The Report Committee for Ashley Sarah Greenstein
Certifies that this is the approved version of the following report:

Mapping Bikeability: A Spatial Analysis on Current and Potential Bikeability in Austin, Texas

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ________________________________
Robert Paterson

____
Ming Zhang

Mapping Bikeability: A Spatial Analysis on Current and Potential Bikeability in Austin, Texas

by

Ashley Sarah Greenstein, B.S. B.A.

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Community and Regional Planning

The University of Texas at Austin

August 2015

Dedication

I would like to dedicate this report to those who are trying to change the way that our society commutes. Whether it is by research, advocacy, planning, or riding your bicycle, thank you for your contribution. We are all in this together and it takes all of our efforts to create change.

Acknowledgements

I would like to thank all of my professors for sharing their breadth of knowledge over the past two years, especially my two readers Dr. Robert Paterson and Dr. Ming Zhang. I would like to thank members of the City of Austin's Active Transportation program for allowing me to gain some real world experience and contribute to bikeability here in Austin. I would specifically like to acknowledge the tremendous support that I received from ATD's Cole Kitten. Thank you for helping me trouble shoot the many issues that arose while producing this analysis. Lastly, I would like to thank my parents for believing in me and providing their unconditional support throughout this stressful yet gratifying process.

Abstract

Mapping Bikeability: A Spatial Analysis on Current and Potential Bikeability in Austin, Texas

Ashley Sarah Greenstein, M.S.C.R.P.
The University of Texas at Austin, 2015

Supervisor: Robert Paterson

Cycling has continued to gain attention as a form of transportation and recreation in Austin, Texas over the last decade. This past year, the City of Austin passed an update to its bicycle master plan that envisions building an all ages and abilities network at a projected cost of $150 million. As the City searches for dedicated funding, it needs to strategize its current holdings to capture short trips in areas that host the most potential for bikeability. Many aspirational bicycle-friendly cities have evaluated existing and potential bikeability through spatial analyses. The goal of this report is to produce a series of maps that attempt to mirror the on-the-ground reality of how cycling feels throughout Austin, Texas. Each recognized factor of the built environment that affects cycling is mapped and then scored, creating composite maps that represent current and potential bikeability. These factors include: bicycle facilities, network density, land use,

topography, and barriers. These maps can be used as a tool by the City of Austin's Active Transportation program and other transportation organizations to better understand which parts of the city are best suited for generating large numbers of cycling trips. It can also be used to explain which areas maximize cycling potential through strategic investments, innovative treatments, or policy changes.

Table of Contents

List of Tables

List of Figures

Chapter One: Introduction

BACKGROUND

Many countries have officially recognized the importance of cycling as a practical mode of transportation as it provides many environmental, economic, and social benefits. Cycling has the potential to reduce traffic congestion, noise, and air pollution. It integrates physical activity into daily routines and helps protect against obesity, diabetes, and other health issues. Cycling is economical for cities and individuals as it is less expensive than the bundled costs of car ownership and the infrastructure investments of public transportation.[1] Its affordability allows cycling to be socially equitable as it has the potential to enhance mobility options for all groups. Communities who rearrange urban form to facilitate bicycle use establish human scale, increase human interaction, and improve the quality of life.

Cycling has continued to gain attention as a form of transportation and recreation in Austin, Texas over the past decade. Since 2009, Austin's bicycle lane network grew from 126 miles to 210 miles, an expansion of 70% in just five years.[2] Last year, the City of Austin passed an update to its bicycle master plan that reflects today's best practices in municipal planning for bicycling at a national and international level. The plan envisions building an all ages and abilities network at a projected cost of $150 million. As the City searches for dedicated funding, it needs to strategize its current holdings to capture short trips in areas that host the most potential for bikeability.

[1] Buehler and Pucher, 2012.
[2] City of Austin Bicycle Master Plan Update, 2014.

Many aspirational bicycle-friendly cities have evaluated existing and potential bikeability through spatial analyses. By mapping features that correlate to bikeability, planners are able to develop powerful visual aids that can guide future transportation planning and policy-making. These tools use quantitative metrics to identify and prioritize locations for new bicycle infrastructure. These analyses can also be used to research the relationship between the built environment and transportation behavior or to engage the public during public planning processes.

PROJECT GOALS

The goal of this report is to produce a series of maps that attempt to mirror the on-the-ground reality of how cycling feels in different areas of the city. Each recognized factor of the built environment that affects cycling is mapped and then scored, creating composite maps that represent current and potential bikeability in Austin. These factors include: bicycle facilities, network density, land use, topography, and barriers. These maps can be used as a tool by the City of Austin's Active Transportation Division and other transportation organizations to better understand which parts of the city are best suited for generating large numbers of cycling trips. It can also be used to explain which areas maximize cycling potential through strategic investments, innovative treatments, or policy changes.

RESEARCH QUESTION

My research question is the following: What areas of Austin foster a built environment that is more conducive and less conducive to cycling? In order to understand and analyze bikeability, this report investigates the following questions:

- What physical factors influence bicycle usage?
- Does bikeability correlate with increased ridership?
- What policies and strategies can be applied to increase bikeability?

Chapter Two: Spatial Analysis Precedents and Case Studies

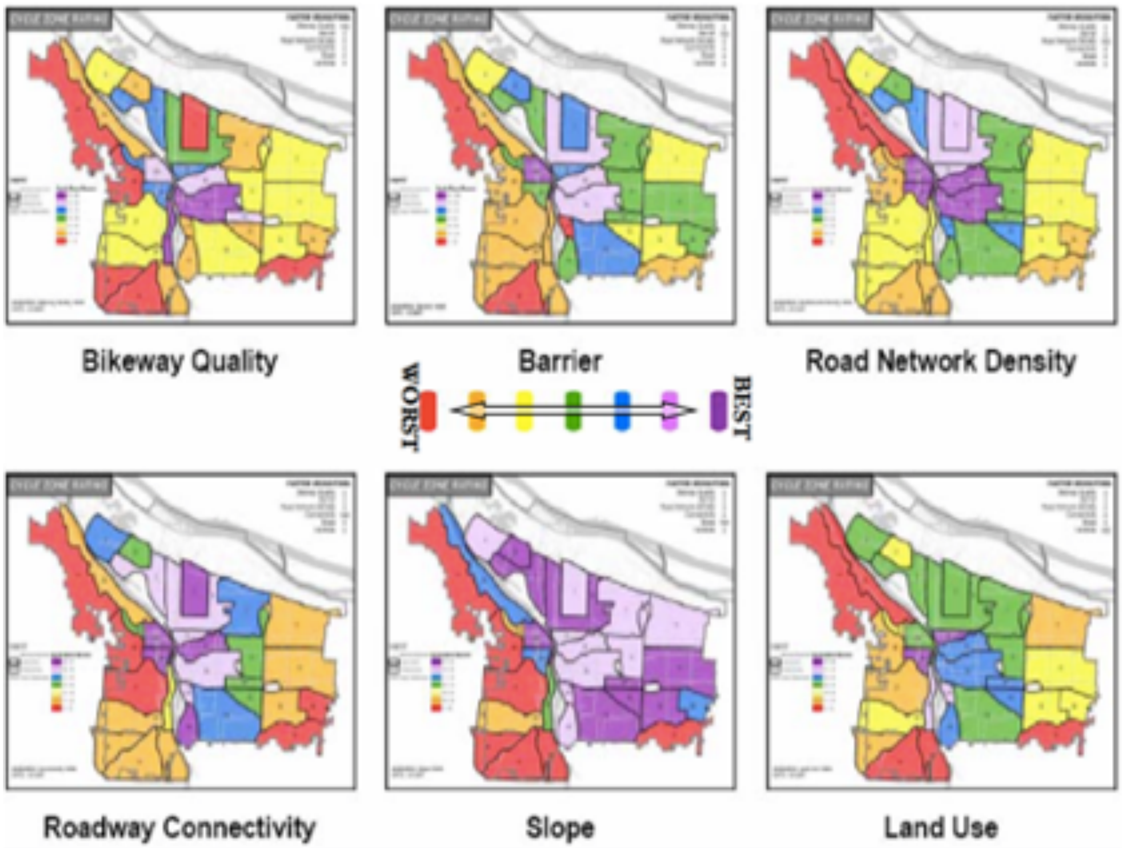
PORTLAND CYCLE ZONE ANALYSIS

In 2008, the City of Portland in conjunction with ALTA Planning and Design conducted a Cycle Zone Analysis to tailor strategies from their new bicycle master plan to districts with similar conditions and the potential for bicycling. This type of analysis enables the city staff to better understand which areas of the City are best suited for capturing large numbers of cycling trips, which areas have a greater potential than their current state, which areas are best suited for strategic investments, and which areas may need innovative bikeway treatments to maximize cycling potential.[3] The City of Portland defines their 32 cycle zones based on the following conditions that define the cycling environment: type, quantity, and quality of the established bikeways; geographic and infrastructure barriers and the frequency and ease of crossings; access to desirable destinations for cyclists; neighborhood and other political boundaries; local knowledge of cycling conditions based on input from Portland bicycling advocates, Bicycle Advisory Committee (BAC) members, residents, and city/consultant planning staff. Each zone is then rated using a Bike Quality Index (BQI). The BQI is based on: automobile speeds and volumes, dropped bicycle lanes and difficult transitions, the number of travel lanes and width of bicycle lanes, jogs in route, quality of pavement, quality of intersection crossings or the number of stops. Once all factors are weighted the analysis results in a series of maps that rate conditions for cycling in each zone by the individual metrics of

[3] Geller and Birk, 2008.

bikeway quality, physical barriers, density of roadway network, street connectivity, land topography, and land use.

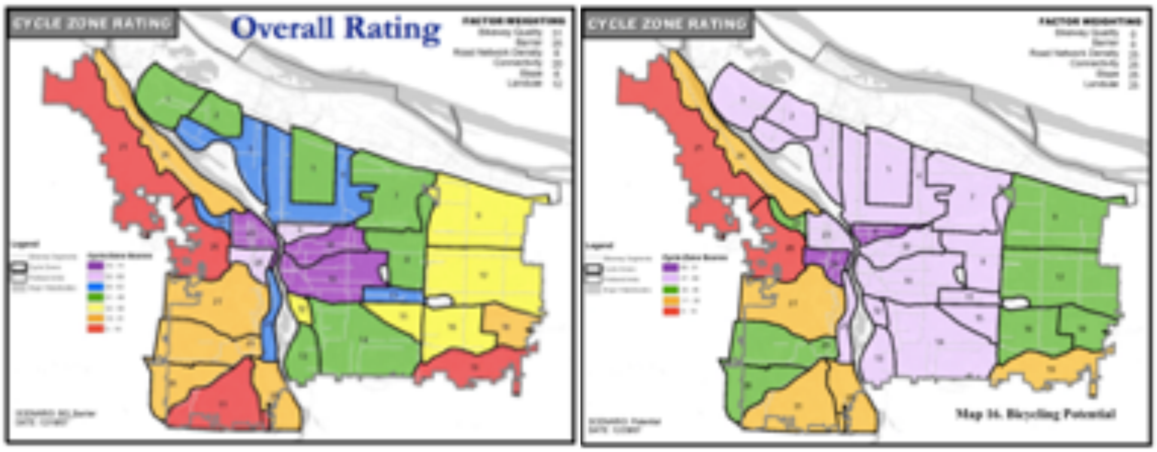
Figure 1: Cycle Zone Ratings per Metric for Portland, OR



Source: City of Portland Cycle Zone Analysis

Individual measurements for each zone are combined into an overall cycle zone rating to create an existing conditions map. Focusing only on street connectivity, roadway network density, land use and topography and removing bikeway quality and barrier metrics from the equation created a potential bikeability map. This type of analysis is beneficial from a policy analysis as opportunities, constraints, and suggested improvements can be discussed for each zone.

