increase the value of adjoining land uses. Further, the presence of greenway networks can facilitate business retention and expansion, as well as decisions to relocate into the region (Rails to Trails Conservancy, 2014; U.S. National Park Service, 1995). Such extensive systems and networks also become a feature that can stimulate tourism and extend visitor stays. A medical survey also found that the investment on greenway trails can save much more medical costs (Wang et al., 2005).

The social benefits of greenway are obvious as well. At the human dimension, the motion that people want to use greenways might come from the associated health benefits (Lindsey, 1999). According to the U. S. national study sample, 80% greenway users spend at least 30 minutes per visit and the number of people who used greenway trails weekly is twice as likely to meet physical activity recommendation (Librett et al., 2006). A comprehensive greenway has the potential to provide trails, linear parks, or bike paths with safety for biking and walking (Lindsey, 1999; Coutts, 2006) while supplying suitable surface for such activities. Unlike other types of physical activities, biking and walking require no specialized equipment or skills so that a large number of populations are able to perform (Coutts, 2006). Additionally, greenways and their facilities can also contribute to access, reliability, social equity, the environment and ultimately to the quality of life (Shafer et al., 2000).
Through a case study of Raleigh, NC, the dissertation aims (1) to explore the evolutionary relationship between greenway networks and urban form; (2) to examine the associations between urban greenway trail characteristics and usage; and (3) to investigate the difference between recreation users and transportation users along the greenway trails.

Chapter II proposes to complete a comparative study between the historical implementation of an extensive open space system and the current practice of the greenway network planning in Raleigh. Two main questions are asked: (1) how did early open space system and greenway network planning efforts affect the evolution of city form; and (2) how does the current greenway planning respond to urban growth pressures and help to repair isolated inner-city? To conclude, greenway is an evolutionary strategy which supports economic, ecological, and cultural sustainability.

The primary goals of Chapter III are: (1) to explore dependable and replicable measures of urban greenway trail usage, characteristics of greenway trails and surrounding neighborhoods; (2) to explore associations between three indicators (greenway characteristics, residential proximity, and surrounding land use) and the use of the greenway. The researcher measured environmental features (trail average slope, elevation change, trail sinuosity, amenity and facility, viewshed openness, maintenance condition, presence of litter, intersecting road’s safety, and visible manufactured structure) of greenway using computer simulation and site observation. The results indicate that people intend to use urban greenway trails with low slope and good maintenance condition, proximate access, and mixed land-use in the surrounding area.

Chapter IV builds on Chapter III by (1) investigating the extent people use greenways as transportation corridors in Raleigh; and (2) comparing the modes of travel between recreation users and transportation users along the urban greenway trails in Raleigh. Although many greenway studies have used mailed questionnaires to collect data from surrounding neighborhoods (Cox, 2013; Elabd, 2013), this study acquired relevant information directly
through a survey of greenway trail users. Since the questionnaires are collected directly from greenway trail users, the data collected are consistent with data gathered for the greenway usage in Chapter III. The results indicate for Raleigh purely recreational users tend to make longer, fewer visits than non-recreational users. The dominant proportions of recreational users in this study indicate greenway plays an important role as recreation resource, but potential number of transportation users along greenways are encouraged.
REFERENCES


Chapter II

Retrofit the City: An Exploration of Evolutionary Relationship between Open Space Systems (Greenway Networks) and City Form

Abstract
The traditions and principles of park planning and design have been developed over the last several hundred years in response to the changing social conditions. Over the past 100 years, the evolution of the greenway has paralleled the history of urban development. Greenways can be a powerful tool in making and shaping urban form by helping to stitch together fragmented cities and urbanized hinterlands. First, a balanced review is needed between historic greenways and contemporary implementations in America to examine evolitional process of the greenway. Second, exploring the relationships between the open space systems (greenway networks) and urban form from both a historical perspective and contemporary trend indicate that the greenway is an evolutionary strategy in conceptualizing a holistic approach which supports economic, ecological, and cultural sustainability. This study also indicates, as an important component of green infrastructure, the greenway system in Raleigh is likely to play a continuing role in helping define and promote transformations that provide environmental benefits at many scales in terms of urban resilience. To conclude, the evolution of the greenway system is an adaptive urban landscape form.

Keywords: Greenway, Urban Form, Open Space, Evolution
1. Introduction
The traditions and principles of park planning and design have been developed over the last several hundred years in response to the changing social conditions (Campbell, 1996). The history of parks in the United States was rooted in Europe, but owned distinct features since late 19th century (Fabos et al., 1968). The greenway idea, an evolved concept, can be traced back to late 19th and early 20th century when landscape architects and city beautiful planners advocated park systems, parkways and boulevard plans for large American cities (Ahern, 2002; Lindsey et al., 2008).

Today, the linear characteristics of greenways make them more attractive and resilient than traditional parks or green spaces in disrupted urban areas because greenways and linear parks make use of adjacent rivers, roadways, railways and pedestrian paths to help to create distinct economic, environmental, health and social benefits (Whyte, 1968). Greenways are sometimes considered as a type of liner park in cities (Coutts, 2006). Ideally, in combination with sustainable transportation infrastructure, greenways can help to create citywide networks of landscape boulevards, greenway streets, and linear parks, which can connect neighborhoods to one another and to public transit hubs (Ahern, 2002). In these scenarios, greenway networks can be substantial contributors to the quality of urban life because of the multiple purposes and functions they can provide. As a bonus, landscape ecologists see greenways as a strategy for sustainable urban infrastructure, which preserves natural habitats and native plant communities, and to help counter ecological fragmentation (Fabos & Ryan, 2006). Urban planners and landscape architects are interested in seeing how greenways can bring order to sprawled suburbs and to rebuild the inner-city. Community leaders and activists see greenways as great value for their people to access and use. Trails were ranked the second most desirable community amenity in a study (National Trails Training Partnership, 2002).

Many metropolitan areas, such as Boston, New York City, and Chicago have well-connected networks of urban greenways (Erickson, 2004). However, some smaller cities, like Raleigh,
NC, are not as well known for contemporary greenway planning efforts, even though these cities have a history for open space planning. The present study reviews the urban development in Raleigh as well as the emergence and evolution of its open space system. This paper also explores the contemporary greenway movement in Raleigh, which has been in response to urban expansion.

The purpose of this study is twofold. First, to provide a review of historic greenway principles and contemporary implementation strategies, adding to the literature of the evolitional process of the greenway. Second, this research addresses the struggles that every town or city is suffering with concerning the transformation or transition in terms of economic, environmental, and social changes. The term green infrastructure is likely to play a continuing role in helping to define and promote interventions that provide environmental benefits at many scales in terms of urban resilience. Exploring the relationships between open space systems (greenway networks) and urban form from both a historical perspective and contemporary trends indicates that the greenway is still an important and useful strategy in conceptualizing a holistic approach that supports sustainability.

2. Literature Review
The literature review starts with the introduction of greenway evolution in the past 100 years. Greenway developments in America, Europe and Asia are discussed respectively. Then the relationships between the greenway and urban form are reviewed. In North America, greenways have shaped urban forms primarily in two ways. Today, the concept of greenway systems, which guided and influenced the growth of North American cities for nearly one hundred years, can still reinvent current decentralizing urban from (Walmsley, 1995).

2.1 Greenway Evolution and Development at the Global Level
The origins of greenways can be traced back to late 19th and early 20th century when landscape architects and city beautification planners advocated park systems, parkways and boulevard plans for large American cities (Ahern, 2002; Lindsey et al., 2008). During late
20th and early 21st century, the interest of greenways had become international (Fabos & Ryan, 2006) with eco-design ideas have identified greenways as ecological networks. For example, Jongman (2004) reviewed how European countries make efforts to develop ecological greenway networks. Also, Yu (2006) and his colleagues identified greenway as a strategic element of ecological infrastructure during rapid urbanization in China.

2.1.1 Greenway Development in America

The origin of the greenway is as old as the birth of landscape architecture. A great amount of greenway literature consistently named Frederick Law Olmsted as the father of modern greenway movement in America because of the earliest influential greenway achievement called the Emerald Necklace-Boston Park System (Little, 1990; Fabos, 1995; Fabos, 2004; Searns, 1995). This linear system of Boston Parks is about 25km long and connects through Boston Common, Boston Garden, Back Bay, Jamaica Park, Arnold Arboretum, and Franklin Park (Figure 2.1).

Figure 2.1: Map of Emerald Necklace (Courtesy of Emerald Necklace Conservancy)
In fact, twenty years before the Emerald Necklace, the design idea of the linear Parkway in Brooklyn, also by Olmsted, already expressed the embryonic form of greenway. Therefore, the first true greenways originated as a metropolitan open space system of the late 19th century that link linear public lands (Zube, 1995; Fabos, 1995). Under Olmsted's hand, several other landscape architects and planners, including Charles Eliot, Theodore Wirth, and George E. Kessler were also involved in planning significant greenways and greenway networks throughout the US during the late 19th century (Fabos, 2004). One significant greenway is the Metropolitan Boston Park system, planned by Charles Eliot in 1890s to expand the Emerald Necklace. Five principal landscape elements (oceanfronts, river estuaries, harbor islands, large forests, and small urban squares) resembled a contemporary greenway and also structured a regional open space system (Ahern, 2002). The approach of including rivers as greenway connectors was a pioneering attempt in greenway planning (Fabos, 2004). The early greenway planning was initiated by significant landscape architects, such as Frederick Law Olmsted and Charles Eliot. Their individual innovations started greenway planning.

In 1959, William H. White was the first person, to mention the term greenway (Little, 1990). To invent the term, White combined two terms: *greenbelt* and *parkway*. He also advanced the basic concept by emphasizing linkage as the key feature of greenway.

Between 1960s and 1970s, the environmental movement pushed sustainable planning and greenway development. During 1960s, Phil Lewis initiated a mapping technique to identify 220 natural and cultural resources for the Wisconsin Outdoor Recreation Plan (Fabos, 2004). Lewis' study found 90% resources are along corridors so that his work is well known as a precursor to modern greenways. In a later study, greenway corridors have proven crucial for education by increasing connections of natural and cultural resources (Lewis, 1996). Lewis' environmental corridor concept, with a focus on protecting environmentally sensitive areas, has provided theoretical perspective for the greenway movement. McHarg (1969) is another pioneer of the environment movement, with numerous case studies on the green space
systems and greenways. McHarg argued ecological issue was the pattern of distribution of occupied and protected land. McHarg (1969) also invented the method of suitability analysis, which used a transparent map overlay technique to find the most appropriate locations for human developments, such as greenway routes. Modern greenway projects, either directly or indirectly, reflect the important contribution of Lewis and McHarg.

Another concept related to greenway is *greenline* park. The idea of a greenline park in 1970s was to protect rural landscapes and provide recreation opportunities near homes through incorporating both public and private land (Belcher & Wellman, 1991). Examples of greenline parks include the Cape Cod National Seashore in Massachusetts, Pineland National Reserve in New Jersey, and the Adirondack Mountains in New York. The idea was to decrease federal funding for public recreation while at the same time raise awareness of open space protection. However, unlike traditional parks, greenline parks were operated and managed by diverse owners with huge challenges. Thus, the pursuit of greenline parks was hampered by operational challenges (Belcher & Wellman, 1991). Greenline park was an American phenomenon, and today people do not use the term any more.

Since 1980, the loss of urban open space and the demand for outdoor recreation areas focused attention on greenways. In 1987, a significant event helped the spread of the greenway movement: the US Present’s Commission on American Outdoors Report (1987). The term greenway endorsed in the President’s Commission Report and advocated as “living network to provide people opportunity to access to nearby open space, and to connect rural and urban space throughout America landscape” (Presidents’ Commission, 1987).

Since 1986, the Rails-to-Trails Conservancy (RTC) has been active in greenway and trail creation and recreation movement. Rails-to-Trails Conservancy is a non-profit organization with a mission “to create a nationwide network of trails from abandoned rail lines and connecting corridors to build healthier places for healthier people” (RTC, 2014). Today more than over 20,000 miles of abandoned railroads have converted to greenway trails with the
help of RTC.

In 1998, a partnership was formed between the White House Millennium Council, the Department of Transportation and Rails-to-Trails Conservancy and with cooperation from other agencies and organizations to create Millennium Trails with the idea that it would recognize, promote, and support trails as a means to preserve open space, interpret history, and enhance tourism (Jongman, 2004). Under this initiative, more than 2,000 trails across America were recognized, enhanced, or built to connect communities. Besides Rails-to-Trails, landscape designers also applied greenway as an innovative approach to solve urban problems.

Figure 2.2: Highline Park In New York City
Unlike conventional greenways, Highline Park (Figure 2.2), initiated since 2002 in New York City is an elevated, innovative greenway that can bring nature into the city without occupying ground space, promoting timely principles of ecological sustainability, urban regeneration, adaptive reuse, and social equity implications. Preservation and innovation come together to establish an urban corridor for habitat, wildlife and people. In addition to providing valuable open space for New York City, the Highline Park has become an economic generator for the neighborhood, attracting investment toward new cultural institutions, commercial and residential development (David & Hammond, 2011). Highline Park is a model of contemporary greenway for the sustainable city.

Olmsted’s Park System was primarily designed for recreational function. However today, the most significant changes of greenway are its definition and function. Based on different functions, contemporary greenways are defined and classified mainly into three categories: ecological greenways, recreational greenways and historical heritage greenways (Fabos, 1995). Ecological greenways are “significant corridors of natural systems: along rivers, coastal areas, roads, and to provide wildlife migration and maintain biodiversity” (Fabos, 1995). Recreational greenways are “networks of trails and water routes, which have scenic quality as they pass through diverse and visually significant landscape” (Fabos, 1995). Historic heritage greenways are “to attract tourists while providing recreational, educational, scenic, and economic benefits” (Fabos, 1995). The three types are increasingly integrated into comprehensive greenways systems and providing multi-purpose functions and benefits. Contemporary greenways also represent a distinct strategic approach to landscape planning by supporting combinations of spatially and functionally compatible land uses within a network (Ahern, 2002). Thus, greenway is an evolutionary and dynamic term.

A review of greenway history in America illustrates evolution and innovation in landscape planning. Unlike more remote national parks and other protected landscapes, greenways focus on linear open space and are located near population centers for large and multiple uses to access (Ahern, 2002). The urban sprawl has motivated interest in alternative development
and transportation models.

2.1.2 Greenway Development in Europe

The idea of the greenway in Europe can be traced back to the Boulevard concept from France and the Greenbelt concept from Britain (Toccolini et al., 2006; Jongman et al., 2004). Today, the European Greenway Association defines greenway as “transport routes dedicated to light non-motorized traffic or a communication route which has been developed for recreational purpose and necessary daily trips” (European Greenway Association, 2000). It is obvious that the role of transportation route is the primary component of this definition. Before this definition was announced, there was a lack of commonality of greenway in Europe. However, ecological networks are more common in Europe while greenways are more an American product because of geographical, economic, cultural, and social differences as well as urban development models. Within Europe, there is a diversity of greenway planning approaches. Some countries, such as England and Italy focus on recreation networks; while some countries, such as Netherlands and Germany emphasize ecological functions (Toccolini et al., 2006). In Italy, greenway is "system of routes, from the environmental point of view and dedicated to non-motorized traffic, connecting people with landscape resources and the life" (Toccolini et al., 2006). Greenway planning in Italy has been underway on green trails for many years, and today the central role is transforming historical linear infrastructure (e.g. historical routes or towpaths) to greenway networks. In other words, greenway is a method to salvage existing or abandon infrastructures rather than the construction of new ones. The Italian Rail to Trail conversion started in 1970s but only individual greenway trails were constructed. The concept of greenway network, taken from the U. S. Rail to Trails Conservancy became popular in Italy since 1990s (Toccolini et al., 2006).

In Britain greenway is defined as "linear space containing elements planned, designed, and managed for multiple purpose including ecological, recreational, cultural, aesthetic, and other purposes compatible with the concept of sustainable land use" (Turner, 2006). Greenway is argued as “a superior approach than the park, greenbelt and public open space concepts.
because of its permeable characteristics throughout urban context rather than paved route with little green” (Turner, 1995). The greenway development in London is as an example. Inspired by Olmsted's work in Boston, early greenway planning in London (Figure 2.3) created an immense network to interlinked open spaces in the center and periphery of London Metropolitan area (Turner, 1995). Through overlapping networks of the pedestrian layer, the cycleway layer, and the ecological corridor layer, the 1991 Greenway Strategy of London provided opportunities for both recreation and nature conservation. Today the greenway in Britain is as a landscape-planning tool of considerable potential (Turner, 2006).

In contrast to US, where greenway trails and habitat networks are multi-functional concepts, Greenways in Germany use differentiated approaches where recreational greenways and species-oriented habitat network systems are separated (Hearen & Reich, 2006). The cultural value also addressed in Germany but not as a specific goal. Greenway in Germany initially established to prevent urban sprawl, to separate settlements, and to provide recreational opportunities (Hearen & Reich, 2006). Today greenways are also coordinated with other planning efforts in Germany.

In France, greenways are routes reserved for non-motorized travel by pedestrians, cyclists, skaters, and people with reduced mobility (Cormier et al., 2010). Since the definition of greenway was added to the Traffic Law in 2004 by a governmental decree and as part of the policies in favor of non-polluting mobility in France, greenway has become trendy in the French planners' vocabulary (Benissan, 2013). In France, the term of greenway has many meanings, including both environmental and social characteristics of a territory (Cormier et al., 2010).
Figure 2.3: The 1943-1944 London Open Space Plan Proposed A Vast Web of Interconnected Open Space (Turner, 1995)
The original inspiration for The Highline Park in New York City comes from Promenade Plantée in Paris. Built in 1993, the greenway (Promenade Plantée) was the first elevated parkway in the world, reimagining obsolete infrastructure and giving Parisians and tourists an alternate route around the city (Figure 2.4). Similar to the “rails to trails” movement in the US where rail beds have been repurposed to bike trails, Promenade Plantée was transformed from railway to a 4.7km tree-lined linear park with gardens strewn throughout its many foot bridges and tunnels (Littke et al., 2013).

In Europe, greenway networks have enormous potential in recreational and ecological perspectives but also to unite Europe as social integration (Jongman et al., 2004). For
example, most networks are developing at local or regional level while cross-border cooperation is not sufficient. Thus, in the future development, the cross-country greenway network can be applied to broaden ecological networks as well as strengthen social integration.

### 2.1.3 Greenway Development in Asia

Following the global interest in greenway movements, Asian countries have their own responses in developing greenway systems. Although started late by comparison to the West, greenway planning in Asian countries has also made significant contributions including New Town greenway in Japan and greenway in highly dense urban area in Singapore.

![Figure 2.5: New Town Greenway Network in Tsukuba, Japan (Yokohari et al., 2006)](image)

*An aerial view and a building plan of Tsukuba Science City with greenways marked out.*
In Japan, networks of greenways were planned in New Towns to provide pleasant corridors for residents in 1960s (Yokohari et al., 2006). For example, the Tsukuba New Town greenway network, planned under Urban Park Act to run throughout the city, connects all 83 green spaces with various corridor widths (Figure 2.5). After 40 years of greenway development, those created in the New Towns have matured and provide ecological service with its density and rich greenery.

The greenway movement in Singapore began in the 1980s as a network of green corridors or urban greening, which has evolved into a matrix of greenways (Figure 2.6). In Singapore, greenway networks connect people to places to ensure experiencing life’s essential moments of rest and recreation (Tan, 2006). Because of a burgeoning population density, Singapore has developed its unique strategy for greenways through identifying and maximizing low-
economic or abandon lands. *Ang Mo Kio* connector is an example of greenway in Singapore that developed within public housing land managed by the Housing and Development Board (HDB) to link parks and public housing.