Figure 2: Overall and Potential Cycle Zone Ratings for Portland, OR

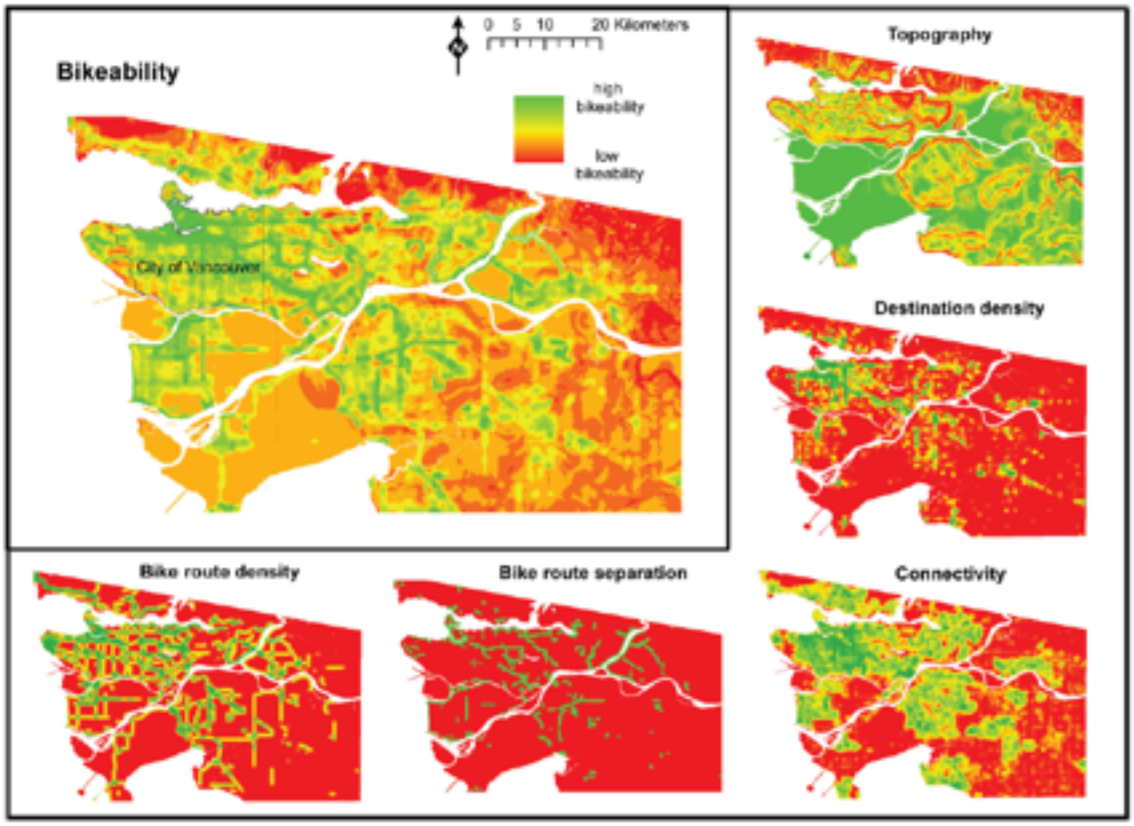


Source: City of Portland Cycle Zone Analysis

VANCOUVER BIKEABILITY ANALYSIS

In Vancouver, Winters, et al, built a tool to identify the areas that are more favorable and less favorable to cycling. Empirical research from an opinion survey, travel behavior studies, and focus groups were used in order to identify components of the bikeability index and their relative importance. Pertinent geospatial data layers were scored and combined using a flexible weighting scheme to create a composite map highlighting both high and low bikeability areas. The bikeability index was comprised of five factors shown to consistently influence cycling: bicycle facility availability, bicycle facility quality, street connectivity, topography, and land use. Similar to existing walking and sprawl indices, the index was built as an additive model. This approach allows future users to examine the results of the index and each of its components separately.

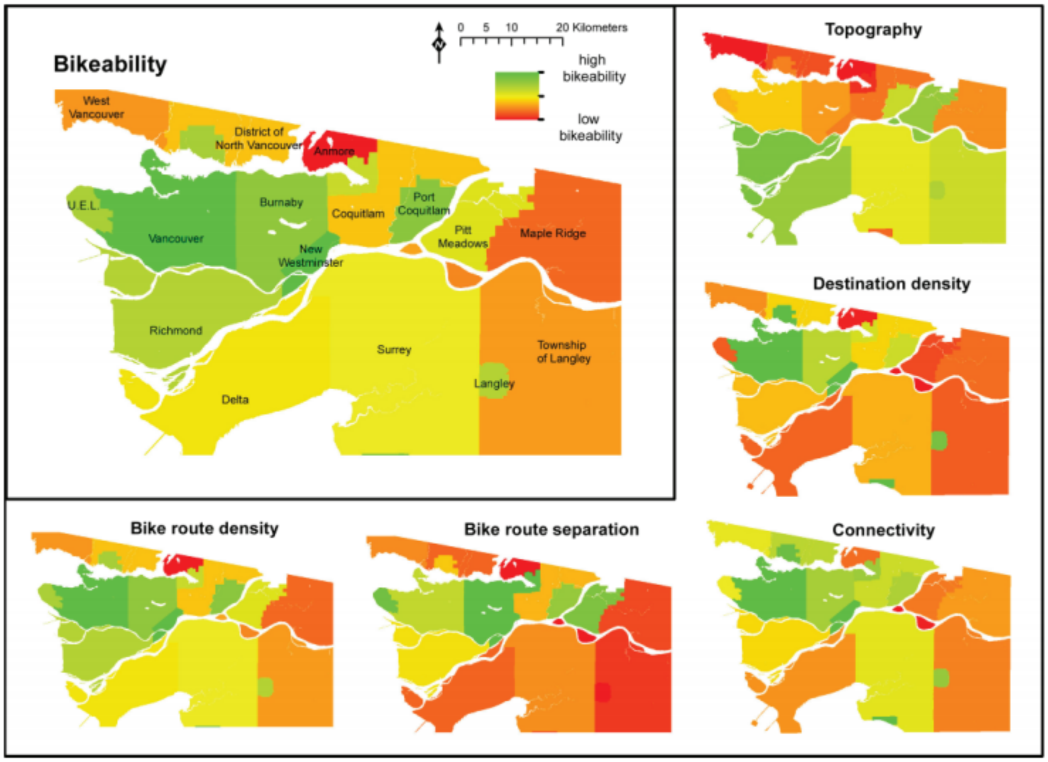
Figure 3: Bikeability and Component Maps for Metro Vancouver



Source: Winters, Brauer, Seet on, and Teschke. Mapping Bikeability: A Spatial Tool to Support Sustainable Travel. 2012.

For mapping purposes, the following metrics were generated: density of bicycle facilities, separation from motor vehicle traffic, connectivity of bicycle-friendly roads, slope, and density of destination locations. Data layers were combined to generate high-resolution bikeability maps for the region, depicting bicycle-friendly areas and areas where cycling conditions need to be improved. In addition, maps with the mean values for the bikeability index were produced for each municipality in the Metro Vancouver region to illustrate different planning policies needed.

Figure 4: Zoned Bikeability and Component Maps per Municipality



Source: Winters, Brauer, Seeton, and Teschke. Mapping Bikeability: A Spatial Tool to Support Sustainable Travel. 2012.

By creating maps showing the mean values for neighborhoods, it was easy to tell that there was not just variability between cities but also within cities. When examining the relationship between cycle-to-work modeshare and bikeability, they found a significant positive correlation between the two measures.[4]

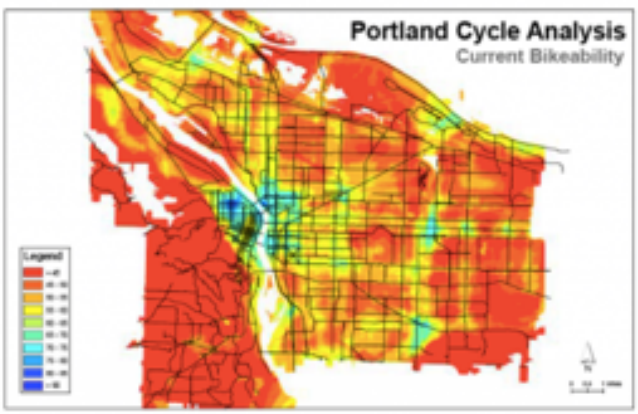
SEATTLE BIKEABILITY ANALYSIS

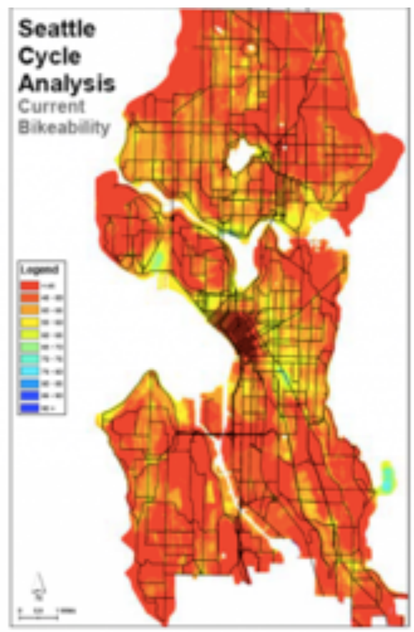
In 2010 Adam Parast, a transportation planner and graduate student at the University of Washington released a GIS study in which he compared the bikeability of

[4] Winters, et al, 2012.

Seattle to Portland. He used the same factors that the City of Portland used in their Cycle Zone Analysis including street connectivity, land use, bicycle facilities, slope, and barriers such as high density of vehicle traffic. Instead of breaking his analysis into zones, he scored the entire city with the weighted factors creating a heat map of bikeability for Seattle and Portland.

Figure 5: Current Bikeability in Portland and Seattle

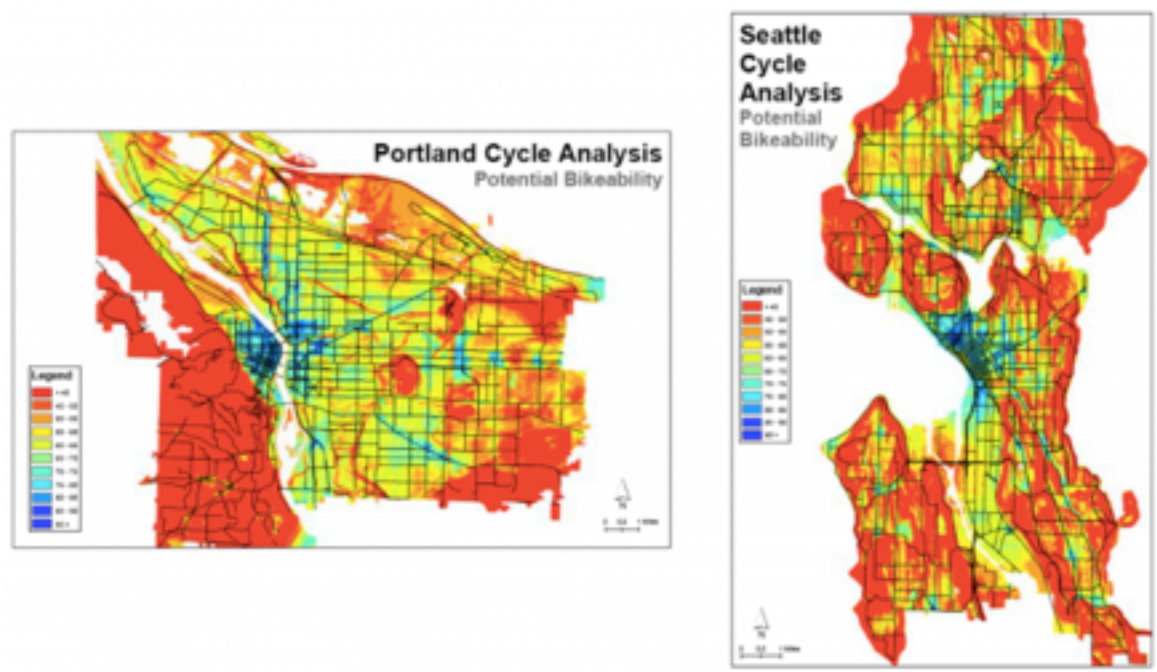




Source: Adam Parast. Bikeability Analysis: Portland and Seattle

The study describes that the most bikeable areas in Seattle are located near multi-use trails like the Burke-Gilman and Elliot Bay trails. Although downtown Seattle ranks low in bikeability, the Ballard neighborhood shows high potential in bikeability when only the permanent features such as slope, street connectivity, and land use are included in the analysis. Parast notices that Seattle is "spotty with 'islands' of good bikeability surrounded by areas of low bikeability.[5] However, many of Seattle's urban villages are in the center of the bikeable islands as many are located at either the top of the hill or in the bottom of the valley.

Figure 6: Potential Bikeability in Portland and Seattle



Source: Adam Parast. Bikeability Analysis: Portland and Seattle

By replicating this process to apply to Portland, Parast identifies that Seattle has potential to create a high quality biking community by creating bike boulevards in urban village areas. In areas challenged with hilly terrain, Parast recommends better integration between bicycling and transit.

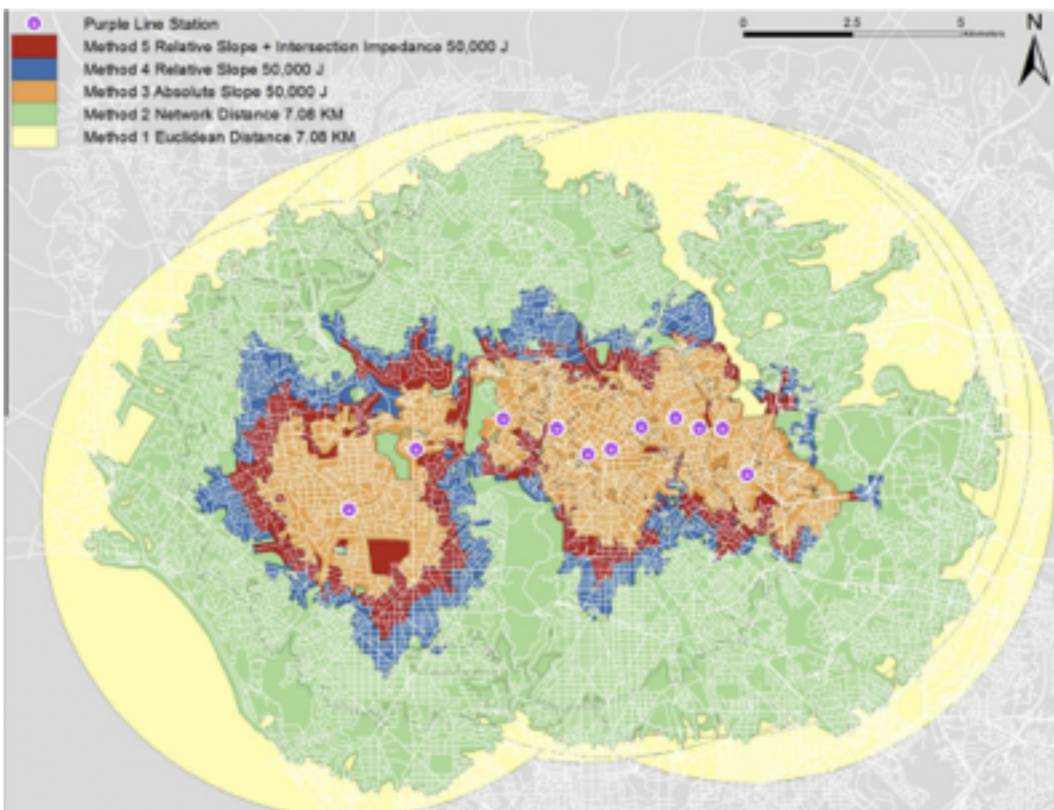
---

5 Parast, 2010.

BIKESHED ANALYSIS OF MONTGOMERY COUNTY

University of Maryland professor Hiroyuki Iseki and student Matthew Tingstrom have used GIS bikeshed analysis to analyze how overlapping factors affect how far bicyclists are willing to travel. The maps produced identify routes and destinations that require a similar amount of effort to cycle to, and offer an opportunity to find routes that are most desirable for cyclists.

Figure 7: Map of Bikesheds for Montgomery County



Source: Iseki and Tingstrom. A New Approach for Bikeshed Analysis with Consideration of Topography, Street Connectivity, and Energy Consumption.

This is the first study to incorporate energy consumption of travel into bicycle planning spatial analysis. The study uses Montgomery County in Maryland, where elevation and street connectivity differ substantially among neighborhoods, to show how size and shape of bikesheds vary in the analysis. Bikesheds are the method used to measure bikeability and unlike other studies, he creates the bikesheds around proposed light rail stations to reinforce the necessary integration between cycling and transit. In order to determine bicycle sheds, he incorporates distance, street slope, and the presence of intersections/ street connectivity into his GIS analysis methods to estimate the energy required. The combination of bikeshed analysis methods results in a single travel impedance factor measured in watts. This factor, instead of travel distance or time, is then used in the travel band analysis to identify bikesheds. This study proves that existing methods substantially overestimate bicycle level cycle catchment area and demand level.[6] The main impedances to cyclists found in this study are topography and the demand of constant starts and stops at major intersections. Although not much can be done about slope, Iseki suggests that policy reforms for bicycle boulevards can create routes, which are easier for cyclists to travel throughout the city.[7]

---

[6] Iseki and Tingstrom, 2014.
[7] Iseki and Tingstrom, 2014.

Chapter Three: Factors Contributing to Bikeability

A significant body of research has emerged over the past several years that delineates the significant relationship between peoples' transportation choices and the way that communities are designed. Several built environment factors have a significant correlation with bicycle use. This includes: accessible and safe facilties, a well-connected road network, a dense land use mix, topography, and major barriers.[8] While accessible facilties, roadway network connectivity, and a mix of dense land uses promote cycling; high to moderate slopes and major barriers prevent cycling. This section describes all of the factors used in the Austin bicycle quality index and how they are applicable in the current and potential bikeability analysis.

BICYCLE FACILITIES

Bicycle facilities are a critical component in determing the bikeability of a community. In order for bicycles to be suitable for transportation, bicyclists need adequate route infrastructure that meets their preference. Bicycle infrastructure investments are proven to be associated with higher rates of reported cycling. They are also preferred by a majority of cyclists, especially those who are intimidated to ride next to vehicles.[9] A survey of six U.S. cities reports that cycling frequency is related to both perceived safety of the cycling environment and the extent of local bike lanes.[10] In a 2003

---

[8] Geller and Birk, 2010.
[9] Pucher, Dill, & Handy, 2010.
[10] Xing & Handy, 2010.

report, Professors Dill and Carr from Portland State University discovered that for each additional mile of bike lanes that were added, ridership increased by one percent.[11] A complementary before and after study by Seattle's Department of Transportation revealed that the removal of car lanes and addition of bike lanes on Stone Way North street increased cyclist volumes by 25% while motor traffic on adjacent streets decreased by 12-34%, speeding by 80%, and collisions by 14%.[12]

Over the past decade, North American cities have been shifting faciltiy design to better reflect European standards of seperating bicycle and motor traffic. Recently, the National Association of City Transportation Officials (NACTO) sanctioned cycle-tracks, exclusive bike facilities that combine the user experience of an off-street multi-use path with the on-street infrastructure of a conventional bike lane, as best practices in facility design. Seperated facilties will receive the highest scores as these facilties are preferred by most users and have the ability to encourage ridership. Bicycle facilties such as bike boxes, two-stage turn queues, bicycle signals, and end of trip facilties will not be included in this analysis as they do not directly relate to all of factors of bikeability.