In China, historically greenways are categorized into three types: riparian greenways along rivers, streams, and water channels, greenways along transportation corridors and greenways along farmland for wind protection (Yu et al., 2006). In 2010, China started to build up its first contemporary greenway network (Figure 2.7), located in the Pearl River Delta. The goals of this project are to maintain regional ecological safety, to improve regional livability,
to stimulate economic growth, and to protect cultural and historic resources (He et al., 2010). Besides Pearl River Delta, a tremendous number of regions and cities in China have started to plan their own greenway network, and a national landscape security pattern has proposed to address natural resource, fragile ecosystems and urbanization (Yu et al., 2009). In China, Greenways are primarily planned and implemented through top-down planning application, which is highly effective under a centralized system (Yu et al., 2006), especially at a national dimension.

However, in North America, centralized planning approach is less common. Greenway plans initiates at local and regional scale, and then greenways tend to involve a diverse and broad supports (Ahern, 2002). Additionally, Greenway is recognized as a new strategy of spatial development of Chinese urban and town green space (Liu, 2012). Greenways have evolved in China from means for protecting ecological system to include other functions, such as recreation, transportation, and education.

Some Chinese scholars argued that the idea of greenway planning and construction in China can be traced back more than 3000 years (Yu et al., 2006; Tan, 2006). However, the greenways like the forests along farmland for wind protection or riparian corridor along rivers, are not in accordance with the essence of contemporary, comprehensive greenway. Contemporary greenway is defined as “networks of lands that are planned, designed, and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use” (Ahern, 2002). In other words, besides ecological purpose, contemporary greenways also focus on recreational, cultural, and aesthetic purposes.

The identification of an international greenway movement (Fabos, 1995; Fabos, 2004; Ribeiro et al., 2013) and its practices in different countries enrich theories and principles contributing to landscape planning. Although contemporary greenways can be traced back over 100 years, it is clear that the greenway movement has never been as active as today. In
developing countries, such as China, the government has started to construct greenway network throughout the country as a landscape strategic network. The global conclusions for all the countries demonstrate the viability and advantages of the greenway concept are both as a way of thinking and an instrumental tool (Ribeiro et al., 2013). An examination of this recent global greenway activity is useful to identify opportunity for future applications.

2.2 Greenway and Urban Form

Figure 2.8: An Aerial View of the Rose Fitzgerald Kennedy Greenway in Downtown Boston
Over the past 100 years, the evolution of greenway has paralleled the history of urban development. Greenways can be “powerful makers and shapers of urban forms by stitching together fragmented cities and urbanized hinterlands” (Walmsley, 1995). In North America, greenways have shaped urban forms primarily in two ways. Historically, greenways (as park systems) have shaped cities by laying out a pattern in advance of urbanization (Walmsley, 1995). For example, the greenway network in Boston was originally developed as a greenbelt, extending from downtown Boston to suburban Brookline, structuring the urban form in combination with other factors, and linking large parks and green spaces together (Fabos, 2004). This greenway plan structured city growth rather than reacted to it.

Today, greenways could be the new method of providing a useful bridge between two design innovations: New Urbanism and Ecological Design (Arendt, 2001). Specifically, contemporary greenway trails combine compatible land uses (residential land, commercial land, school land, and parkland) within a structured network and provide alternative routes for transportation. “The linkage of greenways is the key that could contribute to place economic development and neighborhood revitalization” (Erickson, 2004). While urban politicians and planners face the challenge of bringing middle and upper class residents back to the city through various public projects (Steinacker, 2003), contemporary greenways could be applied as a part of landscape strategy for urban regeneration. The Rose Fitzgerald Kennedy Greenway, known as "the big dig", in Boston is a contemporary innovative transformation from an elevated highway to a spectacular series of linear parks and open space through greenway approach. The 15 acre park connects some of Boston’s oldest, most diverse and vibrant neighborhoods, public art, fountains, gardens and plazas. The transformation from highway to greenway is the most expensive urban infrastructure project in the history of Boston, which has impacted other American cities in terms of urban regeneration (Tajima, 2003).

Highline Park in New York city is another example of reshaping urban form through contemporary greenway implementation, which demonstrates "how the physical form of the
industrial era is reinvented in order to challenge prevailing notions of economic development and social change" (Svendsen, 2013). As an easily accessible neighborhood park, Highline Park redefines the relationship between open space and urban structures through the reuse of abandoned infrastructure and landscape. As the "gentrifier", Highline Park transforms the whole area and brings the middle-class back in order to help urban regeneration (David & Hammond, 2011).

A considerable number of researchers try to summarize the evolution of greenways through different periods (Fabos, 2004). Although some of these studies explore greenway evolution while considering the context of urban development, few of them paid much attention to the relationship between greenways and urban form over time. Erickson (2004) explored the association between the historic city form and contemporary greenway implementation, showing that both Milwaukee and Ottawa have outstanding historical greenways that shaped urban form. Like a number of other North American cities, the greenways at Milwaukee and Ottawa are evolving to satisfy multiple demands because of the urban and social dynamics. Thus, greenways could be illustrated as “an adaptive urban landscape forming to the physical and psychological pressures of urbanization” (Searns, 1995).

Most North American cities are developed under a suburban model with less dense land use, which provides enormous opportunities for large area of green space and greenways. In contrast, most Asian cities are intensively developed with compact forms, which is considered as a sustainable model (Jim & Chen, 2003), but lacking capacity for urban green space. A good example of dense Asian cities that attempt to alter urban space through greenways is Nanjing, China. In Nanjing, a heterogeneous green network proposed for different levels, aiming at flexibility for potential urban expansion, recreational amenities, and wildlife habitats and environmental benefits (Jim & Chen, 2003). At the Metropolitan level, five green wedges (Figure 2.9) recommended to generate a star urban form to link the extensive countryside to the inner city (Jim & Chen, 2003). At the city level, three cultural greenways, including Inner-Qinhuai River greenway, Canopy-road greenway, and city-wall
circular greenway proposed as a permeating framework to link existing parks (Jim & Chen, 2003). The green wedge and greenway network in Nanjing resonate with Forman's *Patch-Corridor-Matrix* concept (Forman 1995). Similarly, through unique strategic planning to maximize potential lands, Singapore builds up a model in greenway planning and implementation for densely populated city (Tan, 2006).

Figure 2.9: Five Green Wedges Are Proposed at the Metropolitan Level for Nanjing, China (Jim & Chen, 2003)

To sum up, during the late 19th and early 20th century, Olmsted's planning concept of parks and open space system has structured the growth of cities. Today, the concept of greenway
systems, which guided and influenced the growth of North American cities for nearly one hundred years, can rediscover and reinvent current decentralizing urban form, multiple transportation systems, and multi-cultural societies (Walmsley, 1995). In order to serve all population and to physically connect urban areas, the concept of the greenway system or greenway infrastructure needs to be applied at all scales.

3. Methods

3.1 Case Study

"A case study is a descriptive, exploratory, or explanatory analysis of a person, group, or event, in order to find underlying principles" (Yin, 1994). The present study proposes to complete a comparative study in Raleigh between the historical implementation of an extensive open space system and the current practice of the greenway network planning through explorative and observational methods, including the analysis of historical documents and maps, site visits, and journal reviews. The present study also tries to explore the relationships between the greenways and urban form from both a historical perspective and contemporary trends. Two main questions are asked: first, how did early open space system and greenway network planning efforts affect the evolution of city form? For this question, the author extensively analyzed open space planning, and the physical change of Raleigh over time. Second, how do the current greenway planning respond to urban growth pressures and help to repair isolated inner city areas? For this question, a recent greenway system plan was reviewed.

3.2 Study Area

Raleigh is the capital and the second largest city in the state of North Carolina. Like much of the southeastern United States, Raleigh has a humid subtropical climate, with four distinct seasons. Winters are short and mild, with a January daily average of 41.0 °F (5.0 °C). Summers are hot and humid, with a daily average in July of 80.0 °F (26.7 °C). Raleigh is known as the *City of Oaks* for its many oak trees, which line the streets in the heart of the city. It is the home of North Carolina State University and is one of the vertices of the
Research Triangle area. With the opening of the Research Triangle Park in 1959, Raleigh began to experience a dramatic population increase. According to the U. S. Census Bureau, the city's 2012 estimated population was 423,179, covering an area of 142.8 square miles, making Raleigh the 42nd most populous city in the United States. In addition, the population of Raleigh metropolitan area was estimated at 1,214,516 in 2013. Raleigh is also ranked as the second highest growth area in U. S. cities.

Raleigh is a pilot city of contemporary greenway system implementation in USA (Little, 1990). The Capital Area Greenway System of Raleigh is a network of public open spaces and recreational trails, which provide for activities such as walking, jogging, hiking, bird watching, nature study, fishing, picnicking and outdoor fun. The trails connect many of Raleigh's parks and in many cases provide a complement to the recreational activities at the parks. Today, the Capital Area Greenway has grown to 117-mile trails system, covering 3700 acres. Now, the Capital Area Greenway has become a model for not only North Carolina cities, but also across the United States and the whole world.

4. Results
The functions and goals of parks and open space in the United States were recognized as 5 phrases: Pleasure Ground (1985-1990); Reform Park (1900-1930); Recreation Facility (1930-1965); Open Space System (1965-1990); and Sustainable Park (1990-Present) in the last 150 years (Raleigh Parks, Recreation, and Cultural Resource, 2014). During these phrases (Figure 2.10), guiding principles have evolved by changes in society, which shaped our parks.

Raleigh is an early example in the United States of a planned city, chosen as the state capital of North Carolina in 1788 and incorporated in 1792. Since its incorporation, the city has been expanding almost continuously. Unique to the history of Raleigh, the function of parks was organized into five periods: the Formative Period (1792-1941); Consolidation and Refinement (1942-1970); the Expansion Era (1971-1981); the Open Space Era (1982-2004); and the new Collaborative Era (2004 to present) (Raleigh Parks, Recreation, and Cultural
Resource, 2014). However, in this study, the evolution of open space system are organized into six periods (Table 2.1), as well as the growth of the city: the Formative Period (1792-1870s); the Olmsted Period (1870s-1940s); the Park System Period (1940s-1970s); the Greenway Period (1970s-1980s); the Open Space Period (1980s-2000s); and the Collaborative Period (2000s-now).

![Diagram 1. Goals and functions of parks eras of the last 150 years in the United States, (Galen Cranz)](image)

Figure 2.10: Goals and Functions of Parks Eras of the Last 150 Years in the United States (Raleigh Parks, Recreation, and Cultural Resource, 2014)

During the Formative Period, national trends and significant individuals with young parks and urban squares emerging in Raleigh (Raleigh Parks, Recreation, and Cultural Resource, 2014) influenced the city. In the Olmstead Period, Raleigh established official recreation and parks institutions, and a philosophy of providing critical services meeting needs for Raleigh's
Park system also formed. In the Park System Period, the Park System of Raleigh was established as a response to citizen demand and the realization of urban growth pressure. In the Greenway Period, the Capital Area Greenway 1976 Master Plan was a response as an action to foster a complete and lasting solution to the flooding problems in Raleigh’s urbanizing area, as well as an response to citizen’s demand for park and recreation areas. The Open Space Period was marked with relatively slow growth in the parks and recreation system but high population growth. Bond referendums have been an innovative way to fund parks and recreation elements during this period. During the Collaborative Period, in order to provide more opportunities for parks, recreation and cultural resources at a reasonable cost, the city of Raleigh has made efforts to collaborate with partners to keep pace with growth.

Table 2.1: The Evolution of Open Space in Raleigh

<table>
<thead>
<tr>
<th>Periods</th>
<th>Significant Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Formative Period</td>
<td>Young parks and urban squares as parts of initial layout of the city of Raleigh</td>
</tr>
<tr>
<td>(1792-1870s)</td>
<td></td>
</tr>
<tr>
<td>The Olmsted Period</td>
<td>Establishment of recreation and parks institution while ecological function of parks and open space was undesirable at this point</td>
</tr>
<tr>
<td>(1870s-1940s)</td>
<td></td>
</tr>
<tr>
<td>The Park System Period</td>
<td>Initiative of park system as a response to urban sprawl, but no greenway yet</td>
</tr>
<tr>
<td>(1940s-1970s)</td>
<td></td>
</tr>
<tr>
<td>The Greenway Period</td>
<td>Greenway was introduced to ecologically connect existing open space system as well as to provide recreation and transportation opportunities</td>
</tr>
<tr>
<td>(1970s-1980s)</td>
<td></td>
</tr>
<tr>
<td>The Open Space Period</td>
<td>Relatively slow growth in the parks and recreation system but high population growth</td>
</tr>
<tr>
<td>(1980s-2000s)</td>
<td></td>
</tr>
<tr>
<td>The Collaborative Period</td>
<td>The greenway system includes more than 100 miles of trails to serve more users as well as to connect different land-use</td>
</tr>
<tr>
<td>(2000s-now)</td>
<td></td>
</tr>
</tbody>
</table>
4.1 The Formative Period (1792-1870s)

The original 400-acre city plan of Raleigh prepared by William Christmas, was laid out through 1,000 acres of woodland in 1792, and included five public squares centered in a grid of streets (Figure 2.11). Along with Philadelphia and Savannah, Raleigh was one of the early American cities incorporating squares of green space in their original city designs. In the 1792 Plan, William created a central site (Union Square) for the State Capitol and four axial streets, following the compass points, which divided the city into four quadrants (Raleigh Parks, Recreation, and Cultural Resource, 2014). The heart of each quadrant was a public square (Moore, Nash, Caswell, and Burke) initially. Today, Moore Square has still maintained its identity and use as a public green. Deeply loved by the citizens of Raleigh and listed on the National Register of Historic Places, Moore Square is uniquely positioned to respond to the growing park needs of a City that has grown in population by more than 40,000% since its founding. Nash Square also remains as a historic square today. At the corners of the rectangular plan, four lots were left open for future parks. Of the original city plan, nearly 20% of developed area was reserved for open space.

The 1792 Plan worked very well for almost 50 years before the city began to grow with the new construction of the railroad in 1840s. The new economy pushed the city beyond the original boundaries. Then two original squares: Caswell Square and Burke Square were transformed for other uses. However, the vision for parkland never vanished. Oakwood Cemetery was founded in 1869, near the State Capitol, for a memorial park, but also served as carriage grounds for the living. This parkland became a pioneering field in Raleigh with a multi-use, privately funded recreational and open space facility (Raleigh Parks, Recreation, and Cultural Resource, 2014). Today, Historic Oakwood Cemetery's 102 acres is a beautiful, noble resting place, providing permanent memorialization for the departed, and a source of serenity for visitors.
To sum up, influenced by national trend and significant individuals, during the Formative Period, young parks and urban squares emerged in Raleigh. Creeks and floodplains were undesirable at this point in history.

4.2 The Olmsted Period (1870s-1940s)

A bird's-eye view of Raleigh in 1872 shows the arrangement of the community after the Civil War (Figure 2.12). Commercial areas emerged along Fayetteville Street, which is south of the State Capitol. Factories, warehouses, and foundries are located near the tracks on the west and north sides of the city. The remaining space within the city limits was occupied with private residences, hotels, and boarding houses.
During that time, Citizen's demand on pleasure grounds or natural retreats was growing as well as the civil rights movement. Inspired by Frederick Law Olmstead's principles and theories, Raleigh had its own response to the park movement and Pullen Park is the outcome. Pullen Park was founded in 1887 when Richard Stanhope Pullen donated farmland to the city of Raleigh to be used as a space for recreational enjoyment and visitors to Raleigh. At that time, the land was on the outskirts of the city and Pullen Park became the first public park in North Carolina. Today, Pullen Park is a 466 acres park, adjacent to the campus of North Carolina State University, between Western Boulevard and Hillsborough Street. The park

Figure 2.12: 1872 Map of Raleigh, North Carolina
http://upload.wikimedia.org/wikipedia/commons/8/85/Raleigh1872_BIG.jpg
features picnic areas, concessions stand along with several small rides including the Pullen Park Carousel, train, and paddleboats.

Influenced by City Beautiful Movement in 1890s, Raleigh's public and private sector leaders were determined to improve the cityscape to their advantage. Investment in parks where seems a way to beautify the urban form. The typical examples are landscape boulevards of Glenwood and New Bern Avenues (Raleigh Parks, Recreation, and Cultural Resource, 2014). Meanwhile, a shift in park philosophy from individuals to a system of parks gradually gained popularity. Parks also became amenities of middle class residential neighborhoods, which were linked to downtown by trolley services. The public transportation services brought citizens to parks at the edge of towns. Bloomsbury Park, Brookside Park, and Pullen Park all belonged to this category of open space. Cameron Park set another model by arranging streets around natural drainage ways, leaving the creeks as neighborhood open space.

Between 1900 and the beginning of World War I, the construction of hospitals, schools, churches and residences at Raleigh's urban and suburban sections added diversity to the urban fabric. In addition, at the beginning of twenties, a large group of prominent citizens were appointed as City Park Commission to plan for the development of the parks system and the maintenance and beautification of current amenities.

The Olmstead Period ended with the establishment of official recreation and parks institution of Raleigh in 1938 while the philosophy of providing critical services to meet needs for Raleigh's Park system also formed. Ecological function of parks and open space was undesirable at this point in history while the quantity of leisure space was more important.

4.3 The Park System Period (1940s-1970s)

In 1940, Raleigh was the fifth largest city in North Carolina. After World War II, the city began to transform from governmental and educational only center to the development of industry and technological research facilities (Little, 2006). During 1950s, Raleigh
experienced an explosion of industrial and commercial growth that challenged new infrastructures for the developments. With the opening of the Research Triangle Park in 1959, Raleigh began to experience a population increase, resulting in a total city population of 100,000 by 1960.

From the late 1940s through the 1960s, Raleigh was a proving ground for the architectural movement known as Modernism. After the World War II, the building of homes in Raleigh occurred in neighborhoods inside and beyond the city limits. Postwar retail architecture consisted largely of suburban shopping centers, often built as part of a residential community. Cameron Village shopping center was first planned mixed-use development in North Carolina. Also during 1950s, Raleigh's private developers began to undertake development within the stream valleys using large machines (Flourney, 1972). The machine driven developments have led to the locating of residential, industrial, and commercial land uses within the flood plains.

In 1941, the City Commissioners of Raleigh combined the Parks Commission and the Recreation Commission into the Recreation and Park Commission. Until 1950, the Park System of Raleigh included 189 acres in the form of 16 parks, 12 playgrounds, and two recreation centers. In 1950s, professional consultants were hired to prepare a Master Plan by using citizen surveys and growth trends to mold parks and recreation elements into an ideal acquisition and development program. Not only did the plan increase parkland and improve facilities in existing park property, but also the plan brought standards and methods for determining park needs and growth. In 1960, a new study with a 20-year projection of parks needs indicated that refining the desirable park sites would be an urgent effort to adapt to rapid urbanization. In 1969, the city of Raleigh published "Raleigh, The Park with a City in It", open space plan for the pending decade, to deal with citizen demand and the realization under urban growth pressure.

During the Park System Period, the idea of creating park system in Raleigh has developed in
order to not only provide more recreational space, but also as a response to rapid urbanization. People began to care about ecological issues caused by urban sprawl, but no greenway was planned in Raleigh yet.

4.4 The Greenway Period (1970s-1980s)

Since 1792, Raleigh has had its comprehensive land use plans, yet few of them protected the flood plains from the development. Until 1960s, flood plains were designated as public corridors along city's streams within the city's land development plan. Then, the original plan for the Capital Area Greenway System was initiated in 1972 by Bill Flournoy, who was fulfilling the thesis for his Master degree in Landscape Architecture (Little, 1990). The objectives of the greenway system were:

(1) Promote the strategic use of flood prone lands for an open-space corridor system.
(2) Establish a linear park network, left primarily in its natural state.
(3) Complement the existing and future park system through the introduction of a linear park network that will accommodate public recreation desires which are now unmet.
(4) Enhance private development by giving a common structural system to the elements of urban amenity.
(5) Introduce a trail system, which connects compatible land uses.
(6) Buffer conflicting land uses.
(7) Give an alternative to the automobile for short commuter trips by developing a safe passageway for bicycles and pedestrians.
(8) Retain natural ecological functions in the urban growth.
(9) Allow more effective planning for future urban growth.
(10) Elevate the livability of the urban environment.
(11) Stimulate the most beneficial expenditure of public funds through the multiple uses of public property (Flournoy, 1972).
Figure 2.13: 1974 City-Wide Greenway System Plan
(Raleigh Greenway Commission, 1981)
Flournoy’s plan has evolved into 1974 City-Wide Greenway System Plan (Figure 2.13), which illustrated how the greenway provided social, economic, environmental, and aesthetic benefits. The Greenway concept in 1974 linked floodway development and flood control issues brought about by development to a system of open space preserves and recreational trails. This greenway plan was a response as an action to foster a complete and lasting solution to the flooding problems in Raleigh’s urbanizing area, as well as an action to citizen’s demand for park and recreation areas since 1950 and 1960s.

Additionally, this greenway system also tried (1) to influence urban growth patterns by conserving open spaces in the Raleigh urban area; (2) to separate and to buffer conflicting land uses while connecting compatible land uses along the greenway’s parameter, and (3) to produce an active commitment among all involved with Raleigh’s growth to planning for and implementing open-space networks in developing areas. The 1974 Greenway Plan crystallized in the final refinement of the park system in the 1979 Comprehensive Plan of Raleigh. As an initiative, the Greenway Capital Greenway Plan has been a model for many cities in North Carolina, such as Charlotte and Greensboro.

During the Greenway Period, greenway was introduced in Raleigh to ecologically connect and conserve existing open space system as well as to provide more recreation and transportation opportunities.

4.5 The Open Space Period (1980s-2000s)

During the Open Space Period, land mass and population were growing in the city of Raleigh while at the same time taxing the parks, recreation, and cultural system infrastructure in response to the rapid growth. The responsibility of the Recreation and Park department was to retain its services throughout the city while it is expanding in geography (Raleigh Parks, Recreation, and Cultural Resource, 2014). Thus, more parklands and acreage were required to add to the park system. A park classification system included mini park, neighborhood park, community park, metro park, nature preserve and special, was updated to ensure
standards of services for the whole city.

Since 1981 when Federal funds were withdrawn, the city of Raleigh has been responsible for funding its parks program. The city began to look for creative ways of obtaining funding, as a response to accelerated population growth. As a result, Raleigh started to collect facility fees from developers in order to directly fund new parks in pace with the expansion of the city.

Bond referendum has been another important way to fund parks and recreation elements. In 1984, $8 million bond was approved for future parks program while, in 1987, the bond number was $10 million. Since then, citizen desires of a wide variety of parks and recreation facilities made the City Council appoint Parks, Recreation, and Greenway Advisory Board.

Until 1989, Raleigh's greenway system has already included more than 900 acres of land and nearly 25 miles of completed trails (Raleigh Parks and Recreation Department Design/development Division, 1989). Greenway has been the major shaper of both urban form and city recreation policy, as well as zoning administration policy and law. During that time, the population ratio of the greenway system was 5.7 acres for every 1000 citizens, as the largest acreage among the park categories. The role of the greenway system has become increasingly important as trail segments connected for users with the general population growth and development in the outlying area of the city.

4.6 The Collaborative Period (2000s-now)
While many American cities were losing population since 2000, the population of Raleigh has grown steadily from 290,184 (year of 2000) to 423,179 (year of 2012). A significant project after 2000 was an $88 million bond for parks and greenway in 2007. In order to provide more opportunities for parks, recreation and cultural resources at a reasonable cost, the city of Raleigh has made efforts to collaborate with partners to keep pace with growth. Through collaborating with Wake County Public School System, two community centers: Brier Creek and Barwell Road were constructed for public services. The creation of the
Neuse River Greenway Trail is an example of partnering with Wake Forest and Knightdale to lead the major efforts in greenway trail system development. Meanwhile, nonprofit, volunteerism, and private corporate programs have grown over the last several years.

In 2009, the city of Raleigh adopted the 2030 Comprehensive Plan while the City of Raleigh Parks, Recreation, and Cultural Resources System Plan is a supplement to the 2030 Comprehensive Plan. Through extensive public participation, the System Plan aims to shape the framework of the direction, development, and delivery of the City's Parks, recreation, and cultural resource service in the next 20 years.
Today, the Park Division is comprised of five operating divisions: Parks, Highway, Cemetery, Greenway, and Urban Forestry. Current greenway system includes 117 miles of trails (Figure 2.14: 2013 Raleigh Greenway System Plan (City of Raleigh Parks and Recreation, 2013))
2.14) and 3750 acres of the greenway property. Initiated as amenities to provide recreational and social opportunities for Raleigh residents, the current Capital Greenway System, has been a component of highly connected bicycle and pedestrian network for not only recreation, but also transportation. With over 100 miles of trails, the downtown, suburban, commercial areas, and more rural landscapes are physically connected.

5. Discussions

5.1 Greenway Objectives for 2030 Comprehensive Plan

The objectives of developing greenways have changed over time. While recreation and conservation have dominated for many years, contemporary greenways are expected to provide more benefits, such as social and environmental education. Today, both recreation and transportation are foremost (Erickson, 2004). The existing greenway system in Raleigh has been successful by providing diverse user experience and navigation and wayfinding.

As Mitchell Silver, Raleigh Planning Director indicates, the Raleigh 2030 Comprehensive Plan will be more predictable than 1989 Plan, which is more flexible. The greenway planning in Raleigh has its own correspondence to the 2030 Plan, including "Wayfinding for Health and Economic Vitality", "Closing Gaps and Identifying Alternatives", and "Programming and Economic Contributions" (Raleigh Parks, Recreation and Cultural Resource, 2014). To serve more users and as means of contributing to economic development, extensive Wayfinding would be implemented. For example, signs can indicate proximity to shopping, restaurants, grocery stores, parks, museums and cultural resource. In order to fill the gaps of greenway system, the greenway planning should extend routes into additional neighborhoods and commercial areas, incorporate bicycle and pedestrian network connectivity, and integrate public transit. While the greenway system in Raleigh was planned and design as a passive recreation walking trail, it does not connect to major utilitarian functions and uses very well. Thus, special greenway programming should be developed for social interaction. For example, large events including trail marathons, natural run and orienteering run may be appropriate for the greenway system.
5.2 Greenway and Urban Resilience

In recent years, many cities or towns in America are suffering transformation or transition in terms of economic, environmental, and social changes. Urban resilience is defined as the "capability of the system to prepare for, respond to, and recover from change or disturbance with minimum damage to public safety and health, the economy and security within a given urban area" (Walker & Salt, 2006). Understanding urban resilience is central to understanding sustainability because sustainability address the long-term needs. However, urban resilience is a new way of thinking about sustainability, since resilience is more strategic than normative (Ahern, 2010). Green infrastructure is new and evolving term to combine with traditional grey infrastructure at the local level to achieve greater urban sustainability and resilience. Green infrastructure is also defined as "the interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, forest preserves and native plant vegetation that naturally manages storm water, reduces flooding risk and improves water quality" (Benedict & McMahon, 2006). As much of the infrastructure of the developed world will be replaced or rebuilt in the 21st century (Ahern, 2011), green infrastructure is an innovative way to provide resilient and affordable solutions that meet many objectives at once.

Over the past 100 years, Raleigh has transformed from a small town of less than 20,000 to a metropolitan city with a population of 423,179 (Raleigh Parks, Recreation and Cultural Resource, 2014). As a result of its growth, Raleigh faces challenges of providing the right parks, recreation and cultural resource services to the growing population as well as incorporating resilience into urban planning. As an important component of green infrastructure, the greenway system in Raleigh is likely to play a continuing role in helping define and promote interventions that provide environmental benefits at many scales in terms of urban resilience. The term greenway provides an opportunity to integrate many of the features that are being defined as green infrastructure. The need for stakeholder interaction and educational integration between water-related intervention and trail-related improvements suggests that the term greenway be still important and useful in
conceptualizing a holistic approach that supports economic, ecological, and cultural sustainability.

6. Conclusion

The aim of this study is to explore the evolutionary relationship between open space system (greenway system) and city form. This study concludes that the greenway is an evolutionary strategy in conceptualizing a holistic approach, which supports economic, ecological, and cultural sustainability.

As well as other North American cities, Raleigh possess a greenway system to achieve a comprehensive regional green network that joins inner cities to the suburban areas (Walmsley, 1995). Although there are no historical precedent greenways in Raleigh, the strong historic open space framework and recent greenway implementation made the city a distinct case. In Raleigh, like other metropolitan areas, two key drivers are behind greenways: environmental quality and social amenity. The historic open space framework has provided fundamental support to the complexity of linking physical landscapes and multiple demands that contemporary greenways try to satisfy. The current greenway planning in Raleigh is an example of responding to urban sprawl and inner city disorders.

This paper shows that the open space idea of Raleigh, initiated since the birth of the city, has shaped the contemporary implementation of the greenway system. The evolution of the greenway system is an adaptive urban landscape form (Searns, 1995) as well as providing ecological service within the urbanized context. Today’s interest in greenways is an esthetic counter-balance to urbanization. The greenway planning has become an important component of urban planning in Raleigh. The greenway system in Raleigh has great potential for social interaction while more special greenway programming is needed. In order to be well connected to major utilitarian functions and uses, future research should explore the human dimension of greenway in Raleigh, such as accessibility, use activity, user safety, and trail amenities.
REFERENCES


Landscape and Urban Planning. 76(1-4), 1–6.


of Massachusetts, Amherst.


Chapter III

Urban Greenway Trail Characteristics as Correlates of Trail Usage

Abstract
Urban greenway systems that link home and workplace might help to meet quality of life objectives by not only offering alternative transportation routes but also by providing access to nearby nature, opportunities to recreate, exercise and to interact face to face with others in the community. The purpose of this study is twofold: (1) explore dependable and replicable measures of urban greenway trail usage, characteristics of greenway trails and surrounding neighborhoods; (2) explore associations between three indicators (greenway characteristics, residential proximity, and surrounding land use) and the use of the greenway. Fifteen greenway trail segments were selected from over 100 miles potential candidates as study sample in Raleigh, NC. The researcher measured environmental features (such as trail average slope, elevation change, trail sinuosity, amenity and facility, viewshed openness, maintenance condition, presence of litter, intersecting road’s safety, and visible manufactured structure) of greenway using computer simulation and site observation. The usage of greenway trails measured through site observation and six variables (amount, gender, age, ethnicity, user group size, and physical activity types) recorded. Four multiple regression models were tested in Statistical Package for the Social Sciences (SPSS) [version 22] to identify the combination of environmental feature variables, residential proximity variables, and the surrounding land-use variables that contribute to use of greenways. The refined regression model explained approximately 86.5% of the variation in greenway trail usage. Trail use correlated positively and significantly with maintenance condition and 1/2-mile population. Trail use correlated negatively and significantly with trail average slope. The results add to previous findings on greenway trail use by established four predictive models with more urban form variables. The results also indicate that people tend to use urban greenway trails with low slope and good maintenance condition, proximate access, and mixed land-use in the surrounding area. The regression models provide an adequate estimate
of the urban trail use in Raleigh, but mediating factors may also play a role in the results.

**Keywords:** Usage, GIS, Greenway Characteristics, Residential proximity, Land Use

1. Introduction
The context for this research is the rapid development of greenways across U. S. in the last two decades, as well as the recent greenway movement emerging around the world. Although greenways could provide alternative routes for both transportation and recreation and connecting various land uses, there are still emerging problems, especially at the dimension of human use. Overused and insufficiently used greenways are both very common in American cities (Gobster, 1995). In addition, researchers have reported access inequality for greenway users (Moore et al., 1992; Bowman, 2009). Planners, designers and city officials are interested in gathering scientific data in order to measure the effectiveness of the use of the greenway and to use this information as the basis for expanding the regional greenway network. Information about the use of greenways, such as activity level, frequency of use, duration of use, will be useful to plan and expand greenways, evaluate benefits of proposed improvements, assess traffic, and manage demand. Gobster (1995) examined thirteen trails in Chicago to identify a diverse range of greenway trails, to examine people’s use patterns, perceptions and preference, and to identity location, design and management factors for the development. Lindsey (1999) reported surveys of users on three linked greenway trails in Indianapolis, IN, and the results show intensity and patterns of use vary considerably by greenway segment. However, it is not easy to predict the use of greenways because there are multiple dimensions of influence, from personal and social factors to policy factors, on activity type or activity duration. A national study found that personally perceived access to greenway trails is positively associated with physical activity (Brownson et al, 2001). Some studied agreed that most users of the greenway in U. S. come from within five miles (Furushth & Altman, 1991; PKU Consulting, 1994); while others reported that most users living no more than 10 minutes or 1.5 miles from greenway trails (Lindsey, 2001). Therefore, the residents that live in proximity to greenways are the potential users. Planners also
claimed that mixed land-uses might encourage pedestrian activity on the street (Frank et al., 2003). However, few studies have explored the relationship between the use of the greenway and surrounding urban context. For example, what kinds of the surrounding land uses are convenient for users to access via greenways? The explanation for scarcity of research on exploring urban greenway and the surrounding urban context, may be due to the complexity and the uniqueness of urban structure. Because of the growth of spatial analytic technologies applied in the domain of urban planning and design, testing new hypotheses using more detailed and quantitative data with spatial modeling is necessary. In urban areas, estimating who will use the greenway includes, in part the population density and the people that live and work near greenways. Additionally, environmental features of greenways would also motivate users’ preference. For example, paved greenways complement the existing automotive transportation network and in some cases may be more attractive for users. Thus, to guide future renovation and expansion of greenway systems, it is urgent to explore dependable and replicable measurements on how the environmental features and surrounding urban environment affect human use of the greenway.

Therefore, the purpose of this study is twofold as follows:
(1) Explore dependable and replicable measures of urban greenway trail usage, characteristics of greenway trails and surrounding neighborhoods.
(2) Explore associations between three indicators (greenway characteristics, residential proximity, and surrounding land use) and the use of the greenway.

The hypothesis of this study is that a greenway is associated with more accessible points, diverse surrounding land-use mixture, or with more amenities and facilities will increase the extent of human use. Thus, the urban greenway segments, which are typical with more diverse adjacent land use, should have significant potential for a high number of people.

Additionally, this paper illustrates how Geographic Information Systems (GIS) technologies can be used to collect data in modeling environmental features, residential proximity and surrounding land use mixture, and explores how these data can be incorporated in statistical
models that explain associations. Although these data from new technologies cannot be conclusive evidences to describe particular environmental feature cause specific usage, they would facilitate understanding of the spatial relationship between urban greenways and urban land-uses, and explore sustainable urban design strategies.

2. Literature Review

2.1 The Built Environment and Physical Activity

The changes in the social and physical environments are largely responsible for changes of lifestyles (Sallis et al., 1998). For example, since the rapid development of the automobile industry, active transportation, such as walking or jogging trips has declined in recent decades. Machines and computers also reduced physical activity at work. Low levels of physical activity could threaten the health both directly and indirectly, and has become a global pandemic that causes deaths each year. Overweight has become a global problem, and some countries are worse than others are.

The United States of America is an example. In the U.S., excess weight is an apparent outcome of physical inactivity. As of 2010, 68% of the U. S. population is overweight and obese (Centers for Disease Control and Prevention, 2010). Today, obesity is also a major concern in some developing countries, such as China. In China, the overweight population has shifted from 8.8% in 1989 to 26% in 2006 (Popkin, 2011). Research showed that a sedentary lifestyle is responsible for cardiovascular disease, stroke, and all cause mortality (Department of Health and Human Services, 1996). Medical research also show that physical activity can help people maintain their weight over time and can be effective at all phases of chronic disease as well, and suggest at least 150 minutes of moderate-intensity activity a week (Centers for Disease Control and Prevention, 2010). The data from Centers for Disease Control and Prevention (CDC) indicates that a half-hour of walking five times a week would achieve it. People categorize physical activity into four domains: recreation, occupation, transportation, and household. Different environmental features drive these domains. In other words, there are great opportunities to increase daily active trips through changing built
environment to support.

2.1.1 Measuring Environmental Features
Physical activity is usually done in specific types of places, such as parks, trails, fitness centers, schools, and streets, referred to as physical activity environments (Sallis, 2009). In recent years, scientific researchers are increasingly interested in measuring physical activity environments. Sallis (2009) presents various disciplines (health study, urban planning study and leisure study) to measure physical activity environment. Different disciplines have different targets with different approaches. Health studies evaluate a wide variety of built environment variables, which may be related to recreational physical activity with direct observation methods (Sallis, 2009). GIS is widely used to evaluate walkability, residential density, and land-use diversity in the planning related fields. In the leisure studies, researchers focus on people's use of leisure time rather than physical characteristics of parks and other recreation facilities.

2.1.2 Measuring Physical Activity
Regular physical activity is an important part of people's daily life to keep healthy. When people are talking about measuring behavior and physical activity in parks or greenways, it usually refers to measuring frequency, duration, intensity, and mode of physical activity. There are three typical measurement strategies for physical activity and behavior: 1) Self-report; 2) Activity monitors (accelerometers); and 3) Direct observation (Dishman et al., 2002).

The advantages of Self-report include a larger sample size and the gathering of broad data information such as frequency, type, mode, and context (Prince et al., 2008). The limitations of Self-report are about reliable and accuracy (Shephard, 2003). The benefits of direction observation include objectivity and validity (Welk, 2002). However, the challenge of this method of data gathering is that measuring activity in settings, such as parks, is complicated because both numbers of participants and their activity levels change frequency. As a labor
and time-intensive method for systematic observation, "System for Observing Play and Recreation in Communities" (SOPARC) addresses this issue (Mckenzie, 2010). The strengths of accelerometers include high validity, high reliability and comprehensive activity profile (intensity, when and how). However, the limitations of accelerometers are obvious, such as cost and missing data (when losing signal) issues.

2.1.3 The Built Environment and Active Transportation
Statistics shows worldwide active transportation has declined in the recent decades, both for youth and adults, accompanied by increasing use of mechanized transportation (World Health Organization, 2014). For example, between 1969 and 2009, the number of children 5 to 14 years old walked or cycled to school dropped from 48% to 13% (The National Center for Safe Routes to School, 2001). Key elements of urban built environments include land use types (residential, commercial, industrial, institutional, and recreational), population density, spatial relationship of destinations, and aesthetic quality (Sallis et al., 2012). Research with transportation planning and urban design tried to explore characteristics of the urban environment might facility walking and cycling (Sallis et al., 2004; Saelens et al., 2003), and indicate that multiple destinations close by population density and transportation facilities were all positively associated with active transportation (Heath et al., 2006; Saelens & Handy, 2008; Durand et al., 2011; Ewing & Cervero, 2010; Fraser & Lock, 2010). Multiple destinations refer to diverse land uses that are relevant to daily life of shopping, working, and exercise. A multi-ethnic study found proximity to parks and commercial areas is associated with active transportation (Rodríguez et al., 2009). One explanation is the attractiveness of these destinations. High population density means more needs on shops, public service, schools, and open spaces, which also stimulate active transportation. People who frequently use public transportation tended to more active (Lindstrom, 2008) because they need walk or bike to transit. Conversely, a considerable number of studies indicated that urban sprawl, measured by low residential density and low connectivity, is negatively associated with walking and bicycling (Berrigan & Troiano, 2002; Frank & Pivo, 1995).
In many urban areas, built environment characteristics are combined with high population density served by good public transit to connect destinations. Since cumulative effects of environmental attributes might contribute to physical activity, it is methodologically and conceptually difficult to isolate characteristics of built environments (Sallis et al., 2012).