NETWORK CONNECTIVITY

In addition to the quality of the bicycle facilities, density and connectivity of networks are also essential. Network design directly influences route and mode choice. As connectivity increases, travel distances decrease and route options increase,

[11] Dill and Carr, 2003.
[12] SDOT, 2010.

supporting the idea that higher levels of connectivity are more conducive to cycling than lower levels.[13] Several studies have shown the relationship between road network connectivity and bikeability. In 2008, Dill and Gliebe used global positioning system (GPS) technology to track where a sample of 164 Portlanders rode their bicycles. This study exposed that bicycle trips of less than three miles were more likely to occur in highly connected areas that in unconnected areas.[14] Similarly, in 2003 Cervero and Duncan used household activity data from the San Francisco region to discover that areas with 4-way intersections were positively associated with cycling, while neighborhoods with large shares of 3-way intersections and dead-end streets were not as bicycle-friendly.[15] In a series of focus group sessions of Vancouver cyclists, Winters and Cooper found that a well-connected street network ranked as the third most important factor influencing cycling. The only factors found to be more important were the presence of bicycle routes and motor vehicle traffic.[16] Winters and Cooper also found that cyclists were more likely to cycle the area if it consisted of a grid-network.

For bicycle facilities to be effective, routes must form a network connecting neighborhoods with destinations such as employment sites, schools, shopping areas, recreational areas, and transit stops. Cities with leading policies on cycling place priority on filling existing gaps and creating a tighter bicycle network. Research on the effect of bicycle facility networks on bicycle use generally indicates that dense, well-connected

13 Reilly and Landis, 2002.
14 Dill and Gliebe, 2008.
15 Cervero and Duncan, 2003.
16 Winters and Cooper, 2008.

networks with high intersection density, and relatively straight streets encourage more people to use bicycle transportation. On the other hand, sprawling suburban environments that characterized by curvy streets with dead ends and few intersections exhibit low connectivity and are less conducive to cycling. While network connectivity may not be extremely important for motorized transportation, since effort is low and speeds are high, it is very important for non-motorized transportation since speeds are low and only increased by effort.

LAND USE

A mixture of land uses encourages bikeability. Areas encompassing a high mix of land uses have an increased diversity of destinations, which thereby reduce the distance required to travel to a variety of destinations. Mixing land uses also constructs the possibility of higher densities. It is also safe to assume that dense areas with sound planning practices have limited or expensive parking, which further encourages other modes of transportation.

Multiple studies have uncovered that proximity of mixed-use development significantly induces active transportation usage. In the San Francisco region study, Cervero and Duncan found that people are more likely to commute by active transportation if the destination is within 300 feet, or several city blocks from their residence.[17] In another San Francisco study on travel behavior, Kockelman found that the heterogeneity of land uses as well as the number employers within a thirty-minute walk

[17] Cervero and Duncan, 2003.

from origins or destinations positively correlated with the decision to cycle.[18] A study by Rutherford, McCormack, and Wilkinson concluded that mixed-use neighborhoods could reduce the amount of auto travel for most households.[19] As for density, Parsons Brinkerhoff Quade and Douglas, Inc. found that bicycle trips only accounted for 2% of all trips in low-density neighborhoods, but accounted for 10.4% of all trips in denser neighborhoods.[20]

Jobs-Housing Balance is another important factor of land use planning that largely affects commute patterns. The jobs-housing ratio quantitatively expresses the relationship where people work and where they live.[21] Giuliano defines jobs-housing balance as "the distribution of employment relative to distribution of workers in a given geographic area."[22] Over the past few decades, populations in American cities have decentralized into suburban areas, yet job centers have remained central. This imbalance of growth between jobs and housing has escalated commute times and congestion for those living outside of the city center. By adopting policies that force cities to become "compact and connected," communities are provided the ability to become self-reliant and are given employment and housing options in close proximity to each other. A 2006 study by Cervero and Duncan reported that every 10% increase in the number of jobs

---

18 Kockelman, 2007.
19 Rutherford, McCormack, and Wilkinson, 2006.
20 Parsons Brinkerhoff Quade and Douglas, Inc., 1993.
21 California Planning Roundtable, 2008.
22 Giuliano, 1991.

within four miles of one's residence is associated with over a 3% decrease in daily work-hour vehicle miles traveled (VMT).[23]

TOPOGRAPHY

A significant amount of research has proven that topography can influence the decision to cycle, however, the degree of influence is uncertain. Cervero and Duncan found that increased slope results in decreased cycling.[24] Yet other studies show that slope is a subjective metric that's impact is hard to model. In the 2006 Cycling in Cities focus group of current and potential cyclists in Metro Vancouver, most participants agreed that bicycle routes with a few small hills had no influence on the decision to bicycle, but nearly half of the participants indicated that they were less likely to cycle if a route included steep, long slopes.[25] However, this was not the result from a study by Dill and Voros in the Portland, Oregon region. They found that topography did not have a statistically significant influence on the decision to bike when they used GIS to calculate the average percent slope within ¼ mile of each telephone survey respondent's place of residence.[26] These mixed results reveal that the degree of slope that a cyclist is willing to endure is based on their individual abilities and preferences. However, it is safe to assume that when the purpose of riding a bicycle is for daily commute, more bicycle commuters prefer a flat terrain than a hilly terrain. When it comes to recreational riding on the other hand, preferences can be more varied.

---

[23] Cervero and Duncan, 2006.
[24] Cervero and Duncan, 2003.
[25] Winters and Cooper, 2008.
[26] Dill and Voros, 2006.

Chapter Four: Methodology & Factor Maps

This section explains the methodology for the bikeability spatial analysis, which includes the mapped environmental factors for the bike quality index index or multi-criteria evaluation. Like many precedent studies, this analysis used a multi-criteria evaluation because there are multiple competing factors that impact the quality of the bicycling environment. The five factors used are bicycle facilities, network connectivity, land use, slope, and barriers. No single factor has an overriding impact, yet none of them can be overlooked.

The raster math for the evaluation was done within ArcMap. Factor maps were first created from the input data and then re-classed on a scale from 0 to 100. Zero being the worst possible score and 100 being the best possible score. Finally, factors were weighted and combined to create composite bikeability maps. All factors were used to analyze both current bikeability and potential bikeability. Included in this section is a table of all of the city shapefiles used in the geospatial analysis and an explanation of the weights and scoring for each factor. Lastly this section includes the maps produced for each factor and an analysis of the results. Each map displays the bikeability of each factor within the full purpose and limited jurisdictions of Austin. The raster of all maps have been stretched with a .05 percent clip gradient to maintain the same appearance. The most bikeable areas are represented by the blue gradient and the least bikeable areas transition to a red gradient.

DATA

The data used in this analysis was obtained from the City of Austin's Geospatial Database, known as Data Mart. Most of the data used in this analysis is fairly common and universally available to the rest of the community. Most data was only briefly reviewed for accuracy, however, a large amount of data manipulation and reclassing was conducted.

Table 1: Data for Bikeability Analysis

Factor	Shapefile (s)	Source	Methodology
Bicycle Facilties	2014_BicycleMasterPlan_Exisiting 2014_BicycleMasterPlan_Rec	COA GIS Data	Line Density Method
Network Density	Street Segment	COA GIS Data	Point Density Method
Land Use	Zoning	COA GIS Data	Polygon to Raster
Slope	National Elevation Dataset (NED)	TNRIS	Digital Elevation Model
Barriers	Created using Lakes (feature to line) Street Segments (Roadclass = 1 & 2)	COA GIS Data	Line Density Method

BICYCLE FACILITIES

Facilties are ranked based on quality, safety, and comfort. Multi-use paths were awarded the highest score followed by cycle track, bicycle boulevards, buffered bike lanes, bike lanes, bike lanes with parking allowed, climbing lanes, and sharrows. All other facility types were given a score of 0. Bike lanes and sharrows on a one-way street are assigned half the score of a two-way street. This prevents any facilities from being double counted. Facility definitions, sited from a combination of the City of Austin 2014 Bicycle Master Plan and the National Association of Transportation Officials (NACTO) 2015 Urban Bikeway Design Guide, and their scores can be found in Table 2.

Table 2: Facility Terms and Scores

Facility	**Definition**	**Score**
Multi-Use Path	Also known as an Urban Trail, these hard surface trails are designed for use by pedestrians, bicyclists, and other forms of transportation for both transportation and recreational use.	10
Cycle Track	Cycle Tracks are exclusive bicycle facilities that combine the user experience of a separated path with the on-street infrastructure of a conventional bike lane.	9
Bike Boulevard	Known as quiet streets in Austin, these local neighborhood streets contain traffic calming devices that optimize them for bicycle use. They are often found adjacent to large arterials and include way-finding signage, which integrates them into the bicycle network.	9
Buffered Bike Lane	Buffered bike lanes are conventional bicycle lanes paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane.	9
Bike Lane (With and without parking allowed)	A portion of the roadway that has been designated by striping, signage, and pavement markings for the preferential or exclusive use by bicyclists. It enables bicyclists to ride at their preferred speed without interference from prevailing traffic conditions.	6
Climbing Lane	A hybrid bicycle facility that designates space for slower-moving uphill bicyclists. It includes a 5-foot bike lane on the uphill side of the roadway and a sharrow on the downhill side of the roadway.	6
Sharrow	This treatment includes a bicycle symbol and two white chevrons in the middle of the street. It is used to remind motorists that cyclists are permitted to use the full lane.	3

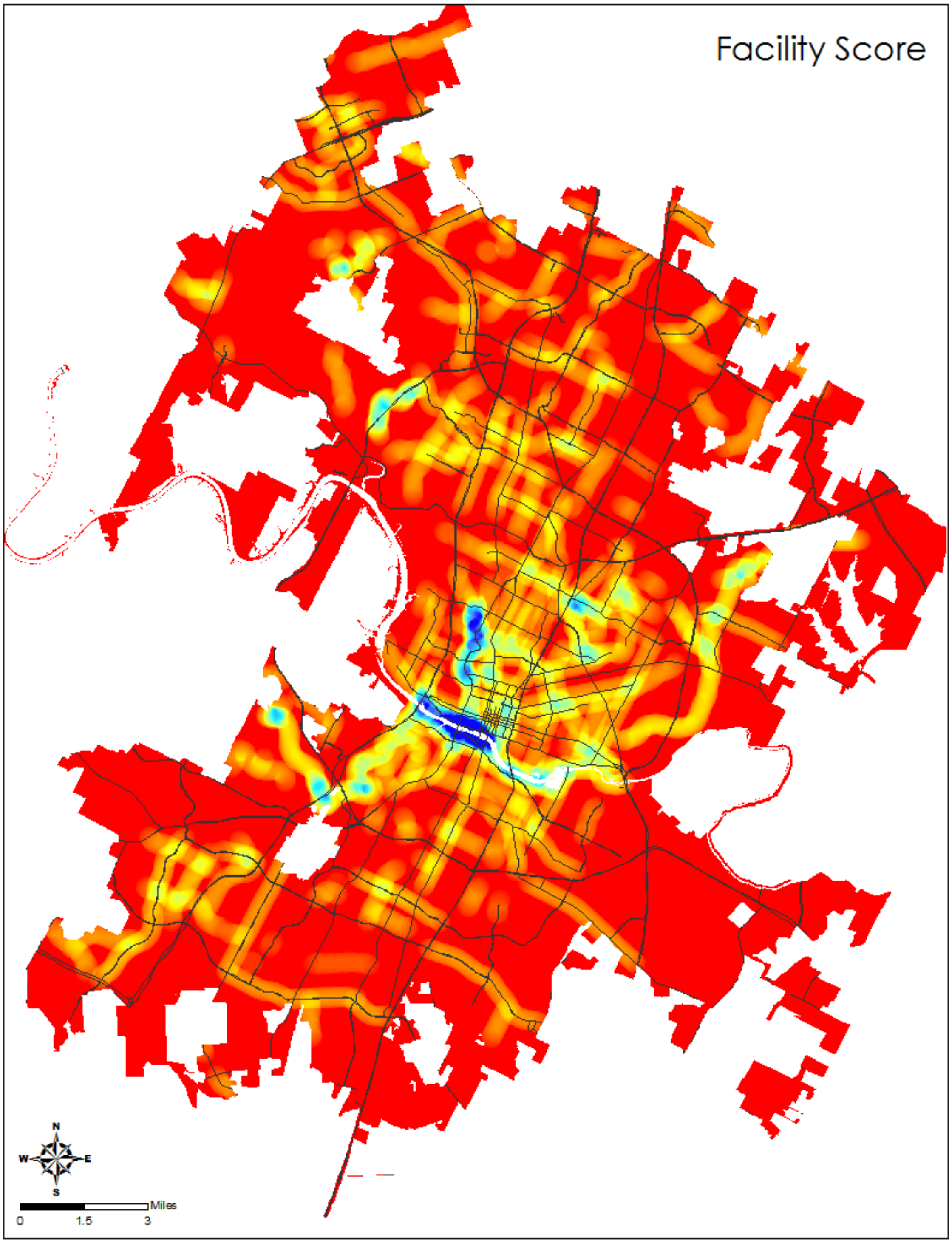
Once all facility types are scored, the vector data is converted into raster data using the line density method. This creates a heat map that intensifies where dense, high quality bicycle facilities are located. Values were then re-classed to cover a range of 0 to 100 using a linear conversion so that this factor can be added to the final composite map. Unlike similar studies, only exisiting facilties are included in the Facilties Score Map and the Current Bikeability Map. Planned or Recommended Facilties, however, are included in the Potential Bikeability Map.

Figure 8 displays the facility scores for Austin, Texas. As previously mentioned, these faciltiy scores are based on quality and density. Most of the bicycle network is outlined in yellow, displaying that while the bicycle network is extensive, it is comprised of lower quality facitlies that suffer from gaps in connectivity. Unsurprisingly, most high scores are located downtown due to the number of facilties available and their proximity to each other. Major facilities that contribute to bikeability downtown are the Ann and Roy Butler Hike and Bike Trail, the Pfluger Bicycle and Pedestrian Bridge, and the Lance Armstrong Bikeaway. The Butler multi-use path and Pfluger bridge are high quality facilties that offer connectivity for alternative transportation modes along and across Lady Bird Lake. The Lance Armstrong Bikeway, LAB, is a seperated bicycle facility that increases crosstown mobility from the far west side of town to the east side of town. As a part of LAB, cycle tracks have recently been built on 3rd Street and a portion of 4th street near the Capital Metro Downtown Red Line station. In addition many bike lanes and sharrows exist on downtown streets, especialy those which offer north-south connectivity.

A strand of high scoring facilties also exist along the North Lamar Boulevard corridor. Although Lamar itself does not maintain any bicycle facilties, its proximity to the Shoal Creek Trail and the high-quality bicycle network around the University of Texas, strengthens the overall score of the area. Other small scattered ranges of high scoring facilities are the result of urban trails located on greenbelts and parkland.

This map clearly portrays that while some areas have a dense amount of cycling facilties, other areas lack them completely. While facilties begin to loose connectivity north of Highway 290 and south of Oltorf Street, they appear to taper off completely north of Highway 183 and south of Highway 71.

Figure 8: Facility Score for Austin, TX

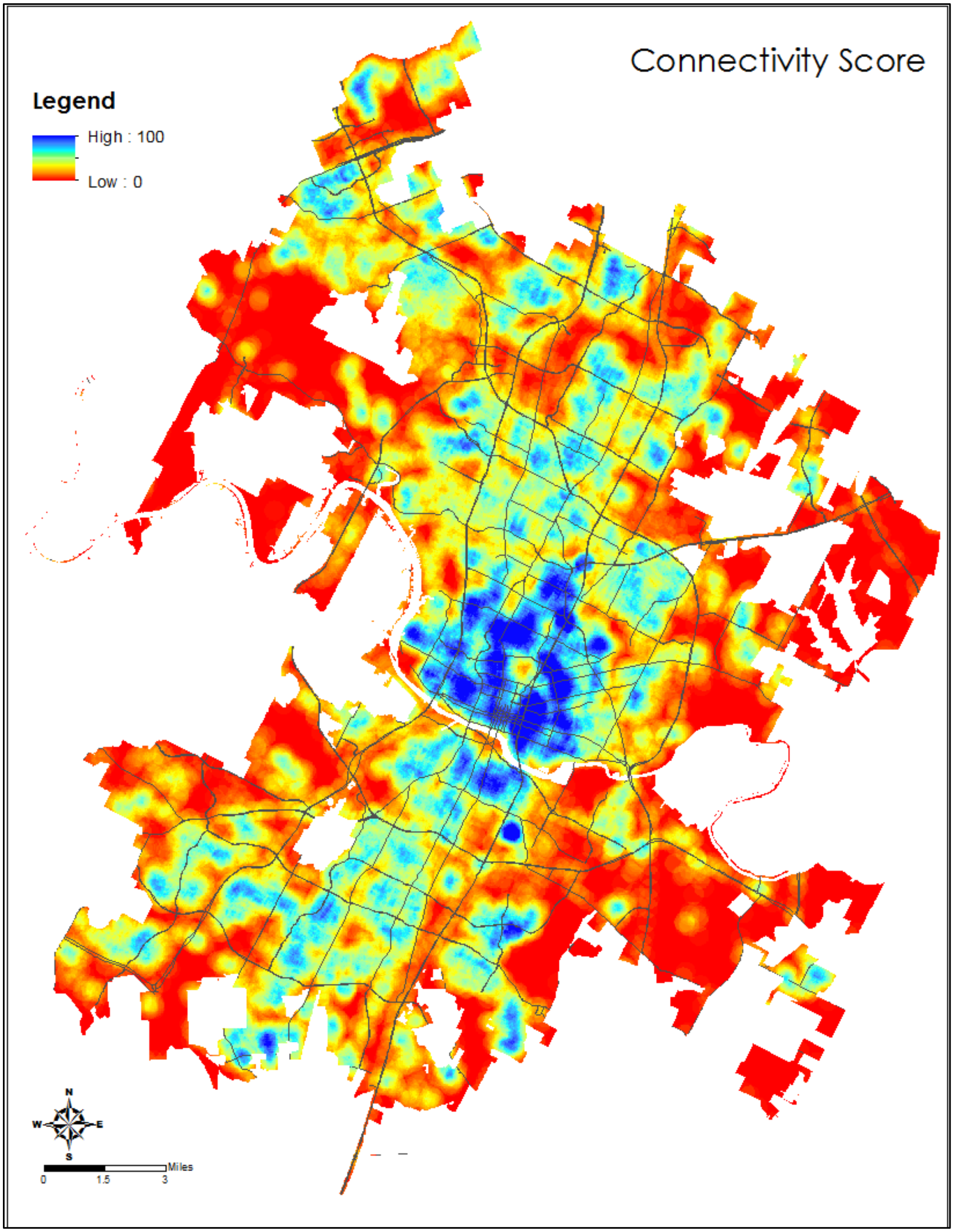


NETWORK CONNECTIVITY

Previous studies have used 4-way intersection density and road network density as a corollary for a connected and direct street network. However, this analysis measures network connectivity by converting raster data using the point density method. This method highlights the connectivity provided by high intersecton densities of grid networks and prevents highway networks from being included in the analysis. Once mapped, the values were then re-classed to cover a range of 0 to 100 using a linear conversion.

Figure 9 displays the connectivity scores for Austin, Texas. Compared to the Facilties Map, Austin's vast network of roads enables the City to have a majority of high connectivity scores. The tradtional grid network design exhibited by neighborhoods built before WWII provides Central Austin with higher scores than further stretches of the city. These older neighborhoods of high connectivity include: downtown, Hyde Park, East Cesar Chavez, Holly, Central East Austin, Clarksville, North Loop, West and North University. The Mueller development, a new neighborhood designed with New Urbanist principles, also exhibits high connectivity. Neighborhoods such as Windsor Road, South River City and Travis Heights earn medium scores of connectvity as their grid-like network is fragmented by hilly terrain.

Figure 9: Connectivity Score for Austin, TX



Outside of the city center, it is evident that the lack of connectivity is a consequence of sprawl. The rapid increase in population has forced Austin to expand beyond its means in an extremely short period of time. Connectivity scores decrease further from the city center as development transitions from urban to suburban. These neighborhoods lack of adhererence to traditional neighborhood design (TND) and New Urbanist principles, force node density to decrease and block sizes and dead ends to increase which weakens connectivity.

LAND USE

Land use data was scored using two criteria, destination and originating quantity of trips. Commercial, industrial, and retail land uses are considered destination-based uses while residential land uses were primarily origination-based uses. Scores were given on a scale of 1 to 10 for each type of trip and then added together for a total score. Although zoning codes were aggregated, codes that included mixed use (MU) or vertical (V) were provided an additional point. Detailed scores for Austin can be seen below in Table 3.