2.1.4 Accessibility and Active Recreation

Accessibility is a key issue whether people are able to use parks and recreation facilities. Studies have found that access to recreation facilities is positively associated with physical activity (Brownson et al., 2001; Wilson et al., 2004; Commbes et al., 2010). A study by Commbes (2010) showed that residents of Bristol England who lived further from urban green spaces are less likely to use them. The study also indicated that the same residents were less likely to meet the established average physical activity levels.

Some studies focused on disparities in access to activity-supportive built environment (Gordon et al., 2006; Wilson et al., 2004), and found mostly low socioeconomic groups are facing less supportive environmental condition for active recreation (Casagrande et al., 2009; Sallis et al., 2011). A nation-wide study in America showed that people with a college degree have more outdoor recreation resource than those less educated population (Gordon et al., 2006). Similar results, found from an urban trail study in Spartanburg, South Carolina that most trail users have a college education (Maslow et al., 2012). Political issues, such as historical segregation ordinances, might also cause disparities in use of built environment, like parks or open spaces. For example, Boone and his Colleagues (2008) examined the distribution of parks in Baltimore and found out that African Americans have better access to parks with walking distance while white Americans have access to more acreage of parks. Bowman (2009) found trails in some North Carolina towns have inequitable access for African-Americans, and she attributed this to the influence of developers and neighborhood input.
2.1.5 Interventions and Physical Activity

Urban planners, landscape architects, recreation specialists, sociologists, health professionals and behavioral scientists are all curious about how the built environment spatially correlates to physical activity, where are the active and inactive live, the reasons that may influence the willingness and ability to be active (Coutts, 2006), and how intervention can stimulate physical activity. Theoretically, a randomized research that assigns to two group people (one group live in a walkable neighborhood and the other live in a suburban area without sidewalks) might ideally explore the association between built environment and physical activity. However, this experiment is difficult to conduct in the real world.

People from diverse discipline stimulated innovative methods and experiments of intervention to characterize the relationship among land use, travel patterns, and physical activity. Fitzhugh and his colleagues (2010) used a quasi-experimental multiple-control neighborhood research design to detect changes after exposure to an improved trail that enhanced connectivity to retail and school destinations at Knoxville, and the result indicates the pre- and post-intervention changes between experimental and control neighborhoods are significantly different. In order to examine visitation and physical activity levels, Tester and Baker (2009) used System for Observing Play and Recreation in Communities (SOPARC) to collect data in two intervention parks and a control park at San Francisco. This study demonstrated an increase of visit in overall physical activity because of these interventions (Tester & Baker, 2009). For those physical intervention studies above, the acquisition of pre-intervention data is critical and challenging.

Policies also play an important role in encouraging physical activity. Many government agencies and public health organizations advocate more cycling and walking to improve individual health. An international review showed two key findings in increasing bicycle: one is that specific interventions are associated with levels of bicycle; the other is that most cities adopt comprehensive packages of interventions to increase the number of bicycle user (Pucher et al., 2010). Another review found that two types of policy interventions: urban
design strategy that involve street-scale changes and land use regulations can be effective in increasing activity (Kahn et al., 2002).

### 2.2 Mixed Land-Use as an Alternative Planning Strategy

Urban sprawl is a multifaceted concept, referring to a complex pattern of land use, low-density pattern, transportation and social and economic development (Frumkin, 2004). Different land uses including residential, commercial, recreational, industrial, and institutional areas, kept separate from each other, due to the traditional zoning ordinances (Knaap & Nelson, 1992). The rise of sprawling cities emerged after World War II, largely because the opportunities for large-scale housing developments (Nechtba & Walsh, 2004). Although associated with sustained debate and negative connotations due to the health, environmental and cultural issues, today the low-density suburb model is still dominating in most American cities (Frumkin, 2004). For example, occupants’ mobility is dependent on automobiles as high-frequency public transport is not available in such a low-density environment; distances to reach jobs, shops, and recreation areas are long. Newly built suburbs are relatively homogeneous, compared with conventional urban or town settings. The old and poor people, who usually lack access to cars and live in downtowns, are suffering worse with uncompleted streets restrict them from getting around even by biking or walking (Vermont Department of Health, 2012).

In recent decades, to redefine the contradicted relationships between human beings and their surrounding environments, planning experts and critics advocated other alternatives, such as the model of the compact city, which promotes relatively high residential density with walkable mixed land uses. Scholars argued that the compact city is a more sustainable urban settlement type rather than urban sprawl because it is less dependent on cars, and requiring less infrastructure provision (Dempsey, 2010). Benefits of mixed land-use development include more affordable housing; reduced distances between housing, workplaces, retail businesses, and other amenities and destinations; better access to fresh, healthy foods; stronger neighborhood characteristics and sense of place; pedestrian and bicycle friendly
environments (APA, 2013). It is an antidote to the widely separated live and work centers that are conducive to urban sprawl.

Researchers are seeking to establish a causal relationship between land use and travel behavior. Land use grain is a commonly used concept, which captures both land use types and density (Lynch, 1981). Land use grain is proved consistently to correlate with transportation choice, mobility and accessibility (Benjamin, 2012). However, measuring land use grain is a relatively new task in North America. Song and her colleagues (2004) summarized existing measures of mixed land use and categorized these various measures based on the concept of proximity, of intensity and of distribution pattern. Lindsey and his team (2008) calculated the Shannon Diversity Index (SHDI) developed from land-use GIS data to analyze viewsheds from urban greenway trails.

Studies on land use patterns proved that travel behavior is determined by the distribution and types of land uses (Frank et al., 2006; Frank, 2004). For example, people drive less in more walkable area. Although residential density and diverse land use are positive indicators of non-vehicle trips (Frank et al., 2004; Greenwald & Boarnet, 2001; Song et al., 2004), these potential opportunities do not necessarily stimulate non-vehicle activities. However, greenway trails, combining compatible land uses within a network and proving alternative routes for transportation, which also own aesthetic features could be a catalyst influencing people's willingness to use pedestrian routes in the urban area. The present study tries to test if there is a significant relationship between use of the greenway and surrounding land use mixture.

3. Conceptual Framework

3.1 Theoretical Perspective
The theoretical root of this research comes from human ecology. Human ecology provides an ecological framework that is relevant to examine the interrelatedness of people and their physical, emotional, and cognitive behaviors as they occur in relation to specific
environmental contexts. In 1979, Bronfenbrenner envisioned the ecological paradigm as an approach to explicate human ecology as inter-affected relationships that occur within the environmental setting (Bronfenbrenner, 1979). Particularly, in domains of urban planning and environmental design, the purpose of the ecological model in general is to focus on identifying environmental inventions (McLeroy et al., 1988).

Figure 3.1: The Ecological Model of Physical Activity (Sallis et al, 2006)
The environmental causes of physical activity, conceptualized through Sallis’s ecological mode, which specified multiple levels of influence on physical activity, from personal and social factors to built environment and policy factors (Sallis et al., 2012). Built environments refer to the whole places built or designed by humans, including constructions, communities, infrastructure, and parks and greenway trails (Transportation Research Board and Institute of Medicine, 2005). Characteristics of built environments, from communities to cities have also related to the physical activities (Frank et al., 2003; and Frumkin et al., 2004). Physical activity can be classified into four domains of life: leisure exercise, occupation, transportation, and household, which are driven by different built environments (Figure 3.1). Figure 3.1 also illustrates all possible environmental settings that are relevant to each physical activity domain.

3.2 Conceptual Framework
The conceptual framework of this study, as illustrated in Figure 3.2, attempts to elaborate a conceptual idea and measurement through research design. Ecological models provided a conceptual basis for comprehensive interventions focus on environmental changes that might have sustainable effects (Sallis et al., 2012). Ecological models are particularly well suitable for studying human use and effects because physical activity takes place in special behavior setting. Both accesses to setting and characteristics are important. Two domains (built environment and human use) from Sallis' ecological model (2006), specified and incorporated into this study through multiple dimensions. Specially, built environment refers to urban greenways and the surrounding land-uses; while use of the greenway refers to how people perform physical activities on greenways. Urban greenway systems that link home and workplace might help to meet quality of life objectives by not only offering alternative transportation routes but also by providing access to nearby nature, opportunities to recreate, exercise and to interact face to face with others in the community.
The conceptual model of human use of urban greenways comprised of three dimensions: environmental features, residential proximity, and surrounding land use (Coutts, 2006; Reynold et al., 2006). These three dimensions stand for designed landscape, people, and urban context. Each dimension also incorporates several components. Environmental features include trail characteristics, greenway buffer characteristics, and amenity and facility. Surrounding land use contains land use types and land use mixture. Residential proximity includes population density, access point number, and traveling time to greenways. Residential proximity and surrounding land use are both due to the physical structure of urban forms. In addition, environmental features, potentially correlated to surrounding

Figure 3.2: Conceptual Framework
neighborhood characteristics. This research is an effort to examine how important is each of these domains in influencing human use of greenways. Applying the ecological model of physical activity, this study would expect the independent variables (environmental features, residential proximity and surrounding land use) to influence the dependent variables (human use). It is also theorized that an urban greenway with more accessible point, with more surrounding land-use, and with attractive landscape features will enhance the extent of human use. Eventually, based on multivariate associations this research has explored, the hope is to generate a spatial model, which can predict human use of urban greenways.

3.3 Research Questions

The following four questions are raised in this dissertation:

**Research Question 1**: To what extent do specific environmental features of greenway effect the use?

**Sub-question 1A**: What are the relationships between trail features (trail slope and trail sinuosity) and user activity type on the greenway?

**Sub-question 1B**: What are the relationships between greenway viewshed openness and the number of group users on the greenway?

**Hypothesis 1A**: A decreased level of trail slope would increase the number of biking users on the greenway.

**Hypothesis 1B**: A decreased level of greenway viewshed openness would increase the number of group users on the greenway.

**Research Question 2**: To what extent does residential proximity, as measured by population and access point, influence use of the greenway?

**Sub-question 2A**: What is the relationship between population and amount of users on the greenway?

**Sub-question 2B**: What is the relationship between access point and user activity type on the greenway?
Hypothesis 2A: An increased level of population within 0.5-mile distance would increase the user number of the greenway.

Hypothesis 2B: An increased amount of the access point would increase the amount of walking users on the greenway.

Research Question 3: To what extent does the surrounding land-use as a destination opportunity to influence the use of the greenway?

Sub-question 3A: What is the relationship between land-use mixture and amount of users on the greenway?

Sub-question 3B: What is the relationship between spatial interaction (connectivity and integration) and the amount of users on the greenway?

Hypothesis 3A: An increased level of land-use mixture would increase the amount of users on the greenway.

Hypothesis 3B: An increased level of spatial interaction, as measured by Sidewalk Connectivity would increase the amount of users on the greenway.

Research Question 4: How important greenway environmental features, residential proximity and surrounding land use cumulative to effect use of the greenway?

Hypothesis 4: A greenway with more accessible point, with more diverse surrounding land-use mixture, or with more amenities and facilities will increase the extent of human use.

4. Methods
This section described the research strategy and methods used to explore the research questions, including case study city and physical characteristics of research sites, sampling strategy, research procedures and data analysis techniques.

4.1 Study Area and Sampling Strategy
Raleigh was selected as the case study city since it is satisfied the designed criteria below.
(1) It has a Greenway Master Plan and constructed greenways.
(2) It has mixed land uses at urban area.
(3) Residential neighborhoods are located close to greenways.
(4) A considerable number of people use greenways for either recreation or transportation.

Raleigh is the capital and the second largest city in the state of North Carolina. It is the home of North Carolina State University and is one of the vertices of the Research Triangle area. With the opening of the Research Triangle Park in 1959, Raleigh began to experience a population increase. According to the U. S. Census Bureau, the city's 2012-estimated population was 423,179, over an area of 142.8 square miles.

Raleigh was one of the first cities to pilot greenway system planning in U.S. The Capital Area Greenway System of Raleigh is a network of public open spaces and recreational trails, which provide for activities such as walking, jogging, hiking, bird watching, nature study, fishing, picnicking and outdoor fun. The trails connect to many of Raleigh's parks and in many cases provide a complement to the recreational activities at the parks. The original plan for the Capital Area Greenway System, created in 1976 by Bill Flournoy, was used it as part of the requirements for fulfilling his thesis for a Master degree in Landscape (Little, 1990). In this plan, Bill Flournoy has already illustrated how the greenway provided social, economic, environmental, and aesthetic benefits (Flournoy, 1972). Today, the Capital Area Greenway has grown to a 117-mile trails system, covering 3700 acres. Now, the capital Area Greenway has become a model for not only North Carolina cities, but also across the United States and the whole world.

In this research, greenways were divided into segments as study samples. The rationale of using segmentation technique was to acquire detailed data for collection and analysis purpose. The segmentation technique requires each segment to be short enough to observe usage, and to be long enough to distinguish variations of environmental features among segments. The criteria of choosing greenway segments include:

(1) Every segment should be a similar length and have at least one parking access
(2) Each segment should be an intermediary portion of greenway trails, rather than a beginning or an ending portion.
(3) Each segment should be within a continuous greenway system.
(4) The buffer distance between two closer segments are long enough so that the surrounding urban context of two closer segments are not overlapping.

Based on the listed criteria, 15 greenway trail segments were selected from over 100 miles of potential candidates by using a web-based search and on-site pilot study. Two greenway segments (Lake Johnson trail and Shelley Lake park trail), fit the criteria, but were excluded from these samples because the presence of lakes was considered a distracter for this study. During the pilot study, a large number of users were observed in Lake Johnson trail and Shelley Lake park trail; however, it is not quite sure how many users were attracted only by the lake. The location of these greenway trails, shown in Figure 3.3, along with their major characteristics are described in Table 3.1. The major access points are located in the middle of all the greenway segments and the length of each segment is approximately 1/2 mile. Figure 3.4 illustrates a typical greenway segment and the surrounding urban context.
Figure 3.3: Location of Greenway Segment Sample within Raleigh Metropolitan Region
Table 3.1: Description of Greenway Trail Sample

<table>
<thead>
<tr>
<th>No.</th>
<th>Trail name</th>
<th>Residential Density</th>
<th>Location notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Little Rock Trail</td>
<td>High</td>
<td>Downtown Raleigh</td>
</tr>
<tr>
<td>2</td>
<td>Rocky Branch Trail</td>
<td>High</td>
<td>Pullen Park</td>
</tr>
<tr>
<td>3</td>
<td>Walnut Creek Trail</td>
<td>Low</td>
<td>Eliza Pool Park</td>
</tr>
<tr>
<td>4</td>
<td>Walnut Creek Trail</td>
<td>High</td>
<td>Wetland Center</td>
</tr>
<tr>
<td>5</td>
<td>Walnut Creek Trail</td>
<td>High</td>
<td>Apollo Height Park</td>
</tr>
<tr>
<td>6</td>
<td>Walnut Creek Trail</td>
<td>Medium</td>
<td>Worthdale Park</td>
</tr>
<tr>
<td>7</td>
<td>Walnut Creek Trail</td>
<td>Medium</td>
<td>Parking lot</td>
</tr>
<tr>
<td>8</td>
<td>Walnut Creek Trail</td>
<td>Medium</td>
<td>Parking lot</td>
</tr>
<tr>
<td>9</td>
<td>Walnut Creek Trail</td>
<td>Low</td>
<td>Parking lot</td>
</tr>
<tr>
<td>10</td>
<td>Walnut Creek Trail</td>
<td>Medium</td>
<td>Parking lot</td>
</tr>
<tr>
<td>11</td>
<td>Walnut Creek Trail</td>
<td>Low</td>
<td>Lassiter Mill historical park</td>
</tr>
<tr>
<td>12</td>
<td>Centennial Bikeway Connector</td>
<td>Medium</td>
<td>Famers Market</td>
</tr>
<tr>
<td>13</td>
<td>Crabtree Creek Trail</td>
<td>High</td>
<td>Parking lot</td>
</tr>
<tr>
<td>14</td>
<td>House Creek Trail</td>
<td>Medium</td>
<td>Glen Eden Park</td>
</tr>
<tr>
<td>15</td>
<td>Reedy Creek Trail</td>
<td>Medium</td>
<td>NC Museum of Art</td>
</tr>
</tbody>
</table>

**Notes:** Low = 0-2500 (population); Medium = 2501-5000 (population); High = 5001-7500 (population)
4.2 Data Collection

The hypothesis of this study is that an urban greenway with more access point, with more diverse set of land-use, and with more attractive landscape features will enhance the extent of human use (more people or longer use). To examine the hypothesis, the present research collected data in four parts: characteristics of greenway trails, residential proximity, the surrounding land-use, and the usage of greenway trails. Characteristics of greenway trails refer to the overall structure and the designed features of greenway trails, as measured by computer simulation and site observation for nine variables (trail average slope, elevation change, trail sinuosity, accessible from park, viewshed openness, maintenance condition, presence of litter, intersecting road’s safety, and visible manufactured structure). Residential proximity refers to the potential population that might use greenway trails, measured by using GIS to capture number of access point, 1/2-mile population, and 4-mile population. The surrounding land-use refers to the layout and the content of adjacent land-use in certain radius. Four variables (HHI, sidewalk connectivity, sidewalk network distances, and bicycle route connectivity) identified as independent variables to measure the surrounding land-use. The usage of greenway trails measured by site observation and six variables (amount, gender, age, ethnicity, user group size, and physical activity type) recorded.

4.2.1 Measure Characteristics of Greenway Trails

The characteristics of greenway trails and their unique atmosphere are the prerequisites that attract people to use the greenway. Trail characteristics, including surface condition and amenities and facilities are associated with human use of greenways (Reynolds et al., 2007). The multi-use trail width needed to accommodate a wide variety of user group (Flink et al., 2001). For example, a typical two-way bicycle trail is 10ft wide. In most cases, the width of the trail depends on the amount of available land within the boundaries of the project. The trail surface also has a great amount of influence on the degree of access for all user groups. Lindsey and his study group (2008) reported trail use is high when the surface is paved. However, it has not been determined whether asphalt or concrete pavement is more attractive to trail users. The trail slope has a significant impact on the level of access of a trail to not
only wheelchair users but also to seniors. However, most mountain bicyclists prefer technical sections rather than level sections of trails (Hopkin & Moore, 1995). Curve is another important feature of greenway trails according to the natural condition. Trail sinuosity is a measure of the presence of curves along a trail segment.

For safety and aesthetics, characteristics of green buffers might influence human use. Openness refers to the percentage of the surrounding environment seen from trail segments. Openness is directly related to mystery because the more can be seen from greenway trail segments, the less mystery the trail has. Studies indicated mystery could be a positive contributor to both environmental preference and perceived danger, depending on contexts (Herzog, 1998). In addition, Reynold and his colleagues (2007) reported that vegetation density is negatively related to greenway trail use due to safety consideration.

Table 3.2: Measurement of Greenway Characteristics

<table>
<thead>
<tr>
<th>Location (segment number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
</tr>
</tbody>
</table>

**Part 1: Overall structure**

(1) Trail average slope
- a. 0-3%  
- b. 3-6%  
- c. >6%

(2) Elevation change
- a. 0-20ft  
- b. 20ft-40ft 
- c. >40ft

(3) Trail sinuosity
- Vary from 1 to 2

(4) Accessible from park
- a. Yes  
- b. No

**Part 2: Design features**

(5) Viewshed openness
- a. very close  
- b. close  
- c. Semi-Open  
- d. Open  
- e. very open

(6) Maintenance condition
- 1-5 scale

(7) Presence of litter
- a. Presence  
- b. Not Presence

(8) Intersecting road’s safety
- 1-5 scale

(9) Visible manufactured structure
- a. 0-5  
- b. 6-10  
- c. 11-20
After a careful review of existing instruments for environmental features of greenway
(Lindsey et al., 2008; Pikora et al., 2002; Ryan, 1993; Reynold et al., 2007; Troped et al.,
2006) and a preliminary study of the research site, nine variables were identified in Table 3.2.
Other important environmental features, such as trail width, trail-paving types and greenway
buffer width are not variables in this study because these features are rarely distinctive from
one greenway segment to another within this study parameter.