Table 3: Austin Zoning Code and Assigned Scores

Zoning Type	Name	Origin	Destination	Total
AG	Agricultural District	1	0	1
AV	Aviation Services	0	1	1
CBD	D	5	5	10
CH	Commercial Highway	0	7	7
CR	Commercial Retail	0	2	2
CS	Commercial Services	0	5	5
DMU	Downtown Mixed Use	5	5	10
DR	Development Reserve	0	1	1

Table 3: Austin Zoning Code and Assigned Scores (Continued)

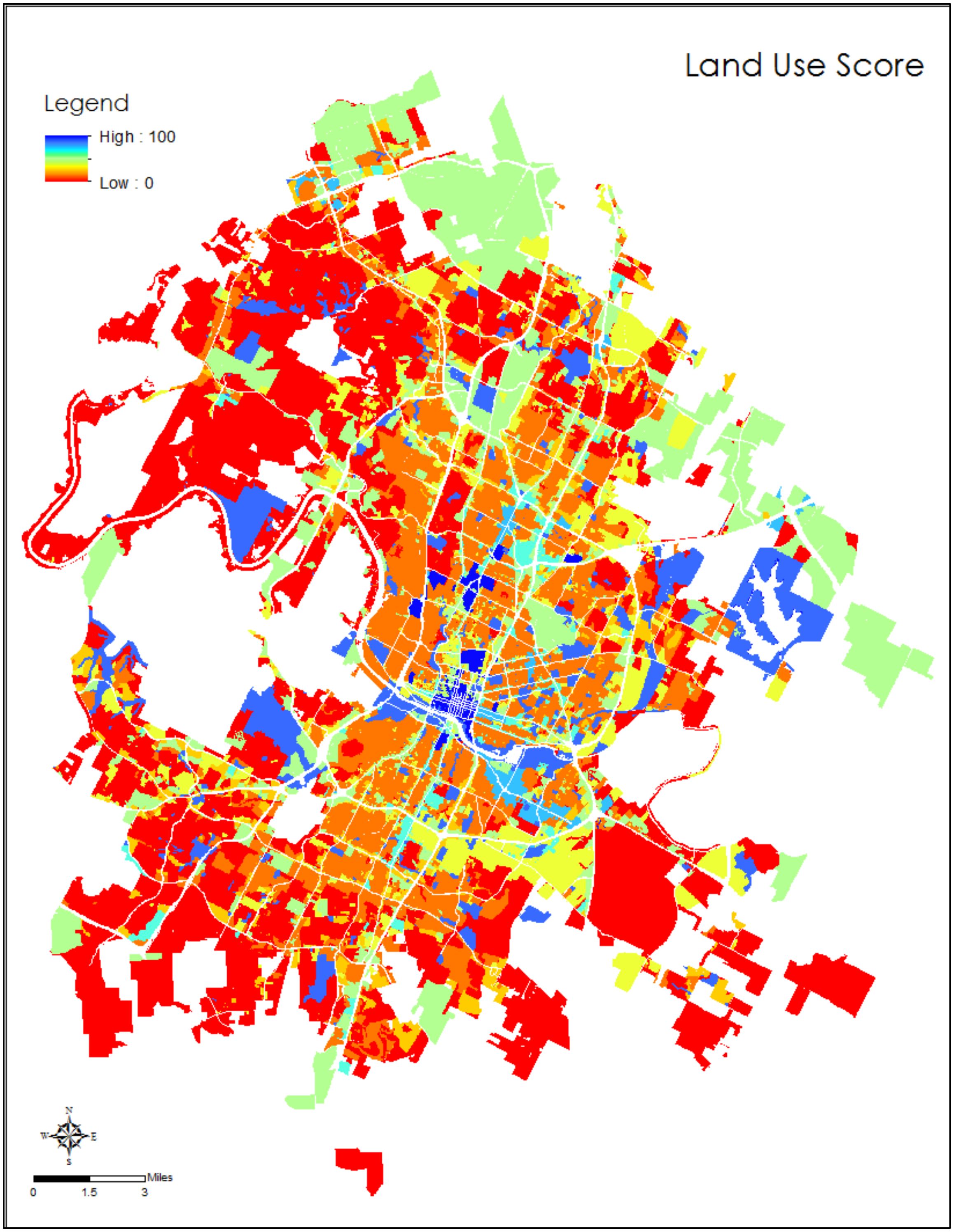
ERC	East Riverside Corridor	3	4	7
GO	General Office	0	5	5
GR	Community Commercial Lake	0	2	2
LA	Lake Austin Residence District	1	0	1
LI	Limited Industrial Service	0	4	4
L-NP	Commercial	0	9	9
LO	Limited Office	0	4	4
LR	Neighborhood Commercial	0	3	3
MF-1	Multi-Family - Limited Density	1	0	1
MF-2	Multi-Family - Low Density	2	0	2
MF-3	Multi-Family - Medium Density	2	0	2
MF-4	Multi-Family -Moderate Density	4	0	4
MF-5	Multi-Family - High Density	5	0	5
MF-6	Multi-Family - High Density	6	1	7
MH	Mobile Home Residence	1	0	1
MI	Major Industrial	1	0	1
NBG	North Burnet Gateway	2	3	5
NO	Neighborhood Office	0	6	6
P	Public	0	8	8
PUD	Planned Unit Development	3	2	5
R&D	Research and Development	0	1	1
RR	Rural Residential	1	0	1
SF-1	Single Family - Large Lot	1	0	1
SF-2	Single Family - Standard Lot	1	0	1
SF-3	Family Residence	2	0	2
SF-4	Single Family - Small Lot Single	3	0	3
SF-5	Family Residence Town Home	4	0	4
SF-6	Condo Multi-Family	4	0	4
TND	Traditional Neighborhood District	3	0	3
TOD	Transit-Oriented Development	0	7	7
UNZ	Unzone	0	9	9
W/LO	Warehouse Limited Office	0	1	1

Although central business districts certainly have the largest concentrations of activity, work related trips make up a small percent of total trips. Trips for other purposes such a shopping, recreation and leisure were also emphasized rather than focusing on commuting trips alone. Overall these scores reflect the City's 2014 Bicycle Master Plan goal of targeting short trips to downtown, institutions and open spaces, transit corridors, and Imagine Austin centers. Although by itself this factor may only correlate to mobility, but when combined with the previous bicycle facilities map these factors demonstrate accessibility. This is due to the facilities raster serving as the midpoint or conduit from origin to destination.

Figure 10 shows the land use scores for Austin, Texas. Each land use was scored and then converted into a raster using the polygon to feature tool. Out of all of the weighted factors, land uses are the only factor that was not calculated based on its density to other uses. This map lacks the consistent transition from low to high scores, as each land use is its own raster. Thus a high scoring land use, such as a park, can be adjacent to a low scoring land use, such as low density residential.

Although there is a strange confluence of land use scores, a majority of high-ranking land uses can be found in Central Austin. These land uses include: high density mixed use of downtown, open space of pocket parks and Zilker Park, and government and educational institutions such as the State Capital and the University of Texas at Austin. High to moderate land uses include: planned unit developments (PUDs), transportation corridors and transit-oriented developments (TODs), and high-density residential and commercial districts.

Figure 10: Land Use Score for Austin, TX



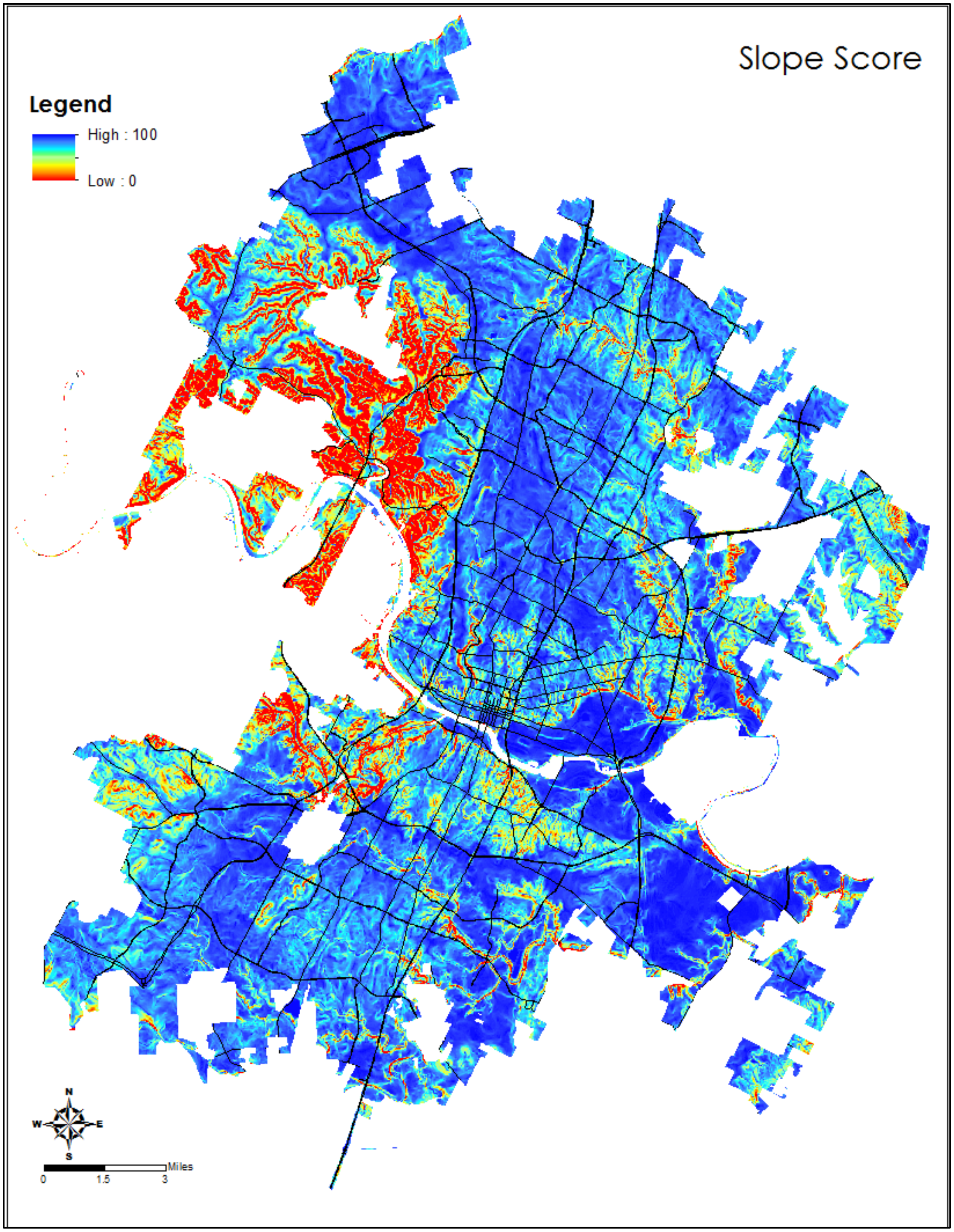
Unfortunately a majority of land uses are moderate to low scoring in terms of bikeability as much of Austin is zoned for low density, single-family housing. The low origin + destination scores inherently show the poor Jobs-Housing balance that currently affects Austin. These neighborhoods are scattered throughout Austin, forcing land uses with high bikeability scores to neighbor lower scoring land uses. However, most low scoring land uses are located near the outer boundaries of Austin.

SLOPE

Slope was calculated with a National Elevation Dataset (NED) downloaded from the Texas Natural Resources Information Center (TNRIS). The dataset was then converted into a raster elevation surface, which was then processed into a percent slope surface. Finally the surface was re-classed with 15% slope as the lowest value equaling 0, and 0% slope as the highest value equaling 100%. Thus all slopes greater than 15% are considered undesirable for ridership, while areas that are completely flat are considered attractive for ridership. Figure 11 displays the distinct topography of Austin, Texas.