The data was collected from both computer simulation (GIS and Google Earth) and site
observation. First, ARCGIS was used to help dividing segments of greenway trails. Maps of
each segment with street names and surrounding aerial photograph were created. Second,
Trail average slope, elevation change, trail sinuosity, and accessible from parks were
measured using Google Earth. Google Earth has been proved as an effective approach to
measure geospatial information by several studies (Miller et al., 2010; Janssen & Rosu, 2012).
The advantages of using Google Earth include ease of access and dynamic. Third, two
observers walked through the entire length of the 15-greenway segments, with each observer
completing the audit of design features for each segment. The inter-reliability of auditing
design features was determined by Kappa statistics in the later analysis.

4.2.2 GIS Analysis for Residential Proximity
The residential proximity data would help to determine user parameters of greenway
segments, and eventually to explore the relationship between the characteristics of the user
parameter and the uses on the same segment. Previous studies reported that most greenway
users only are likely to travel a short distance to use the greenway trails (Gobster, 1995;
Coutts, 2006). However, exact normal traveling distance or time to greenways is unsure
according to different studies. Some research agreed that most users of the greenway in U. S.
come from within five miles (Furushth & Altman, 1991; PKU Consulting, 1994); while
others report that most users are living no more than 10 minutes or 1.5 miles from greenway
trails (Lindsey, 2001).
In this study, a 10-minute temporal measurement conducted to calculate the proximity of greenways access points to the residential areas while two transportation modes (walking and automobile) were considered. Specially, 10 minutes traveling time could reach 1/2 mile by walking, or reach four miles by automobile (TRB, 2005). First, Google Earth and site observation identified the number of access points for each segment. Access points defined in two ways: parking access point and walking access point. Parking access points are greenway entrances with exclusive parking space or street parking. Walking assess points are connected with paths or sidewalks that could be reached from surrounding neighborhood or business area. Second, to calculate pedestrian proximity, the residential population that could reach the access point of the greenway segment within a 10-minute walk by using sidewalks or paths was included through 1/2-mile buffer analysis in ARCGIS 10 (Figure 3.5). Third, to calculate automobile proximity, the residential population that could reach the access point of the greenway segment within a 10-minute drive was included through 4-mile buffer analysis in ARCGIS 10. Fourth, intersect analysis was applied to match census block data with user
parameters to acquire population characteristics.

4.2.3 GIS Analysis for the Surrounding Land-Use

In research by Rodriguez and Joo (2004), the authors found that pedestrian and bicycle trips tend to increase in the presence of mixed land uses, highly connected sidewalks, and high population density at the origin and the destination. Urban greenways are supportive of alternative transportation modes providing adequate regional connectivity. While greenways provide alternative transportation routes and connect various land uses, the surrounding land-use is seen as an opportunity that can be reached from a given greenway segments (Coutts, 2006). Four variables (HHI, sidewalk connectivity, sidewalk network distances, and bicycle route connectivity) were identified as independent variables to measure the surrounding land-use.

Initially, the parameters of surrounding land-use were determined in a similar fashion as the residential proximity. A 10-minute temporal measurement was conducted to calculate the potential of greenways access points to the surrounding land-use while only walking mode is considered. Specially, 10 minutes traveling time could reach 1/2-mile by walking. In ARCGIS 10, buffer analysis was used to identify areas surrounding access points within 1/2-mile, and intersect analysis was applied to acquire land use data within the buffer areas.

Next, to measure the level of land use mixture, Herfindahi-Hirschman Index (HHI) was calculated (Song et al., 2004). HHI is the sum of squares of the percentage of every type of land uses in a defined area. Ideally, the lower the value of HHI, the higher the level of land use mixture. HHI is useful to measure the overall level of land use mixture, but ignores the physical and spatial connectivity. For example, HHI could not explain how sidewalks or bicycle lanes connect the greenway trail segments and surrounding commercial area.

Third, space syntax technique, was applied to help understand the spatial interaction of surrounding land use and greenway segments. Space syntax is a tool for describing and
anticipating human use based on urban connectivity through spatial configuration analysis (Hillier, 1996). Spatial configuration is not only the driving force for human activity within the urban environments, but also it influences individual cognition (Jiang, 1998). In this study, one main syntactic measure of spatial configuration: sidewalk connectivity was calculated. Connectivity is the measure of how well an axial line is intersected by other lines. An application of sidewalk connectivity in this study was to measure how sidewalks intersect greenway segments.

Fourth, sidewalk network distance and bicycle route connectivity were measured, using Google Earth and ARCGIS 10 (Janssen and Rosu, 2012). Bicycle route connectivity measured how a greenway segment was intersected by Raleigh Bicycle Routes, an official map of bicycle routes in Raleigh. Sidewalk network distance measured the total distances of sidewalks within 1/2-mile buffer areas.

### 4.2.4 Measure the Usage of Greenway Trails

There are two approaches to measure the use of greenways. One approach, based on interviews, is to acquire information as users’ preference and perception. The other approach is based on site observation and counts the actual use of the greenway. The present study applied the on-site observation as its approach. Learning from previous research experiences (Lindsey et al., 2004; Coutts, 2006), the present study generated an observation schedule on the 15-greenway segments (Table 3.3). The scheduled two-week period was ideal observation time while the following two weeks was planned as supplementary time for the raining days of the first two weeks. This schedule was trying to observe the use of greenway across different days of the week and meanwhile across various times of a day. The collected data did not intend to forecast daily uses of greenway but rather to reveal variations between uses of greenway segments. For each segment, four-rounds of observations were conducted. The observation schedule worked quite well except for one raining Monday. Thus, the researcher did a supplemental Monday observation in the following week.
Table 3.3: Observe Schedule

<table>
<thead>
<tr>
<th>Time/Date</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00-7:30</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:45-8:15</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00-12:30</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:45-1:15</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:00</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>5:00-5:30</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:45-6:15</td>
<td>9</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Week 2: April 7-13, 2014

<table>
<thead>
<tr>
<th>Time/Date</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00-7:30</td>
<td>10</td>
<td>13</td>
<td>12</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:45-8:15</td>
<td>11</td>
<td>14</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00-12:30</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>12</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:45-1:15</td>
<td>9</td>
<td>11</td>
<td>14</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:00-5:30</td>
<td>12</td>
<td>15</td>
<td>10</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:45-6:15</td>
<td>1</td>
<td>11</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The standard procedure for observation listed as below:

1) Select observation location

A pilot study was conducted to determine the best observation point. Access points are usually an ideal location for establishing observation points. If there was more than one access point for the segment then the researcher chose the one that was nearer the middle of the segment.

2) Arrival and prepare

Before rounds are started, date, weather, and round number are recorded on each table.

3) Official observation

One round observation for each segment is 30 minutes. Observed information includes gender and age of users, user group size, and physical activity types (Table 3.4).

4) Assess inter-reliability
In order to assess inter-reliability of counting “greenway usage”, two researchers conducted 20 samples of observations while each of them recorded the usage individually.

Table 3.4: Measurement of Greenway Usage

<table>
<thead>
<tr>
<th>Segment number</th>
<th>Observation point</th>
<th>Round #</th>
<th>Date</th>
<th>Weather</th>
<th>(1) Gender</th>
<th>a. Male</th>
<th>b. Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2) Age</td>
<td>a. Young adult</td>
<td>b. Middle-age adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(4) Group Size</td>
<td>a. Single</td>
<td>b. 2 or More</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(6) Amount</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3 Analysis Techniques

For data analysis, *Kappa statistics, descriptive statistics, correlation analysis*, and *multiple regression analysis* were employed sequentially to explore relationships between variables.

Kappa Statistics was used to test inter-reliability of the instruments. Descriptive statistics was applied to summarize the main features of the collections of data, such as percentage, mean value, minimal value, maximum value, and standard deviation. Correlation analysis was used to reveal the degree of associations between independent and dependent variables, such as trail average slope and physical activity types. Multiple regression models (Tabachnick & Fidell, 2013) were performed between use of greenways as the dependent variable and environmental features, residential proximity, and surrounding land use as independent variables for evaluation of assumptions.

4.3.1 Inter Reliability

The inter-rater reliability of auditing design features and counting greenway usage were determined using Kappa statistic. Five items (viewshed openness, visible manufactured structure, maintenance condition, presence of litter, and intersection safety) out of environmental features of greenways were measured for inter-reliability, using Kappa statistics in SPSS (Version 22) by two researchers (*n*=2; trail segments=15). Six items (user amount, gender, age, ethnicity, group size, and activity type) from greenway usage were measured for inter-reliability, using Kappa statistics in SPSS (Version 22) by two researchers (*n*=2, round number=20). Inter reliability was assessed at the individual item level, with the criteria for Kappa value established as *excellent* (>0.8), *good* (0.61-0.8), *moderate* (0.41-0.6), or *poor* (<0.4), based on published classification system (Landis, 1977).

Table 3.5 is the summary of Kappa statistic for the eleven items. Kappas of 0.8 or higher were obtained on four of 11 items, and between 0.6 and 0.8 were obtained on six of 11 items (Table 3.5). Only one item (visible manufactured structure) got Kappa below 0.4. The reliability testing demonstrated that the two raters agreed on the rating assigned for 10 of 11
items. The results indicated that the two instruments developed for auditing design features and counting greenway usage are valid and reliable for 10 of the 11 variables.

Table 3.5: Summary of Kappa Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample Size</th>
<th>Kappa Value</th>
<th>Asymp. Std. Error</th>
<th>Approx. T</th>
<th>Approx. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewshed openness</td>
<td>15</td>
<td>0.825</td>
<td>0.113</td>
<td>6.077</td>
<td>0.000</td>
</tr>
<tr>
<td>Visible manufactured structure</td>
<td>15</td>
<td>0.362</td>
<td>0.174</td>
<td>2.031</td>
<td>0.042</td>
</tr>
<tr>
<td>Maintenance condition</td>
<td>15</td>
<td>0.797</td>
<td>0.131</td>
<td>4.409</td>
<td>0.000</td>
</tr>
<tr>
<td>Presence of litter</td>
<td>15</td>
<td>0.842</td>
<td>0.151</td>
<td>3.303</td>
<td>0.001</td>
</tr>
<tr>
<td>Intersection safety</td>
<td>15</td>
<td>0.631</td>
<td>0.196</td>
<td>2.918</td>
<td>0.004</td>
</tr>
<tr>
<td>User amount</td>
<td>20</td>
<td>0.783</td>
<td>0.094</td>
<td>12.223</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>20</td>
<td>0.892</td>
<td>0.071</td>
<td>14.742</td>
<td>0.000</td>
</tr>
<tr>
<td>Age</td>
<td>20</td>
<td>0.683</td>
<td>0.104</td>
<td>13.321</td>
<td>0.000</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>20</td>
<td>0.633</td>
<td>0.108</td>
<td>13.031</td>
<td>0.000</td>
</tr>
<tr>
<td>Group size</td>
<td>20</td>
<td>0.837</td>
<td>0.084</td>
<td>13.048</td>
<td>0.000</td>
</tr>
<tr>
<td>Activity type</td>
<td>20</td>
<td>0.634</td>
<td>0.109</td>
<td>13.277</td>
<td>0.000</td>
</tr>
</tbody>
</table>

4.3.2 Descriptive Statistics

Descriptive statistics were used to summarize the uses and the characteristics of greenway trail users along with demographic characteristics of Raleigh from U.S. census were used to make the comparisons. Then, the use patterns from different times of weekday and the use distribution between weekday and weekend were generated.

4.3.3 Correlation Analysis

The correlations between independent variables and dependent variables were determined by Spearman's rho correlation coefficients. A two-tailed Spearman's rho correlation coefficients were calculated in SPSS (version22) and three correlation matrices were generated.
In statistics, the p-value is the probability of obtaining a test statistic result at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. In this study, p-value was measured at two levels: 0.05 and 0.01.

4.3.4 Multiple Regression Analysis

Table 3.6: Variables in Multiple Regression Model

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Hypothesized effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental feature variables</strong></td>
<td></td>
</tr>
<tr>
<td>Trail average slope</td>
<td>Negative</td>
</tr>
<tr>
<td>Elevation change</td>
<td>Negative</td>
</tr>
<tr>
<td>Trail sinuosity</td>
<td>Negative</td>
</tr>
<tr>
<td>Viewshed openness</td>
<td>Positive</td>
</tr>
<tr>
<td>Visible manufactured structure</td>
<td>Negative</td>
</tr>
<tr>
<td>Accessible from park</td>
<td>Positive</td>
</tr>
<tr>
<td>Maintenance condition</td>
<td>Positive</td>
</tr>
<tr>
<td>Presence of litter</td>
<td>Positive</td>
</tr>
<tr>
<td>Intersection safety</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Residential Proximity variables</strong></td>
<td></td>
</tr>
<tr>
<td>Number of access point</td>
<td>Positive</td>
</tr>
<tr>
<td>1/2-mile population</td>
<td>Positive</td>
</tr>
<tr>
<td>4-mile population</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>The surrounding land-use variables</strong></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>Negative</td>
</tr>
<tr>
<td>Sidewalk connectivity</td>
<td>Positive</td>
</tr>
<tr>
<td>Bicycle route connectivity</td>
<td>Positive</td>
</tr>
<tr>
<td>Sidewalk network distance</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Four multiple regression models were tested in SPSS (version 22) to identify the combination of environmental feature variables, residential proximity variables, and the surrounding land-use variables that contribute to use of greenways. The hypothesized effect of each independent variable is present in Table 3.6. The first regression model included all environmental feature variables. The second regression model included all residential proximity variables. The third regression model included all the surrounding land-use
variables. The fourth regression model (refined regression model) combined all independent variables but excluded those were not significantly associated with dependent variable in correlation analysis.

5. Results
5.1 Descriptive Results
Table 3.7 is the summary of the usage of greenway trails. Only the users engaging in activities on the greenway trail were included while people in spaces adjacent to the greenway trail (e.g., parks, bench or playground) were not counted. A total number of 1840 individuals were counted in the 15-greenway trail segments. Segment 1 had the most users of 252 while Segment 14 was with the least users of 38. The mean number of users for all the segments was 113. Greenway users were 61.25% male and 38.75% female. In terms of the age, 52.28% were young adults; 39.29% were middle age; and 8.42% were seniors. In the observed greenway users, African-Americans, White, Hispanic, and others represented 15.60%, 76.90%, 3.42%, and 4.62%, respectively. A total of 59.46% of the greenway users were counted as single users while 40.54% were counted as group users. For activity type, biking (41.25%) was the most popular one; walking (31.41 %) was the second place; and jogging (27.34%) took up the third place.

Table 3.8 is a simplified demographic summary of Raleigh. While comparing Table 3.7 with Table 3.8, the female percentage (38.75%) of observed greenway users was lower than the female percentage (48.32%) of the population in Raleigh, which indicated females seem to use trails less than males. This phenomenon might be explained by safety reason as natural corridors in the city are often considered as being potential unsafe, especially for women (Luymes and Tamminga, 1995). It is also noticed that only 15.60% greenway trail users were African America, which was much lower than African America percent (29.33%) of the population in Raleigh. This result was consistent with previous findings (Furuseth & Altman, 1991; Lindsey, 1999; Bowman, 2009; Floyd et al, 2008) that ethnic minorities seem to use greenway trails less than white users.
Table 3.7: Usage of Greenway Trails by Gender, Age, Ethnicity, Group Size and Activity Type

<table>
<thead>
<tr>
<th>Segment No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>Total</th>
<th>Percent</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of uses</td>
<td>252</td>
<td>175</td>
<td>152</td>
<td>211</td>
<td>173</td>
<td>123</td>
<td>132</td>
<td>112</td>
<td>65</td>
<td>53</td>
<td>66</td>
<td>38</td>
<td>111</td>
<td></td>
<td>1840</td>
<td>100.00%</td>
<td>38</td>
<td>252</td>
<td>112.67%</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>150</td>
<td>98</td>
<td>102</td>
<td>130</td>
<td>76</td>
<td>80</td>
<td>72</td>
<td>45</td>
<td>47</td>
<td>33</td>
<td>55</td>
<td>39</td>
<td>20</td>
<td>60</td>
<td>1127</td>
<td>61.25%</td>
<td>20</td>
<td>150</td>
<td>75.13%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>102</td>
<td>77</td>
<td>50</td>
<td>81</td>
<td>53</td>
<td>47</td>
<td>52</td>
<td>40</td>
<td>20</td>
<td>37</td>
<td>20</td>
<td>38</td>
<td>27</td>
<td>18</td>
<td>713</td>
<td>38.75%</td>
<td>18</td>
<td>102</td>
<td>47.53%</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young Adult</td>
<td>125</td>
<td>90</td>
<td>70</td>
<td>102</td>
<td>86</td>
<td>70</td>
<td>75</td>
<td>62</td>
<td>35</td>
<td>45</td>
<td>30</td>
<td>53</td>
<td>35</td>
<td>23</td>
<td>61</td>
<td>962</td>
<td>52.28%</td>
<td>23</td>
<td>125</td>
<td>64.13%</td>
</tr>
<tr>
<td>Middle-Age Adult</td>
<td>98</td>
<td>65</td>
<td>69</td>
<td>84</td>
<td>80</td>
<td>45</td>
<td>50</td>
<td>45</td>
<td>23</td>
<td>30</td>
<td>20</td>
<td>32</td>
<td>26</td>
<td>11</td>
<td>45</td>
<td>723</td>
<td>39.29%</td>
<td>11</td>
<td>98</td>
<td>48.2%</td>
</tr>
<tr>
<td>Senior</td>
<td>29</td>
<td>20</td>
<td>13</td>
<td>25</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>155</td>
<td>8.42%</td>
<td>3</td>
<td>29</td>
<td>10.33%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African America</td>
<td>45</td>
<td>30</td>
<td>25</td>
<td>41</td>
<td>23</td>
<td>20</td>
<td>17</td>
<td>15</td>
<td>10</td>
<td>14</td>
<td>9</td>
<td>15</td>
<td>8</td>
<td>5</td>
<td>10</td>
<td>287</td>
<td>15.60%</td>
<td>5</td>
<td>45</td>
<td>19.13%</td>
</tr>
<tr>
<td>White</td>
<td>198</td>
<td>130</td>
<td>112</td>
<td>165</td>
<td>124</td>
<td>95</td>
<td>110</td>
<td>95</td>
<td>52</td>
<td>60</td>
<td>40</td>
<td>73</td>
<td>51</td>
<td>30</td>
<td>80</td>
<td>1415</td>
<td>76.90%</td>
<td>30</td>
<td>198</td>
<td>94.33%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>2</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td>63</td>
<td>3.42%</td>
<td>1</td>
<td>13</td>
<td>4.33%</td>
</tr>
<tr>
<td>Others</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>3</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>18</td>
<td>85</td>
<td>4.62%</td>
<td>1</td>
<td>18</td>
<td>5.67%</td>
</tr>
<tr>
<td>Group Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>140</td>
<td>112</td>
<td>90</td>
<td>120</td>
<td>101</td>
<td>80</td>
<td>75</td>
<td>65</td>
<td>37</td>
<td>52</td>
<td>32</td>
<td>60</td>
<td>42</td>
<td>21</td>
<td>67</td>
<td>1094</td>
<td>59.46%</td>
<td>21</td>
<td>140</td>
<td>72.93%</td>
</tr>
<tr>
<td>2 or More</td>
<td>112</td>
<td>63</td>
<td>62</td>
<td>91</td>
<td>72</td>
<td>43</td>
<td>57</td>
<td>47</td>
<td>28</td>
<td>32</td>
<td>21</td>
<td>33</td>
<td>24</td>
<td>17</td>
<td>44</td>
<td>746</td>
<td>40.54%</td>
<td>17</td>
<td>112</td>
<td>49.73%</td>
</tr>
<tr>
<td>Activity Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walk</td>
<td>74</td>
<td>53</td>
<td>52</td>
<td>66</td>
<td>55</td>
<td>38</td>
<td>42</td>
<td>36</td>
<td>20</td>
<td>29</td>
<td>16</td>
<td>30</td>
<td>21</td>
<td>11</td>
<td>35</td>
<td>578</td>
<td>31.41%</td>
<td>11</td>
<td>74</td>
<td>38.53%</td>
</tr>
<tr>
<td>Bike</td>
<td>88</td>
<td>66</td>
<td>61</td>
<td>83</td>
<td>70</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>25</td>
<td>38</td>
<td>20</td>
<td>40</td>
<td>28</td>
<td>20</td>
<td>50</td>
<td>759</td>
<td>41.25%</td>
<td>20</td>
<td>88</td>
<td>50.60%</td>
</tr>
<tr>
<td>Jog</td>
<td>90</td>
<td>56</td>
<td>39</td>
<td>62</td>
<td>48</td>
<td>35</td>
<td>30</td>
<td>16</td>
<td>20</td>
<td>17</td>
<td>17</td>
<td>23</td>
<td>17</td>
<td>7</td>
<td>26</td>
<td>503</td>
<td>27.34%</td>
<td>7</td>
<td>90</td>
<td>33.53%</td>
</tr>
</tbody>
</table>

Notes: others= unsure of the ethnicity
Table 3.8: Demographic Characteristics of Raleigh (Source: U.S. Census 2010)

<table>
<thead>
<tr>
<th></th>
<th>Counts</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Population</strong></td>
<td>403892</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Population by Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>208749</td>
<td>51.68%</td>
</tr>
<tr>
<td>Female</td>
<td>195143</td>
<td>48.32%</td>
</tr>
<tr>
<td><strong>Population by Ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African America</td>
<td>118471</td>
<td>29.33%</td>
</tr>
<tr>
<td>White</td>
<td>232377</td>
<td>57.53%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>45868</td>
<td>11.36%</td>
</tr>
<tr>
<td>Others</td>
<td>7176</td>
<td>1.78%</td>
</tr>
<tr>
<td><strong>Population by Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 18</td>
<td>93236</td>
<td>23.08%</td>
</tr>
<tr>
<td>18-34</td>
<td>130549</td>
<td>32.32%</td>
</tr>
<tr>
<td>35-64</td>
<td>146969</td>
<td>36.39%</td>
</tr>
<tr>
<td>65 &amp; over</td>
<td>33138</td>
<td>8.20%</td>
</tr>
</tbody>
</table>

**Notes:** others= unsure of the ethnicity

Note: the number of weekday users was divided by three to adjust to weekend users.

Figure 3.6: Use Comparisons between Weekday and Weekend
Figure 3.6 and Figure 3.7 respectively represent use comparisons between weekday and weekend, and the distribution of uses by time of weekdays. In order to compare fairly with weekend users, the number of weekday users were adjusted (divided by three since three-round observations were conducted). After adjustment (Figure 3.6), the researcher could summarize that weekday users (326) was much lower than weekend (862). This phenomenon is consistent with previous research (Coutts, 2006; Hunter et al., 1995) that people are more likely to use greenway trails in weekends. In the observed periods, numbers of morning, noon, and afternoon users during weekdays were respectively 109, 204, and 665 (Figure 3.7). Consistent with previous findings (Lindsey, 1999), observed weekday use was lowest in the morning, higher in the noon, and was highest in the afternoon.
5.2 Correlation Results

A correlation matrix (Spearman's Rho) of the environmental features variables and the trail use variables is presented in Table 3.9. Correlation (r) values and their associated p-values indicated the extent of associations between the environmental features variables and the trail use variables. Since the p-value for the correlation coefficient between trail average slope and trail use was 0.024 and the r-value was -0.577, trail average slope was negatively associated with trail use at the 0.05 level. In addition, since the p-value for the correlation coefficient between maintenance condition and trail use was 0.001 and r-value was 0.756, maintenance condition was positively associated with trail use at the 0.01 level. The negative correlation coefficient between trail average slope and trail use indicated general greenway trail users prefer segments with a smaller slope. The positive correlation coefficient between maintenance condition and trail use indicated a better maintenance condition of the greenway trail would increase the number of users.

Since trail average slope was also negatively associated with bike use at the 0.05 level, hypothesis 1A was not rejected: a decreased level of trail slope would increase the number of biking user on the greenway. This assumption is different from mountain bicyclists' preference for slopes in previous study (Hopkin & Moore, 1995). The p-value for the correlation coefficient between viewshed openness and group user was 0.683. Since P-value > 0.1, there was no presumption against the null hypothesis. So hypothesis 1B (a decreased level of greenway openness would increase the number of group users on the greenway) was rejected. This result is interesting because hypothesis 1B is based on literature (Luymes & Tamminga, 1995, Reynolds et al., 2006) that public safety is concerned in high vegetation density.
Table 3.9
Correlation Matrix (Spearman's Rho) of the Environmental Features Variables and the Trail Use Variables

<table>
<thead>
<tr>
<th>Correlation (r) value</th>
<th>Bike use</th>
<th>Group user</th>
<th>Trail average slope</th>
<th>Elevation change</th>
<th>Trail Sinuosity</th>
<th>Viewshed openness</th>
<th>Visible manufactured structure</th>
<th>Accessible from park</th>
<th>Maintenance condition</th>
<th>Presence of Litter</th>
<th>Intersection safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trail use</td>
<td>.987**</td>
<td>.982*</td>
<td>-0.577*</td>
<td>-0.043</td>
<td>-0.111</td>
<td>-0.087</td>
<td>0.396</td>
<td>0.186</td>
<td>0.756**</td>
<td>0.000</td>
<td>0.352</td>
</tr>
<tr>
<td>Bike use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group user</td>
<td>.994**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trail average slope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevation change</td>
<td>.340</td>
<td>.377</td>
<td></td>
<td>-0.049</td>
<td>-0.114</td>
<td>0.264</td>
<td>-0.401</td>
<td>-0.018</td>
<td>-0.018</td>
<td>-0.021</td>
<td></td>
</tr>
<tr>
<td>Trail sinuosity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viewshed openness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible manufactured structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessible from park</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of Litter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersection safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

88
<table>
<thead>
<tr>
<th>p value</th>
<th>Bike use</th>
<th>Group user</th>
<th>Trail average slope</th>
<th>Elevation change</th>
<th>Trail Simuosity</th>
<th>Viewshed openness</th>
<th>Visible manufactured structure</th>
<th>Accessible from park</th>
<th>Maintenance condition</th>
<th>Presence of Litter</th>
<th>Intersection safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trail use</td>
<td>.000</td>
<td>.000</td>
<td><strong>.024</strong></td>
<td>.878</td>
<td>.693</td>
<td>.757</td>
<td>.144</td>
<td>.508</td>
<td><strong>.001</strong></td>
<td>1.000</td>
<td>.198</td>
</tr>
<tr>
<td>Bike use</td>
<td>.000</td>
<td>.034</td>
<td>.845</td>
<td>.767</td>
<td>.636</td>
<td>.161</td>
<td>.581</td>
<td>.001</td>
<td>.951</td>
<td>.902</td>
<td>.335</td>
</tr>
<tr>
<td>Group user</td>
<td>.017</td>
<td>.775</td>
<td>.767</td>
<td><strong>.683</strong></td>
<td>.144</td>
<td>.582</td>
<td>.001</td>
<td>.951</td>
<td>.902</td>
<td>.335</td>
<td></td>
</tr>
<tr>
<td>Trail average slope</td>
<td></td>
<td></td>
<td>.214</td>
<td>.166</td>
<td>.861</td>
<td>.686</td>
<td>.342</td>
<td>.138</td>
<td>.951</td>
<td>.940</td>
<td></td>
</tr>
<tr>
<td>Elevation change</td>
<td></td>
<td></td>
<td>.367</td>
<td>.156</td>
<td>.494</td>
<td>.036</td>
<td>.821</td>
<td>.838</td>
<td>.762</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trail sinuosity</td>
<td></td>
<td></td>
<td></td>
<td>.655</td>
<td>.707</td>
<td>.009</td>
<td>.449</td>
<td>.121</td>
<td>.804</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viewshed openness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.891</td>
<td>.121</td>
<td>.656</td>
<td>.023</td>
<td>.124</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible manufactured structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.347</td>
<td>.298</td>
<td>.397</td>
<td>.990</td>
<td></td>
</tr>
<tr>
<td>Accessible from park</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.207</td>
<td>.211</td>
<td>.180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.350</td>
<td>.358</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of Litter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.576</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** *p<0.05  **p<0.01
A correlation matrix (Spearman's Rho) of the residential proximity variables and the trail use variables is presented in Table 3.10. Correlation (r) values and their associated p-values indicated the extent of associations between the residential proximity variables and the trail use variables. The p-value for the correlation coefficient between 1/2-mile population and trail use was 0.027, and r-value was 0.568. Therefore, 1/2-mile population was positively associated with trail use at the 0.05 level. This result indicated that the hypothesis 2A (an increased level of population density within 1/2-mile distance would increase the user number of the greenway) was supported. However, the p-value for the correlation coefficient between 4-mile population and trail use was 0.499, which indicated 4-mile population was not associated with trail use. Since the p value for correlation coefficient between number of access points and walking use was 0.895, hypothesis 2B (an increased amount of access point would increase the amount of walking users on the greenway) was rejected. Although in general people thought more access points might provide convenience for people to enter greenways by foot, in this study there was no significant association between number of
access point and walking use.

A correlation matrix (Spearman's Rho) of the surrounding land-use variables and the trail use variable is presented in Table 3.11. The p-value for the correlation coefficient between HHI and trail use was 0.012, and r-value was -0.629. Therefore, HHI was negatively associated with trail use at the 0.05 level. Since lower value of HHI refers to higher level of land-use mixture, hypothesis 3A- an increased level of land-use mixture would increase the amount of users on the greenway- was not rejected. However, hypothesis 3B (an increased level of spatial interaction, as measured by sidewalk connectivity would increase the amount of users on the greenway) was rejected, because the p value for correlation coefficient between trail use and sidewalk connectivity was 0.275.

<table>
<thead>
<tr>
<th>Correlation (r) value</th>
<th>HHI</th>
<th>Sidewalk connectivity</th>
<th>Bicycle connectivity</th>
<th>Sidewalk distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trail use</td>
<td>-.629*</td>
<td>.302</td>
<td>-.247</td>
<td>.211</td>
</tr>
<tr>
<td>HHI</td>
<td>-.055</td>
<td>.155</td>
<td>.282</td>
<td></td>
</tr>
<tr>
<td>Sidewalk connectivity</td>
<td></td>
<td>.173</td>
<td>.603*</td>
<td></td>
</tr>
<tr>
<td>Bicycle connectivity</td>
<td></td>
<td></td>
<td>.093</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p value</th>
<th>HHI</th>
<th>Sidewalk connectivity</th>
<th>Bicycle connectivity</th>
<th>Sidewalk distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trail use</td>
<td>.012</td>
<td>.275</td>
<td>.374</td>
<td>.451</td>
</tr>
<tr>
<td>HHI</td>
<td>.847</td>
<td>.582</td>
<td>.308</td>
<td></td>
</tr>
<tr>
<td>Sidewalk connectivity</td>
<td></td>
<td>.537</td>
<td>.017</td>
<td></td>
</tr>
<tr>
<td>Bicycle connectivity</td>
<td></td>
<td></td>
<td>.742</td>
<td></td>
</tr>
</tbody>
</table>

Notes: *p<0.05  **p<0.01
5.3 Multiple Regression Results

Table 3.12 presents a predictive model of greenway trail uses, based on trail feature variables. In this model, the dependent variable was trail use while the predictors were trail average slope, elevation change, trail sinuosity, viewshed openness, visible manufactured structure, accessible from park, maintenance condition, presence of litter, and intersection safety. The model explained approximately 86% of the variation in greenway trail usage. Most of the variables had associations in the assumed directions. Three variables: average slope (p=0.025), viewshed openness (p=0.019), and maintenance condition (p=0.007) out of the nine variables in this model were statistically significant. The hypothesized effect direction of viewshed openness was positive, however, in this model, viewshed openness was in the unexpected direction (negative direction) to predict trail use.

### Table 3.12

#### Multiple Regression Model 1: Effect of Trail Features on Trail Use

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.975&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.950</td>
<td>.860</td>
<td>22.8230620</td>
</tr>
</tbody>
</table>

<sup>a</sup> Predictors: (Constant), Trail average slope, Elevation change, Trail sinuosity, Viewshed openness, Visible manufactured structure, Accessible from park, Maintenance condition, Presence of litter, Intersection safety

#### ANOVA<sup>a</sup>

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>49328.873</td>
<td>9</td>
<td>5480.986</td>
<td>10.522</td>
<td>.009&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1 Residual</td>
<td>2604.461</td>
<td>5</td>
<td>520.892</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>51933.333</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Dependent Variable: Trail use

<sup>b</sup> Predictors: (Constant), Trail average slope, Elevation change, Trail sinuosity, Viewshed openness, Visible manufactured structure, Accessible from park, Maintenance condition, Presence of litter, Intersection safety
Table 3.12 Continued

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>12.660</td>
<td>49.703</td>
<td>.255</td>
<td>.809</td>
</tr>
<tr>
<td>Trail average slope</td>
<td>-1759.121</td>
<td>554.107</td>
<td>-.491</td>
<td>-3.175</td>
</tr>
<tr>
<td>Elevation change</td>
<td>12.634</td>
<td>10.099</td>
<td>.169</td>
<td>1.251</td>
</tr>
<tr>
<td>Trail sinuosity</td>
<td>-6.913</td>
<td>14.395</td>
<td>-.084</td>
<td>-.480</td>
</tr>
<tr>
<td>Viewshed openness</td>
<td>-24.741</td>
<td>7.289</td>
<td>-.497</td>
<td>-3.394</td>
</tr>
<tr>
<td>Visible manufactured structure</td>
<td>-4.070</td>
<td>8.173</td>
<td>-.066</td>
<td>-.498</td>
</tr>
<tr>
<td>Accessible from park</td>
<td>8.143</td>
<td>11.028</td>
<td>.138</td>
<td>.738</td>
</tr>
<tr>
<td>Maintenance condition</td>
<td>39.817</td>
<td>8.984</td>
<td>.545</td>
<td>4.432</td>
</tr>
<tr>
<td>Intersection safety</td>
<td>31.843</td>
<td>12.849</td>
<td>.323</td>
<td>2.478</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Trail use

Table 3.13 presents a predictive model of greenway trail uses, based on residential variables. In this model, the dependent variable was trail use while the predictors were number of access points, 1/2-mile population, and 4-mile population. As the adjusted R² was 0.398, the model explained approximately 40% of the variation in greenway trail usage. Since the overall p value was 0.036, the model has less than 5% chance of being wrong. However, only one variable: 1/2-mile population (p=0.006) was statistically significant.
Table 3.13
Multiple Regression Model 2: Effect of Residential Proximity Variables on Trail Use

Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>.726a</td>
<td>.527</td>
<td>.398</td>
<td>47.2699943</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), Number of access point, 1/2-mile population, 4-mile population

ANOVAa

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>27354.357</td>
<td>3</td>
<td>9118.119</td>
<td>4.081</td>
<td>.036b</td>
</tr>
<tr>
<td>2</td>
<td>Residual</td>
<td>11</td>
<td>2234.452</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>51933.333</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: Trail use
b. Predictors: (Constant), Number of access point, 1/2-mile population, 4-mile population

Coefficientsa

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>93.936</td>
<td>93.881</td>
<td>1.001</td>
<td>.339</td>
</tr>
<tr>
<td>2</td>
<td>Number of access point</td>
<td>-21.938</td>
<td>-1.702</td>
<td>.117</td>
</tr>
<tr>
<td>1/2-mile population</td>
<td>.028</td>
<td>.008</td>
<td>.819</td>
<td>.006</td>
</tr>
<tr>
<td>4-mile population</td>
<td>-8.444E-005</td>
<td>.000</td>
<td>-.236</td>
<td>.818</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Trail use
Table 3.14
Multiple Regression Model 3: Effect of the Surrounding Land-use Variables on Trail Use

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>(Constant)</td>
<td>172.423</td>
<td>38.500</td>
</tr>
<tr>
<td>HHI</td>
<td>-170.932</td>
<td>73.552</td>
</tr>
<tr>
<td>Sidewalk connectivity</td>
<td>-1.118</td>
<td>8.843</td>
</tr>
<tr>
<td>Bicycle connectivity</td>
<td>-23.559</td>
<td>24.562</td>
</tr>
<tr>
<td>Sidewalk distance</td>
<td>10.923</td>
<td>7.363</td>
</tr>
</tbody>
</table>

Table 3.14 presents a predictive model of greenway trail uses, based on the surrounding land-use. In this model, the dependent variable was trail use while the predictors were HHI, sidewalk connectivity, bicycle connectivity, and sidewalk distance. As the adjusted R² was
0.493, the model explained approximately 49% of the variation in greenway trail usage. Since the overall p value was 0.026, the model has less than 5% chance of being wrong. However, only one variable: HHI (p=0.042) was statistically significant.

Table 3.15
Multiple Regression Model 4: Effect of the Refined Variables on Trail Use

<table>
<thead>
<tr>
<th>Model Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), Trail average slope, Maintenance condition, 1/2-mile population, HHI

<table>
<thead>
<tr>
<th>ANOVAa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Regression</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Trail use
b. Predictors: (Constant), Trail average slope, Maintenance condition, 1/2-mile population, HHI

<table>
<thead>
<tr>
<th>Coefficientsa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>(Constant)</td>
</tr>
<tr>
<td>Trail average slope</td>
</tr>
<tr>
<td>Maintenance condition</td>
</tr>
<tr>
<td>1/2-mile population</td>
</tr>
<tr>
<td>HHI</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Trail use
Table 3.15 presents a predictive model of greenway trail uses, based on significant predictors from Model 1, Model 2 and Model 3. In this model, the dependent variable was trail use while the predictors were trail average slope, maintenance condition, 1/2-mile population, and HHI. The model explained approximately 86.5% of the variation in greenway trail usage. Since the overall p value was 0.0001, the model has less than 0.1% chance of being wrong. All the variables had associations in the assumed directions. Three variables: trail average slope (p=0.011), maintenance condition (p=0.001), and 0.5 mile population (p=0.011) out of the four variables in this model were statistically significant. HHI was an significant predictor in model 3, but was not significant in this model.

6. Discussions
This paper has presented measures and analysis techniques on characteristics of greenway trails and usage of trails for 15 greenway segments in Raleigh. The results add to previous findings (Lindsey et al, 2006; Coutts, 2006; Reynolds et al, 2007) on trail use by four established predictive models with more urban form variables. These results might influence greenway trail planning and design to maximize opportunities for increasing physical activity (Frank et al., 2003). This research is also an explorative study adding to Leadership in Energy & Environmental Design (LEED) 2014 for Neighborhood Development, which is a national rating system for sustainable neighborhood development. Since urban greenway trail is an important element of green infrastructure that connects neighborhoods and diverse uses, the future version of LEED might adopt greenway as one rating item.

6.1 Objective Measures of Trail Use
The data for this study was collected during the winter season (December, 2013 to March, 2014), which in Raleigh was extremely long and cold. The observed number of users during the first two weeks of April, 2014 was much larger than the observation of pilot study in early March, 2014. This phenomenon might be explained by people's strong desire to be in touch with warmer outdoor environment after the long and cold winter. However, the present study does not find that individual users tend to be like more open greenway trail segments.
than enclosed ones. This is not consistent with previous finding that trail use is higher where views are more open (Lindsey et al., 2008). Greenway trails in Raleigh seem to be used primarily by bicycles (41%). Trail use also varied over segment and time. The observers in the site did not distinguish between transportation and recreational users. The following chapter will discuss the intercept surveys that were conducted to investigate the relationship between recreation and transportation users along the greenway trails.