The most extreme slopes are located west in the Hill Country, also known as the Balcones Canyonlands. This area of flat top hills, separated by steep canyons is the result of the faulting of the coastal plains followed by erosion. Yet, hills are still scattered throughout the city. Compared to the rest of Austin, downtown and southeast Austin is relatively flat, simulating a valley, as the Colorado River is one of the lowest points in Austin.

Figure 11: Slope Score for Austin, TX



Slopes increase immediately south of the river, yet are inconsistent after Highway 71. Although hills exist north of downtown, the north side of town fares better when it comes to grade. However, slope does increase on the far north and northeastern neighborhoods.

The most extreme slopes are located west in the Hill Country, also known as the Balcones Canyonlands. This area of flat top hills, separated by steep canyons is the result of the faulting of the coastal plains followed by erosion. Yet, hills are still scattered throughout the city. Compared to the rest of Austin, downtown and southeast Austin is relatively flat, simulating a valley, as the Colorado River is one of the lowest points in Austin. Slopes increase immediately south of the river, yet are inconsistent after Highway 71. Although hills exist north of downtown, the north side of town fares better when it comes to grade. However, slope does increase on the far north and northeastern neighborhoods.

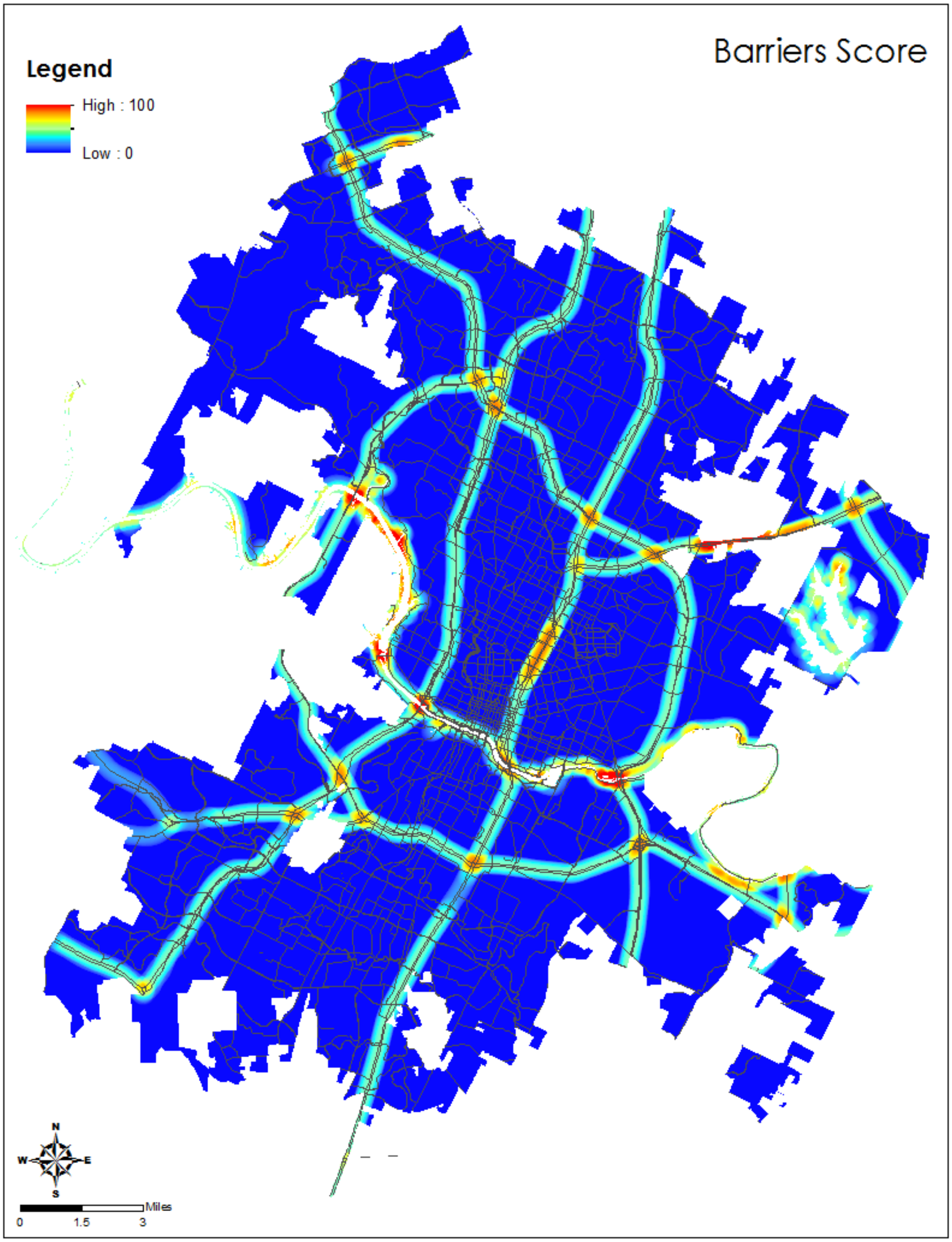
As mentioned before, slope is an extremely subjective measure of bikeability. Although Austin does encompass hilly terrain, this factor should not play as important of a role in bikeability as the presence of bicycle facilities and mix of land uses. Aspirational bicycle cities such as San Francisco and Seattle face much steeper slopes than Austin, yet engage higher amounts of bicycle ridership. The weight of this factor and all other factors will be described in further detail in the next chapter.

BARRIERS

Barriers refer to specific characteristics of streets and the natural environment that are unaccounted for by other factors in the analysis. This factor is an attempt to take into account how vehicle speeds and volume reduce the comfort and safety of cycling. Highways and waterways create barriers for bicyclists to cross and can often be undesirable to ride along unless protected facilities are available. These features were converted into raster data using the line density method. These values were then re-classed to cover a range of 0 to 100 using a linear conversion.

Figure 12 shows the Barrier Score. This map delineates constrains that large arterials and waterways place on cyclists. I-35, also known as "The Great Divide" is identified as the largest constraint in the city. In early Austin history, this interstate played an important role in increasing the segregation between Caucasians on the west side of town and minority groups on the east side. Although this map may not be too revealing by itself, it is an important factor that will counteract some of the misleading high scores created in the facility and connectivity maps.

Figure 12: Barrier Score for Austin, TX



Chapter Five: Bikeability in Austin

A New Plan

Austin, Texas has been making major strides in bicycle planning over the past decade. In 2008, The City of Austin was awareded a Silver Bicycle Friendly Community rating from The League of American Cyclists. From 2009 to 2014, Austin's bicycle network grew by 70%, expanding from 126 to 210 centerlane miles.[27] The addition of new bike lanes has led to an increase in modeshare, as the amount of people commuting by bike at least three times a week has nearly doubled. In 2013, the City of Austin was also asked to be one of the first participants in The Green Lane Project, a program developed by the national organization People for Bikes. This pilot program targets the development of seperated bikelanes and collects data to encourage this reversal in bicycle planning that mirrors European principles. In addition to bicycle specific achievements, the City was nationally recognized for praciticing one of the top Complete Streets Policies in the country for 2014.

The release of both the 2014 Bicycle Master Plan and the 2014 Urban Trails Master Plan indicate the City's dual efforts to continue improving bikeability in Central Texas. These complimentary plans are overhauling the current bicycle network to build a system that follows the 8 to 80 rule or the ability to serve anyone from the age of 8 to 80 years old. The vision for these plans is guided by multiple studies which access Austinites' comfort level of riding on the current bicycle network. According to a phone

[27] City of Austin, 2014.

survey conducted in 2013, only 15% of people will ride in a painted bicycle lane on a busy road in Austin. However, if the bike lane is a protected facility the number of people who would feel comfortable riding rises to 40%.[28] This data reinforces the need for the City to create a network that is safe, direct, cohesive, comfortable, and attractive. The overarching goals of the 2014 Bicycle Master Plan can be viewed in Table 4.

Table 4: 2014 COA Bicycle Master Plan Goals

GOALS	BENCHMARK
Connectivity Create a bicycle network that serves people of all ages and abilities, providing direct and comfortable connections to where people live, work, and play.	Complete 50% of the "all ages and abilties network" and removal of bicycle lane network barriers by 2020 and 100% by 2025.
Increase Ridership Achieve a significant increase in ridership, especially transportation cycling, and a corollary reduction in motor vehicle miles traveled and/or prevented traffic congestion.	Increase citywide workforce commuter bicycle mode to 3% by 2015 and to 5% by 2020. Increase central city workforce commuter bicycle mode to 10% by 2015 and to 15% by 2020.
Improve Safety Reduce bicycle deaths and injuries by implementing safety measures for all roadway users, including bicyclist.	Reduce bicycle fatalities by 50% from 2009 levels by 2015 and eliminate bicycle fatalities completely by 2020. Reduce crash rate by 1% every 5 years starting with 5% in 2015 as a baseline.

Table 4: 2014 COA Bicycle Master Plan Goals (Continued)

[28] City of Austin, 2014.

GOALS	BENCHMARK
Equity Provide equal bicycling access for all through public engagement, program delivery, and capital investment. Provide equal bicycling access for all through public engagement, program delivery, and capital investment.	Provide an all ages and abilties route within ½ mile of all 50% of households, workplaces, and destinations by 2020. Provide an all ages and abilities bicycle route within ½ mile of all 100% of households, workplaces, and destinations by 2035.
Support Imagine Austin Realize the potential of bicycling to support and achieve multiple goals of the Imagine Austin Comprehensive Plan.	Monitor contribution of bicycling in advancing the goals of Imagine Austin and include in an annual report.

The immediate recommendations of the plan are to capture short trips by bicycle; 15% of trips less than 3 miles and 7% of trips less than 9 miles. The plan suggests that this can be achieved if network density is increased so routes are spaced to cover every ½ to ¾ mile in the central city and near transit stations. Other targeted areas for short trips include key feeder routes to the central city, to schools and along parks, and to or near Imagine Austin Centers. Another priority of the plan is to reduce network barriers, specifically gaps in bicycle facility network, highways with few crossing streets, low angle railroad track crossings, and intersections without bicycle facilities.

The methodology of the maps produced in the next section adhere to the goals of the 2014 Bicycle Master Plan Update.

FACTOR WEIGHTS

In order to produce composite maps, factors are weighted based on their degree of influence on overall bikeability. All factors will be included in the Current and Potential Bikeability analyses, however, the Current Bikeability analysis only includes exisiting bicycle facilties while the Potential Bikeability analysis includes recommended facilties. Other studies have differenciated Current and Potentail Bikeability by including only permanent features including street network density, land use, and topography in the Potential analysis. When this methodology was replicated for Austin, potential bikeability was actually lower due to the large amount of low density land uses and high slopes. Thus, this study leaves all factors and weights constant except for facilties as this metric now shows increased bikeability that will result directly from the implementation of the 2014 Bicycle Master Plan. The weights in table 5 are modeled after the Portland Cycle Zone Analysis, but slight variations are made to be more applicable to the Austin area.