6.2 Model for Trail Use

In this study, testing was done on four predictive models. Greenway trail usage, modeled as a combination of particular environmental features, accessible residential proximity, and mixed surrounding land-use. The predictive models could provide insights into covariates of trail use. For example, the results indicate mixed land use might encourage trail activity, which is consistent with previous findings (Frank et al., 2003; Lindsey et al., 2006; Lindsey et al., 2008). However, people living in particular neighborhood might have preference for greenway segments or some segments might have special characteristics to attract users (Shafer et al., 2000). These phenomena could not be tested or analyzed from the predictive models because individual users' preference and perception are not available in this study.

6.3 Implication for Greenway Trail Planning and Design

Although greenway planning has primarily relied on creek route and hydrological flow, the social aspect is also an important factor to influence greenway route. From urban planners' perspective, the most important findings concern the correlation between trail use and proximate population and land-use mixture. These findings supports evidences for the planning theory that high population is associated with high efficiency in utilization of public facilities (Frank et al., 2003).

Design is an important factor in the construction of urban greenway trails, but it is not the only factor that may influence use. A person's decision to use a trail is a combination of many factors including his own preferences and the built environments. From a greenway trail
designer's perspective, the most important findings concern the correlation between trail use and environmental features of the greenways. Three variables (trail average slope, viewshed openness, and maintenance condition), which were significantly associated with trail use in Model 1 need to be considered in the future expansion and management.

6.4 Limitation and Future Research
Several limitation are present in this study. First, one should be cautious when translating the findings into recommendation for future construction. The correlations identified in this research do not determine causal direction. Second, although this study indicates association between trail use and proximate population, it is not sure whether the greenway trail users are all from the estimated parameters. Thus, the following Chapter will investigate individuals who actually use greenway trails through intercept survey. The intercept survey could help verify whether the users of greenway are from defined user parameters or not.

7. Conclusion
A better understanding of the variables associated with urban greenway usage is essential to the successfully planning and managing greenways, because of the difficulty in predicting their use. The aim of this paper is: (1) to explore the cumulative contributions that the three indicators (greenway characteristics, residential proximity, and surrounding land use) predict the use of the greenway; (2) to explore dependable and replicable measures of urban greenway trail usage, characteristics of greenway trails and surrounding neighborhoods. The results revealed significant environmental features, residential proximity and the surrounding land-use variations in trail use on multiuse urban greenways. In general, the results indicate that people tend to use urban greenway trails with low slope and good maintenance conditions, proximate access and mixed land-use in the surrounding area. The regression models could identify urban trail use in Raleigh, but care in generalization is the rule due to interfering factors. Individual users' preference and perception also need to consider. It is concluded that although greenway planning has been primarily relied on creek route and hydrological flow, the social aspect is also an important factor to determine greenway route.
REFERENCES


Fraser, S.D., Lock, K., (2010). Cycling for transport and public health: a systematic review of


Heath, G.W., Brownson, R.C., Kruger, J., Miles, R., Powell, K.E., Ramsey, L.T., (2006). The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. Journal of Physical Activity & Health, 3(suppl.1), 55–76.


Pucher, J., Dill, J., Handy, S., (2010). Infrastructure, programs, and policies to increase bicycling: an international review. Preventive Medicine, 50(suppl.1), 106-125.


Chapter IV

Investigating the Modes of Travel between Recreation Users and Transportation Users along the Urban Greenway Trails

Abstract

Greenways across a range of landscapes can serve society in numerous ways, including as both transportation corridors and as recreation opportunities. This study investigates to what extent people use greenways as transportation corridors in Raleigh. Additionally, this study also explores the modes of travel between recreation users and transportation users along the urban greenway trails in Raleigh. A total number of 450 surveys (30 surveys for each greenway trail segment) were gathered at fifteen greenway segments in Raleigh, with a response rate is 84.4%. The results indicate that 56% respondents live within 1/2-mile, and 98.22% respondents live within 4-mile. In term of use purpose, recreation users, mixed users and commuters are responded as 61.78%, 26.67%, and 11.56% respectively. Modes of travel are different between commuters, recreational users, and mixed users. The findings show that in Raleigh that purely recreational users tend to make longer, but fewer visits than none-purely recreational users. Meanwhile non-recreational users tend to use automobiles less to reach greenway than purely recreational users. The diversity of users along these urban greenway segments confirm the necessity to ascertain who is using the trail and why. The dominant proportions of recreational users in this study indicate that greenways play an important role as recreation resources, but potential number of transportation users along greenways are encouraged. Future research needs to explore how urban greenway system work as urban infrastructure in combination with public transit and urban bicycle routes to facilitate non-motorized transportation.

Keywords: Transportation, Recreation, Greenway, Modes of Travel, Intercept Survey
1. Introduction

The greenway is both an historic and evolutionary product since the spectacular spread of urban parks and parks system in America during the late 19th century (Fabos, 2004; Walmsley, 2006). Historically, greenways served as transportation corridors. For example, the three historic greenways (Gwynns Falls, Hones Falls, and Herring Run) in Baltimore, MD provided transportation routes to facilitate people's movement across the city as well as to support the city's economic growth for several decades. Fueled by rapid post-war industrialization, urbanization, and automobile transportation, American cities grew by adding rings of suburbs around their center (Walmsley, 2006). This expansion has resulted in a hierarchical road network with automobiles as dominated vehicles (Cervero & Gorham, 1995).

Statistics show worldwide active transportation has declined in the recent decades, both for youth and adults, accompanied by increasing use of mechanized transportation (World Health Organization, 2014). For example, between 1969 and 2009, the number of children 5 to 14 years old who walked or cycled to school dropped from 48% to 13% (The National Center for Safe Routes to School, 2001). Research with transportation planning and urban design try to explore characteristics of the urban environment that might facility walking and cycling (Sallis et al., 2004; Saelens et al., 2003), and indicate that multiple destinations close by, population density and transportation facilities are all positively associated with active transportation (Heath et al., 2006; Saelens et al., 2008; Durand et al., 2011; Ewing et al., 2010; Fraser et al., 2010). One important mean of landscape planning is the contemporary urban greenway network, which can create a citywide network of landscape boulevards, greenway streets, and linear parks to provide sustainable transportation infrastructure with potential daily physical activities. As an alternative transportation system, the key benefit of the greenway network is to minimize the use of cars, especially for short or frequent trips.

Greenways across a range of landscapes in the urban area serve society as both transportation
corridors and recreational pathways (Pettengill et al., 2012). The recent growing recreational activities in urban areas are associated with greenway uses (Lynn & Brown, 2002). Urban greenways can provide numerous recreational opportunities: hiking, biking, jogging and wildlife viewing. The greenways have potential to serve as trails, linear parks, or bike paths with safety for biking and walking (Lindsey, 1999; Coutts, 2006) because greenway trails parallel with roadways and supply suitable surface for such activities. Unlike other types of physical activities, biking and walking require no specialized skills so that a large number of populations are able to perform (Coutts, 2006).

As greenways continue to develop and expand across cities, information about greenway users is important to research-based greenway planning and design. Although greenways claim to be a great opportunity for transportation trips by numerous studies (Shafer 2000; Walmsley, 2006; Gobster, 1995; and Lindsey; 2003), this study investigates to what extent people use greenways as transportation corridors in Raleigh. Additionally, this study explores the relationship between recreation users and transportation users along the urban greenway trails in Raleigh.

Three research questions are proposed in this study. They are presented as below.

(1) To what extent are greenway users from assumed distances (1/2-mile and 4-mile)?
(2) What is the difference of frequency between recreation and transportation users of the urban greenway?
(3) Along Raleigh urban greenways, are recreation users more numerous than transportation users and why?

2. Literature Review

2.1 Contemporary Urban Greenway Network

Building on the legacy of historic greenway planning in America, several new initiatives, such as New Urbanism, Smart Growth, and Green Infrastructure have been taking shape and gaining recognition in the recent years (Walmsley, 2006). Today, urban greenway networks
could be the new method of providing a useful bridge between two design innovations: New *Urbanism* and *Ecological Design* (Arendt, 2001). Specifically, contemporary greenway trails combine compatible land uses (residential land, commercial land, school land, and parkland) within a structured network and provide alternative routes for transportation. “The linkage of greenways is the key that could contribute to place economic development and neighborhood revitalization” (Erickson, 2004). In many America cities, contemporary greenway implementations are based on historic greenway and city form. Like a number of other North American cities, the greenways in Milwaukee and Ottawa have evolved to satisfy multiple demands because of the urban and social dynamics (Erickson, 2004). Thus, greenways are an illustration of “an adaptive urban landscape forming to the physical and psychological pressures of urbanization” (Searns, 1995).

### 2.2 Human Use of Greenway

Since urban greenways are normally free of charge, proximity might be the most important aspect of access for urban greenways. Accessibility is a key issue whether people are able to use parks and recreation facilities. Some studies have found that access to recreation facilities is positively associated with physical activity (Brownson et al., 2001; Wilson et al., 2004; Commbes et al., 2010). Other studied agreed that most users of the greenway in U. S. come from within five miles (Furuoshth & Altman, 1991; PKU Consulting, 1994).

A number of studies explored uses of greenways across different locations with diverse research strategies and techniques (Gobster, 1995; Moore et al., 1992; Bowman, 2009; Lindsey, 1999; Brownson et al., 2001; Pettenhill et al., 2012). Gobster (1995) examined thirteen trails in Chicago to identify a diverse range of greenway trails, to examine people’s use patterns, perceptions and preference, and to identity location, design and management factors for the development. The study suggested local, regional and state trails are distinguished by users. Lindsey (1999) reported counts and surveys of users on three linked greenway trails in Indianapolis. The results showed intensity and patterns of use vary considerably by greenway segment. Shafer and his colleagues (2000) studied three greenway...
trails in Texas and distinguished trail users as commuters, recreational users, or mixed users. The findings indicate that commuters care more about pollution and transportation costs reduction while recreational users believe greenway enhance their life quality through fitness and natural environment.

2.3 The Built Environment and Active Transportation

Studies show certain urban environment might facilitate walking and cycling (Sallis et al., 2004; Saelens et al., 2003). For example, a compact multiple destination, referred to diverse land uses that are relevant to daily life of shopping, working, and exercise, was positively associated with active transportation (Saelens et al., 2008). Rodríguez and his colleagues (2009) also found proximity to parks and commercial areas is associated with active transportation. This could explain the attractiveness of these destinations. Research by Nuworson and Cooper (2013) indicates that pedestrians and bicyclists strongly desire automobile-separated facilities on street. People who frequently use public transportation tend to be more active (Lindstrom, 2008) because they need walk or bike to transit. Conversely, a considerable number of studies (Berrigan & Troiano, 2002; Frank & Pivo, 1995) indicate that urban sprawl, measured by low residential density and low connectivity, is negatively associated with walking and bicycling. Studies also indicate that greenway trails with good access to mixed land-uses may encourage pedestrian activity (Lindsey et al., 2008; Coutts, 2006).

Although previous studied have distinguished recreational users and commuters along greenway trails, this study is different in several ways. First, rather than focusing on a single or few locations, this study encompasses a wider range of greenway segments across the city. Second, rather than only exploring users' experience on greenway trails, this study also includes an analysis of the surrounding environment.
3. Methods

3.1 Study Overview
The presented study used an on-site survey from fifteen greenway segments in Raleigh. The design of the surveys was to measure users' trip purpose. Also, demographic information and the activity types of respondents were recorded. Then, observed greenway usage data from Chapter III and greenway surrounding environment were analyzed to interpret survey results.

3.2 Study Area and Sampling Strategy
Raleigh is the Capital and the second largest city in the state of North Carolina. The current greenway system includes 117 miles of trails and 3700 acres of the greenway property. Initiated as amenities to provide recreational and social opportunities for Raleigh residents, the current Capital Greenway System has been a component of highly connected bicycle and pedestrian network for not only recreation, but also transportation. With over 100 miles of trails, the downtown, suburban, commercial areas, and more rural landscapes are physically connected. For this study, the selection of fifteen greenway segments in Raleigh depicted in Figure 4.1. The criteria of selection were described in Chapter III. The plan was to collect from each greenway segment, thirty surveys. To be effective and to obtain a cross section of greenway trail users, the study used randomly selected intercept periods across different times of one day and different days of the week.
Figure 4.1: Location of Greenway Segment Sample within the Raleigh Metropolitan Region
3.3 Data Collection

Since this study is interested in investigating whether a greenway trail user is a commuter or recreational user, intercept survey technique was applied to gather information from individuals who were on greenway trails. The intercept survey could also gather information about users of the trail, such as where are they from or how do they get here. Thus, the intercept survey could help verify whether the users of greenways are from defined user parameters or not.

The intercept survey, conducted on fifteen greenway trail segments during April 2014. The data collection periods were selected randomly across different times of one day and different days of the week. To lower the refusal rate, the intercept points were at the exits of greenway segments, and the researchers tried to intercept users while they were leaving the trails. Within one intercept period, the surveyors would attempt to intercept trail users who passed the intercept point every three minutes to take part in the survey. If the trail user agreed, the researcher asked the questions defined in Table 4.1 and recorded their answers through questionnaire tables. If the trail users were travelling in groups, only one participant participated in the study. In addition, researchers also recorded demographic information and activity types of respondents. A total number of 450 surveys (30 surveys for each greenway trail segment) were gathered, and the response rate was 84.4%.

Although many greenway studies have applied the mail questionnaire strategy to collect data from surrounding neighborhoods (Cox, 2013; Elabd, 2013), this study preferred acquiring relevant information directly from actual greenway trail users. Since the researchers collected the surveys directly from greenway trail users, it is expected that this sample is consistent with data gathered for the greenway usage in Chapter III.
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Where are you from?</td>
<td>Show proximate home location on a tablet computer.</td>
</tr>
<tr>
<td>(2) What best describes the purpose of this trip on the greenway?</td>
<td>(a) Purely Exercise or recreation</td>
</tr>
<tr>
<td></td>
<td>(b) Purely Transportation (Work, School)</td>
</tr>
<tr>
<td></td>
<td>(c) Mixed use travel</td>
</tr>
<tr>
<td>(3) How long is your trip today?</td>
<td>(a) 0-30 minutes</td>
</tr>
<tr>
<td></td>
<td>(b) 30 minutes-1 hour</td>
</tr>
<tr>
<td></td>
<td>(c) 1 hour or more</td>
</tr>
<tr>
<td>(4) How did you get to the Greenway today?</td>
<td>(a) Car</td>
</tr>
<tr>
<td></td>
<td>(b) Bus</td>
</tr>
<tr>
<td></td>
<td>(c) Walk</td>
</tr>
<tr>
<td></td>
<td>(d) Bicycle</td>
</tr>
<tr>
<td>(5) Talk about the reasons of using this greenway (open ended)</td>
<td></td>
</tr>
<tr>
<td>(6) In the past year, how often do you use the greenway?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How often for work, for exercise, and for mixed use travel?</td>
</tr>
<tr>
<td></td>
<td>If not, why not?</td>
</tr>
</tbody>
</table>

**Notes:** Interviewer noted and recorded basic demographic data including gender, age, ethnicity, group size, and activity.
4. Results

4.1 Survey Respondent Characteristics

Table 4.2: Characteristics of Survey Respondent by Gender, Age, Ethnicity, Group, and Activity

<table>
<thead>
<tr>
<th></th>
<th>Use of Respondent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>265</td>
<td>58.89%</td>
</tr>
<tr>
<td>Female</td>
<td>185</td>
<td>41.11%</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young Adult</td>
<td>242</td>
<td>53.78%</td>
</tr>
<tr>
<td>Middle-Age Adult</td>
<td>169</td>
<td>37.56%</td>
</tr>
<tr>
<td>Senior</td>
<td>37</td>
<td>8.22%</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African</td>
<td>73</td>
<td>16.22%</td>
</tr>
<tr>
<td>White</td>
<td>332</td>
<td>73.78%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>17</td>
<td>3.78%</td>
</tr>
<tr>
<td>Others</td>
<td>28</td>
<td>6.22%</td>
</tr>
<tr>
<td><strong>Group Size</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>262</td>
<td>58.22%</td>
</tr>
<tr>
<td>2 or More</td>
<td>188</td>
<td>41.78%</td>
</tr>
<tr>
<td><strong>Activity Type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walk</td>
<td>153</td>
<td>34.00%</td>
</tr>
<tr>
<td>Bike</td>
<td>172</td>
<td>38.22%</td>
</tr>
<tr>
<td>Jog</td>
<td>125</td>
<td>27.78%</td>
</tr>
</tbody>
</table>

Notes: others = ethnicity is not quite sure

Table 4.2 is the summary of trail uses of all the survey respondents and their demographic information. Only people who answered the survey on the greenway trail were included. Included in this study were a total number of 450 respondents from 15-greenway trail segments. Survey respondents were 58.89% male and 41.11% female. Regarding the age of survey respondents, 53.78% were young adults; 37.56% were middle age; and 8.22% were seniors. The ethnicity of the respondents included African-Americans (16.22%), White
(73.78%), Hispanic (3.78%), and others (6.22%). 58.22% survey respondents were counted as single users while 41.78% were counted as group users. For activity type of respondents, biking was the most popular one (38.22%); walking was second (34%); and jogging took up the third place (27.78%). When comparing characteristics of survey respondents with all observed users, there were no significant differences among the groups (Figure 4.2). This indicates the survey sample is a good sample to represent the population (all observed users).

Figure 4.2: Characteristics between Respondents and All Users
4.2 Summary of Survey Responses

Table 4.3 is a summary of all survey responses. In term of trail user’s home location, 56% respondents indicated their homes were within 1/2-mile, and 98.22% respondents indicated their homes were within 4-mile. The results answered the research question 1: to what extent are greenway users from assumed distances(1/2-mile and 4-mile). In term of use purpose, approximately 60% respondents indicated that they only used the greenway trail for recreation and exercise. Another 26.67% reported that they used the greenway for both transportation and recreation (mixed use). About 10% respondents used the greenway trail purely for commuting.

Table 4.3: Summary of Survey Responses

<table>
<thead>
<tr>
<th>Home Location</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within 0.5 mile distance</td>
<td>252</td>
<td>56.00%</td>
</tr>
<tr>
<td>Within 4 mile distance</td>
<td>442</td>
<td>98.22%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise or recreation</td>
<td>278</td>
<td>61.78%</td>
</tr>
<tr>
<td>Purely transportation</td>
<td>52</td>
<td>11.56%</td>
</tr>
<tr>
<td>Mixed use travel</td>
<td>120</td>
<td>26.67%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duration</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30 minute</td>
<td>136</td>
<td>30.22%</td>
</tr>
<tr>
<td>30 minute-1 hour</td>
<td>244</td>
<td>54.22%</td>
</tr>
<tr>
<td>1 hour or more</td>
<td>70</td>
<td>15.56%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trail Access transportation</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>265</td>
<td>58.89%</td>
</tr>
<tr>
<td>Bus</td>
<td>13</td>
<td>2.89%</td>
</tr>
<tr>
<td>Walk</td>
<td>75</td>
<td>16.67%</td>
</tr>
<tr>
<td>Bicycle</td>
<td>97</td>
<td>21.56%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every day</td>
<td>56</td>
<td>12.44%</td>
</tr>
<tr>
<td>Twice a week</td>
<td>137</td>
<td>30.44%</td>
</tr>
<tr>
<td>Every week</td>
<td>158</td>
<td>35.11%</td>
</tr>
<tr>
<td>Twice a month</td>
<td>60</td>
<td>13.33%</td>
</tr>
<tr>
<td>Every month</td>
<td>39</td>
<td>8.67%</td>
</tr>
</tbody>
</table>
Figure 4.3: Summary of Trail Use Duration

Figure 4.4: Summary of Trail Use Frequency
Regarding the duration of trail use, 21.77% respondents reported 0-30 minute, 25.77% reported 30 minute-1 hour, and 52.44% reported 1 hour or more (Figure 4.3). In Figure 4.4, the frequency of trail use included every day (12.44%), twice a week (30.44%), every week (35.11%), twice a month (13.33%), and every month (8.67%). In term of trail access transportation, about 60% respondents indicated that they drove to the greenway trails. Another 21.56% respondents reported that they rode a bicycle to the greenway trail. 16.67% respondents walked to the greenway trail. Only 2.89% respondents indicated they used buses to commute.

4.3 Trail Use Pattern

By looking at respondents’ patterns of use, this research found differences between purely recreational users and none-purely recreational users (transportation only or mixed users). Average time spent on the greenway trail was 1.6 hour for purely recreational users, and 1.3 hour for none-purely recreational users. For the frequency of trail use, 73% respondents who used trails every day or twice a week were none-purely recreational users and 82% respondents who used trails% every week or twice a month were purely recreational users. None-purely recreational users reached the greenway trail mostly by bicycle or on foot, with only 18% of respondents coming by automobile. This contrasted with respondents of purely recreational users, of whom 76% came by automobile.

Individual greenway segments were also associated with different use patterns. Figure 4.5 indicates that three greenway trails significantly differed from average use in terms of trip purpose. Recreational users used greenway Segment 15 most often. Very few people used Segment 15 for transportation or mixed use. Of the greenway users, 53.33% users in Segment 1 were mixed-use travelers, which doubled average percentage (26.67%). In Segment 4, both transportation users and mixed users were higher than the average percentage. However, in terms of recreational use, Segment 1 and Segment 14 were much lower than the average percentage. The discussion attempts to explain the difference.
5. Discussions

5.1 Where Are Greenway Users from?
Since 98.22% respondents indicated their homes were within 4-mile, the present study verifies the assumption in Chapter III that most greenway users are from 4-mile buffer. Another 56% respondents stated their homes were within 1/2-mile, which indicates this percentage of the population may not drive to greenway trails or they have the potential to not drive. However, only about 38% respondents indicated they walk or ride a bicycle to the greenway. Since urban greenways are planned to enable residents to move around the city without driving a car, it is important to note many people drive to urban greenway for exercise or recreation. Although a considerable number of greenway parking spaces are available at several greenway access points in Raleigh to satisfy the planning ordinance, greenway planners and designers encourage people not to drive to use the greenway trail, especially for people who live relatively close. However, street connectivity is an issue. Some streets around urban greenway trails are not pedestrian friendly. Some respondents
stated safety issue pushed them drive to the greenway even though they live nearby. Several respondents also indicated their willingness to use the greenway for work or mixed-use travel if these destinations used greenways as connectors.

5.2 Modes of Travel among Greenway Trail Use
In Raleigh purely recreational user tended to make longer, fewer frequency visits than none-purely recreational users. Meanwhile none-purely recreational users tended to drive less often to reach greenway than purely recreational users. The results are consistent with previous research conducted in Chicago (Gobster, 1995). The modes of travel between purely recreational users and non-recreational users are distinct in Raleigh.

In Raleigh, urban greenways users use the greenways according to various factors. Three typical greenway segments with different trail use profiles are discussed in this study. Responses in greenway Segment 1 suggested this segment receive more mixed-use activity than other segments. Time spent on site inventory and context map analysis (Figure 4.6) indicated this segment connected neighbors, Chavis Park and downtown Raleigh for a diversity of users, such as neighborhood residents, people who work in downtown, and passing through cyclists. This segment may serve as a transition from downtown to the surroundings. Respondents in this segment also indicated their expectations on expansion of downtown greenways. For greenway Segment 15, recreational users were dominant while few people were commuters or mixed users. As an important portion of Reedy Creek Trail, Segment 15 encompasses NC Museum of Art, Museum Park, woodlands and creeks to provide a unique setting to attract users. Passing through group cyclists were dominant on Segment 15, and many respondents in this segment indicated they rode for recreation from Umstead Park, which covers 5,439 acres nestled between the expanding cities of Raleigh, Cary, and Durham. For greenway Segment 4, the trail users were very diverse. Segment 4 runs through neighbors, a middle school, Peterson Street, and Walnut Creek wetland center. A biking respondent indicated he used this segment to go to the local grocery store every day.
Figure 4.6: Context Map of Greenway Segment 1

Figure 4.7: Context Map of Greenway Segment 4
5.3 Greenway Trails and Surrounding Environment

Findings from this study show that the surrounding land use is an important factor affecting how a greenway is used. Most greenway commuters indicated they travelled only a short distance to use the trail. Thus, the pure non-automobile travel of greenway uses relies on whether they live close to the greenways. If the greenway is unconnected to pedestrian accessible land use, such as parkland or residential communities, the pure non-automobile trip is difficult. Public transportation system is key to pedestrian activity in the urban area (Saelen et al., 2003). Raleigh has a well-established public transportation system, which includes 43 public transit routes. However, none of the public transit routes connect to the urban greenway, nor do greenway trail users know the transportation system. For example, a number of respondents in greenway Segment 1 (downtown section) were mixed users, nevertheless, few of them used the bus to connect to the greenway. Officially, designed bike routes in Raleigh (Figure 4.9) provide an opportunity for urban bicycle riders. Fourteen bicycle routes are designed across the city while some of them intersect with the urban

Figure 4.8: Context Map of Greenway Segment 15
greenway trails. However, how to utilize official bike routes as a corridor from urban greenway trails to urban streets is a challenge for trail users. More connected and comprehensive bicycle route system is encouraged, and the signage system is another important consideration.

5.4 Understanding Greenway Users
The diversity of users along these urban greenway segments confirmed the necessity to ascertain who is using the trail and why. The dominant proportions of recreational users in this study indicate the top reason people use greenway trails is because of the contact with the beauty of nature. Strategy for nature management along with safety issues need consideration when planning greenways. Users’ input can facilitate future expansion and management of greenways. Although this study, points to people’s preference and desire for greenways, there is no direct relationship to specific design or management. The majority of recreational users in this study indicate a greenway plays an important role as a recreational resource. Modes of travel were different between commuters, recreational users and mixed users. A better understanding of the needs of users of different modes of travel could help in increasing the volume of greenway activity. There are a potential number of mixed users, which rely on how the surrounding land-use connect with the greenway.
Figure 4.9: Map of Raleigh Bicycle Route
6. Conclusion
This research investigates the modes of travel between recreation activities and transportation activities along the urban greenway trails in Raleigh. Responses from 450 greenway users on 15-greenway segments show that there are a considerable number of transportation or mixed users but still far from the volume that greenways can afford. It is found that in Raleigh purely recreational users tend to make longer, fewer visits than non recreational users. Findings from this study show the surrounding land use is an important factor affecting how the greenway is used. Public transportation system and urban bicycle routes are catalysts for greenway commuters. Future research needs to explore how the urban greenway system is working as urban infrastructure in combination with public transit and urban bicycle routes to facilitate non-motorized transportation. This study only investigates urban greenways in Raleigh, while data from other North Carolina cities or even across the country are encouraged to verify the findings.
REFERENCES


Heath, G.W., Brownson, R.C., Kruger, J.,(2006). The effectiveness of environmental and policy interventions to increase physical activity: a systematic review. Journal of Physical Activity and Health, 3(Suppl. 1), 55–76.


Chapter V

Conclusions

Greenways represent a distinct strategic approach to landscape planning supporting combinations of spatially and functionally compatible land uses within a network (Ahern, 2002). Greenways, as a strategic planning concept, has evolved over the past century in America as a response to dynamic environmental, social, and economic factors. This dissertation starts with reviewing evolutionary relationship between open space systems (greenway networks) and city form. After reviewing the history, the dissertation tries to examine the correlations between urban greenway trail characteristics and trail usage. Lastly, this dissertation investigates the modes of travel between recreation users and transportation users along the greenway trails.

Chapter II shows that as well as other North American cities, Raleigh possess a greenway system to achieve a comprehensive regional green network that joins inner cities to the suburban areas (Walmsley, 1995). Although there are no historical precedent greenways in Raleigh, the strong historic open space framework and recent greenway implementation made the city a distinct case. In Raleigh, like other metropolitan areas, two key drivers are behind greenways: environmental quality and social amenity. As an important component of green infrastructure, the greenway system in Raleigh is likely to play a continuing role in helping define and promote interventions that provide environmental benefits at many scales in terms of urban resilience.

Chapter III is an exploration of developing the conceptual model of human use of urban greenways comprised of three dimensions: environmental features, residential proximity, and surrounding land use. The findings indicate that people intend to use urban greenway trails with low slope and good maintenance condition, proximate access and mixed land-use in the surrounding area. The regression models suggest their use to estimate urban trail use in
Raleigh, but because of possible mediating factors, caution is necessary. The conclusion one makes from this study is that although greenway planning has been primarily relied on creek route and hydrological flow, the social aspect is also an important factor to determine greenway route.

Chapter IV investigates the modes of travel between recreation users and transportation users along the urban greenway trails. Modes of travel were different between commuters, recreational users, and mixed users. To understand different modes of travel could help in increasing the volume of greenway activity. The evidence that in Raleigh purely recreational users tended to make longer, fewer visits than none-purely recreational users. Meanwhile none-purely recreational users tends to drive less often to reach greenway than purely recreational users.

There are several implications of the findings from Chapter II, III & IV. Chapter II indicates that the greenway is still an important and useful strategy in conceptualizing a holistic approach that supports economic, ecological, and cultural sustainability. As many cities or towns in America are suffering transformation or transition in terms of economic, environmental, and social changes, green infrastructure is an innovative way to provide resilient and affordable solutions that meet many objectives at once. As an important component of green infrastructure, greenway can be multi-modal transportation corridor linking residents and other land uses. “The linkage of greenways is the key that could contribute to place economic development and neighborhood revitalization” (Erickson, 2004). The Lafitte greenway in New Orleans, LA is a recent example of transforming abandoned corridor to multi-modal transportation corridor linking residents to the heart of the city (ASLA, 2013). Incorporating sustainable design and public input, adapting re-use of existing buildings, synthesizing many measurable objectives and working across a range of scales, the Lafitte greenway demonstrates that greenway is a useful approach to help urban revitalization.

A better understanding of the variables associated with urban greenway usage is essential to
successful greenway planning and management, because it is not easy to predict the use of greenways. There are two important implications of the findings from Chapter III. From urban planners’ perspective, the most important findings concern the correlation between trail use and proximate population and land-use mixture. These findings support evidences for planning theory that high population is associated with high efficiency in utilization of public facilities (Frank et al, 2003). The findings also support the principles of smart growth and new urbanism. Thus, transportation and greenway planners can use these findings to facilitate benefit-cost analyses undertaken to optimize allocation of resources. From a greenway trail designer’s perspective, the most important findings concern the correlation between trail use and environmental features of the greenways. The variables significantly associated with trail use in Model 1 and that need consideration in future expansion includes trail average slope, viewshep openness, and maintenance condition.

The dominant proportion of recreational users in Chapter IV indicates greenway plays an important role as a recreational resource. Findings from this chapter imply that the surrounding land use is an important factor affecting how the greenway is used. Public transportation system and urban bicycle routes are catalysts for greenway commuters. Future research needs to explore how the urban greenway system is working as urban infrastructure in combination with public transit and urban bicycle routes to facilitate non-motorized transportation.

Discussions and reflections about urban vulnerability and resilience are continuous because of rare and unpredictable events and disasters in the last few years. These especially include: the 9/11 attacks in New York (2001), the Earthquake in Sichuan, China (2008), Hurricane Katrina in the New Orleans area (2005), the Global Financial Crisis (2007-2008), the Great Smog in Beijing (2013), and Hurricane Sandy (2012). The occurrence of these devastating large-scale events usually intertwines with the presence of large problems, such as sustainability, urbanization, poverty, global climate change and terrorism (Xiang, 2013). In the world that is, growing urbanized and complexly connected, this circumstance presents
tamed and untamed challenges towards the survival of human beings. What do all these mean to planning in general? How the existing or emerging theoretical and practical framework, such as urban resilience and eco-cites respond in particular?

The term green infrastructure is likely to play a continuing role in helping define and promote interventions that provide environmental benefits at many scales in terms of urban resilience. The term greenway provides an opportunity to integrate many of the features that are defining green infrastructure. The need for stakeholder interaction and educational integration between water-related intervention and trail-related improvements suggests that the term greenway is still important and useful in conceptualizing a holistic approach that supports economic, ecological, and cultural sustainability. In addition, in the face of untamed problems, urban planners should take an adaptive, participatory and trans-disciplinary approach (APT approach) in their practice of planning and design. “Good old stuff such as suitability assessment that Ian McHarg advocated,” Dr. Wei-Ning Xiang (2013) said, "can be a powerful tool for avoiding or reducing black swan impacts".
REFERENCES


APPENDIX
From: Jennifer Ofstein, IRB Coordinator
North Carolina State University
Institutional Review Board

Date: March 24, 2014

Title: Count Greenway usage and intercept survey

IRB#: 3883

Dear Di Lu,

The research proposal named above has received administrative review and has been approved as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.101 b.2). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review. This approval does not expire, but any changes must be approved by the IRB prior to implementation.

NOTE:

1. This committee complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU projects, the Assurance Number is: FWA00003429.

2. Any changes to the research must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days.

Please forward a copy of this letter to your faculty sponsor, if applicable.

Thank you.

Sincerely,

Jennifer Ofstein
NC State IRB
North Carolina State University
Institutional Review Board for the Use of Human Subjects in Research
REQUEST FOR EXEMPTION (Administrative Review)

GENERAL INFORMATION
1. Date Submitted: 03/14/2014
2. Title of Project: Count greenway usage and intercept survey
3. Principal Investigator: Di Lu
4. Principal Investigator Email: dlu@ncsu.edu
5. Department: College of Design
6. Campus Box Number:
7. Phone Number: 919-995-1618
8. Faculty Sponsor Name If Student Submission: Art Rice
9. Faculty Sponsor Email Address If Student Submission: ar@ncsu.edu
10. Source of Funding (Sponsor, Federal, External, etc): Sponsor
    If externally funded, include sponsor name and university account number:
RANK:
Faculty ☐ Student ☐ Undergraduate ☐ Masters ☑ PhD ☐ Other ☐

As the principal investigator, my signature (or electronic submission) certifies that I have read and understand the University Policy and Procedures for the Use of Human Subjects in Research. I assure the Committee that all procedures performed under this project will be conducted exactly as outlined in the Proposal Narrative and that any modification to this protocol will be submitted to the Committee in the form of an amendment for its approval prior to implementation.

*Electronic submissions to the IRB are considered signed via an electronic signature*

Principal Investigator:

Di Lu

typed/printed name

signature

03/14/2014
(date)

As the faculty sponsor, my signature (or electronic submission) certifies that I have reviewed this application thoroughly and will oversee the research in its entirety. I hereby acknowledge my role as the principal investigator of record.

Faculty Sponsor:

Art Rice

typed/printed name

signature

Mar. 14 2014
(date)

PLEASE COMPLETE AND E-MAIL TO: irb-coordinator@ncsu.edu

-------------------------------------------------------------------------------------------------------------------------------------

For S.A.S. use only

Regulatory Compliance Office Disposition

Exemption Granted ☑ Exempt Under: ☐ 2 b.1 ☐ 62 ☐ 63 ☐ 54 ☐ 6.6

Not Exempt, Submit a full protocol ☐

[Signature]

[Date]

[Approval w/ mods on]

[Date]

Page 1 of 4

138
Project Description: Describe your project by providing a summary and answering the requests for information below.

1. Project Summary. Please make sure to include the purpose and rationale for your study and a brief overview of your methods.

The greenway usage count will record general data about greenway trail users on selected trail segments. Collected information will include gender, estimated age range, group size, and activity type. The purpose of the intercept survey is to gather more information about users of the trail, such as where they are from or how they got here. The intercept survey could help verify whether the users of greenway are from defined user parameters or not. Surveyors will be required to intercept trail users, ask the questions defined below and record their answers through questionnaire tables.

2. Describe your participant population. This includes age range, inclusion/exclusion criteria, and any vulnerable populations that will be targeted for enrollment.

Greenway trail users at selected greenway segments. They could range from young adults to seniors. Children and adolescents are excluded.

3. Describe how potential participants will be approached about the research and how informed consent will be obtained. Alternatively, provide an explanation of why informed consent will not be obtained. Include a copy of recruitment materials, such as, scripts, letters of introduction, emails, etc. with your submission.

Since the investigator will ask users whether or not to take an anonymous survey, the informed consent will not be obtained. The surveyors will intercept trail users and start to ask “do you have time to answer a few questions about your use of greenway?” If yes, trail users will be provided a questionnaire to answer.

4. Describe how identifying information will be recorded and associated with data (e.g. code numbers used that are linked via a master list to subjects' names). Alternatively, provide details on how study data will be collected and stored anonymously (“anonymously” means that there is no link whatsoever between participant identities and data). Describe management of data: security, storage, access, and final disposition.

No identifying information will be recorded. Greenway users will be counted and numbered in an ipad. Then data will be stored in the investigator's PC and will also be recorded in a CD for backup.

5. Provide a detailed (step-by-step) description of all study procedures, including descriptions of what the participants will experience. Include topics, materials, procedures, for use of assessments (interviews, surveys, questionnaires, testing methods, observations, etc.).

(1) The researchers will arrive at access point of each greenway segment to count greenway usage. For a 30 minute period, the surveyor will remain at the spot and record data for each user passing by this location.

(2) After a period of counting them, the researchers will intercept trail users and start to ask “do you have time to answer a few questions about your use of greenway?” If yes, trail users will be provided a questionnaire to answer. Trail users will be selected randomly at the interview point after 5 minutes interval from the completion of the previous interview. To lower the refusal rate, the ideal interview point would be the exits of the greenway trails and the researchers try to intercept users while they are leaving the trails. In total, the investigator will gather 600 surveys (30 surveys for each greenway trail segment). The collected data will be translated into a digital table for analysis purpose.

6. Will minors (participants under the age of 18) be recruited for this study?

Minors will not be recruited however will be counted in the total.

7. Is this study funded? No
8. Do you have a conflict of interest or significant financial interest in this research?

   No
   a. What does your plan include for managing this conflict of interest and is it being properly followed? NA

9. HUMAN SUBJECT ETHICS TRAINING

   *Please consider taking the Collaborative Institutional Training Initiative (CITI), a free, comprehensive ethics training program for researchers conducting research with human subjects. Just click on the underlined link.

12. ADDITIONAL INFORMATION:

   a) If a questionnaire, survey or interview instrument is to be used, attach an editable version to this proposal.

   b) Attach an editable version of the informed consent form to this proposal. See the IRB website for a Sample Consent Form and Informed Consent Checklist http://www.uc.edu/osp/irb/requirements.html

   c) Please provide an editable version of any additional materials (i.e., recruitment materials, such as “flyers”, recruitment scripts, etc.) that may aid the IRB in making its decision.

   *If a survey instrument or other documents such as a consent form that will be used in the study are available, attach them to this request. If informed consent is not necessary, an information or fact sheet should be considered in order to provide subjects with information about the study. The informed consent form template on the IRB website could be modified into an information or fact sheet.

The following are categories the IRB office uses to determine if your project qualifies for exemption (a review of the categories below may provide guidance about what sort of information is necessary for the IRB office to verify that your research is exempt):

Exemption Category: (Choose only one of the following that specifically matches the characteristics of your study that make this project exempt)

☑ 1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

☐ 2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

*Please Note- this exemption for research involving survey or interview procedures or observations of public behavior does not apply to research conducted with minors, except for research that involves observation of public behavior when the investigator(s) do not participate in the activities being observed.

☑ 3. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph...
(b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute requires, without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

☐ 4. Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

☐ 5. Not applicable

☐ 6. Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome food without additive are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration, or approved by the Environmental Protection Agency, or the Food Safety and Inspection Service of the U.S. Department of Agriculture.