Table 5: Factor Weights for Bikeability

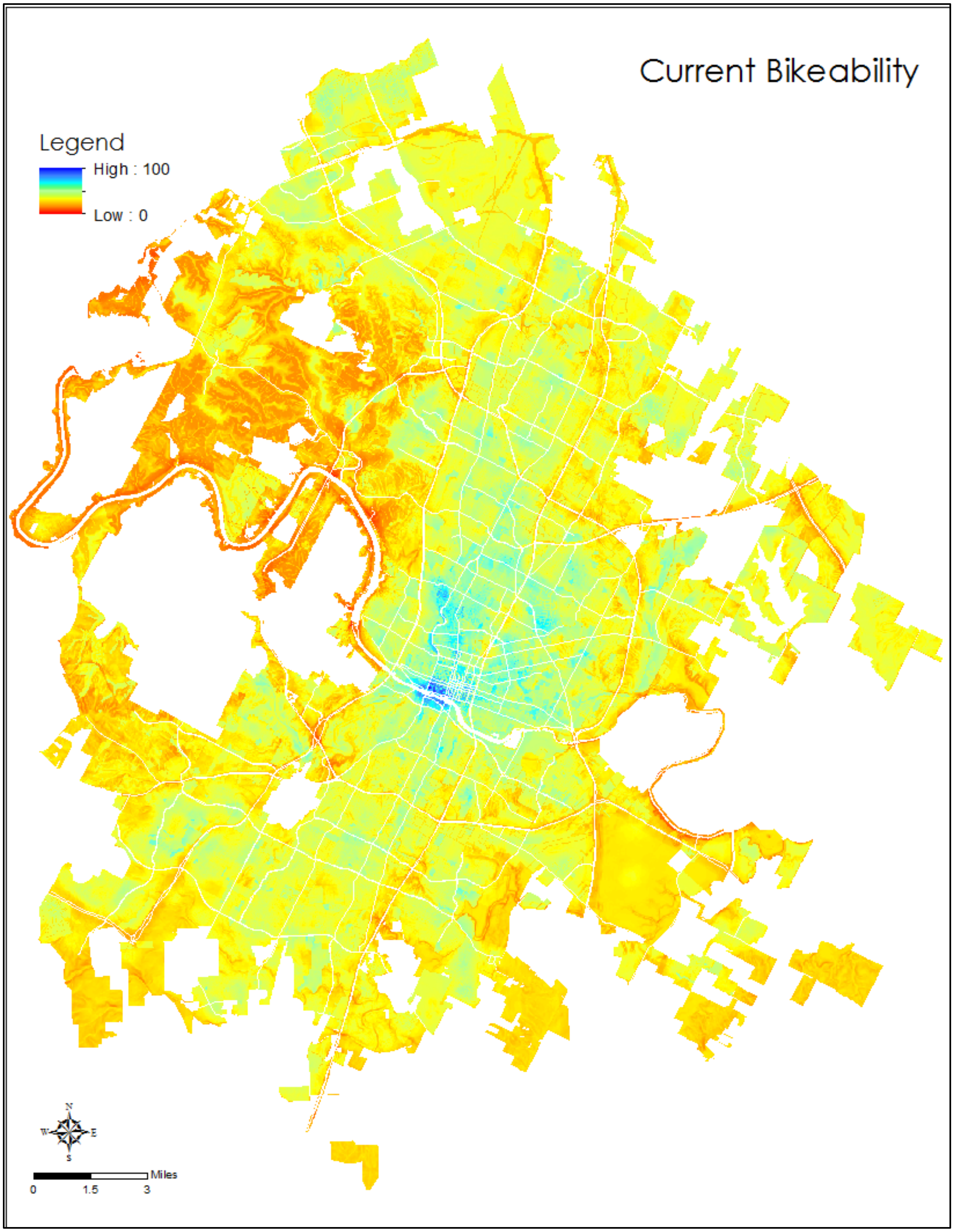
Factor	**Current & Potential**
Land Use	15%
Barriers	15%
Network Connectivity	20%
Bicycle Facilities	35%
Slope	10%

CURRENT BIKEABILITY

Figure 13 displays Current Bikeability in Austin, Texas. This map delineates that Austin's bike shed has a 2-mile radius from the Texas State Capital building. Bikeability is strongest east of Mopac, west of I-35, south of 290, and north of Barton Springs. The most bikeable area of Austin is downtown and along Lady Bird Lake. Bikeability remains somewhat consistent heading north but gradually diminishes south of the lake. The dense grid-like street network and high quality bicycle facilities are the main contributors to downtown Austin's high bikeability rating.

Besides downtown, the Guadalupe and Lamar corridors receive high scores of bikeability. Guadalupe, also known "The Drag," is considered one of the most bikeable streets in Austin as the entire stretch is lined with bicycle facilities. It also borders high destination land uses including the University of Texas and the high density residential West Campus. Although it may not appear to be very bikeable, Lamar ranks highly as its perimeters Pease District Park and the Shoal Creek Multi-Use Trail. Also its sheer contiguity to the dense cycle network of Guadalupe increases bikeability of the area. Neighborhoods with high to medium scores include: Hyde Park, North Loop, Belmont, Mueller, and Central East Austin. All of these neighborhoods are within the bikeshed, have a mixture of land uses, and are close to open spaces and trail systems. Current Bikeability by neighborhood can be seen in Appendix A.

Figure 13: Current Bikeability in Austin, Texas



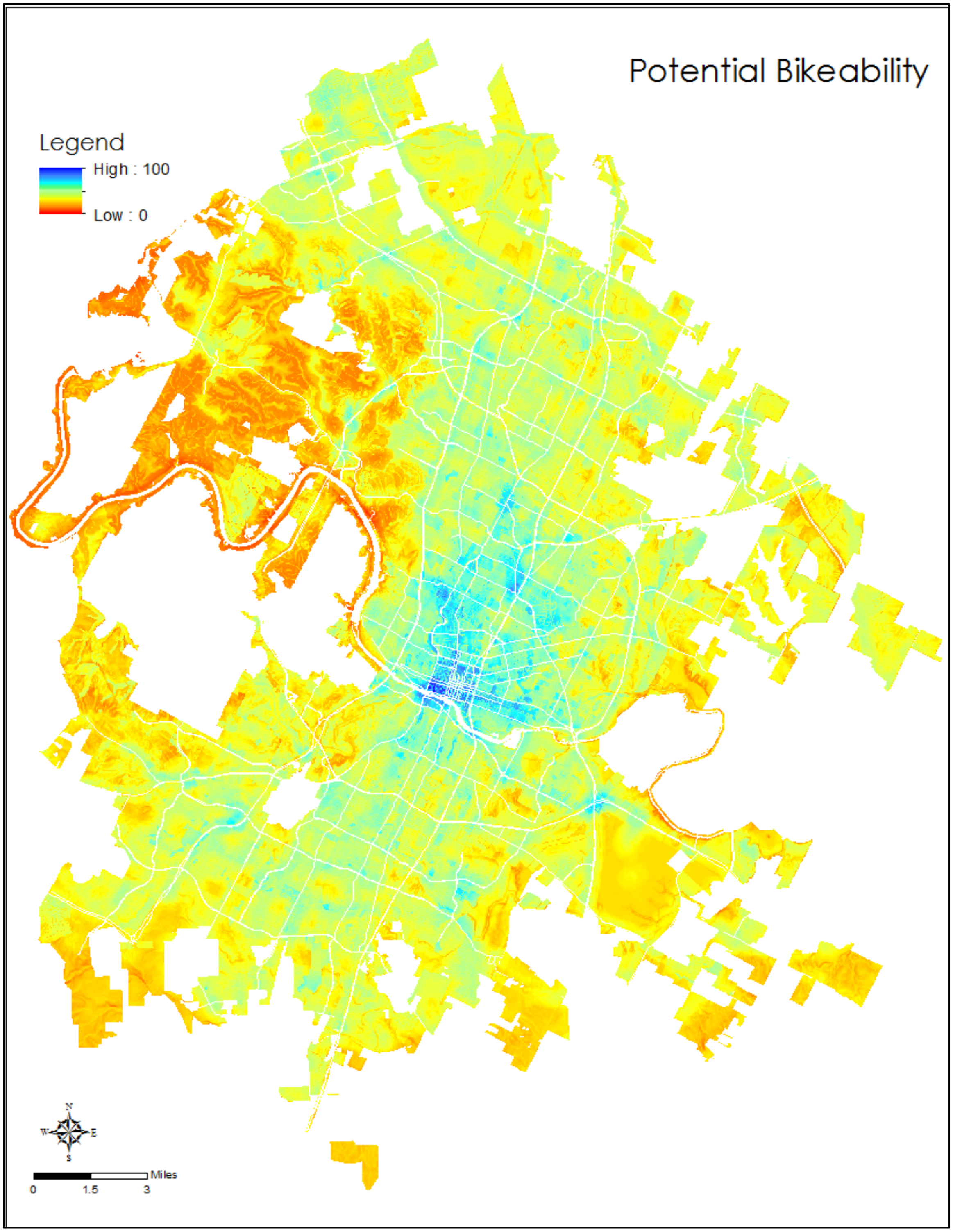
A majority of Austin receives a moderate to low ranking for bikeability. Patches of blue and green are scattered throughout Austin, but are less prevalent in South Austin. Scores also decrease at the extreme north and south ends of the city, north of 183 and south of 290 also known as Ben White Blvd. Lack of dense, high quality bicycle facilities and the abundance of low density, uniform land uses prevent these areas of town from achieving high levels of bikeability. The lowest scoring areas are far west and along major arterials. The far west side of town deemed the Hill Country has extreme slopes that would be regarded undesirable for biking by most cyclists. Highways such as 183, 290, Mopac, and 1-35 are also major barriers when it comes to bikeability.

It is important to remember that existing bicycle facilities are the highest weighted factor in this analysis. Thus areas suffering from barriers, low connectivity, high slopes, and low scoring land uses can achieve high bikeability scores if they are supplemented with dense, high quality bicycle facilities.

POTENTIAL BIKEABILITY

Figure 14 displays Potential Bikeability in Austin, Texas. This map visually portrays how the implementation of the 2014 Bicycle Master Plan will impact bikeability in Austin. The bicycle facilities feature tabulated in this raster are the long term recommendations from the 2014 Bicycle Master Plan. This feature is used instead of short term recommendations as it shows the tremendous impact that bicycle infrastructure investments will have on the entire community over a long period of time.

Figure 14: Potential Bikeability in Austin, Texas



Although changes may appear to be slight, adding recommended facilties to the map enables bikeability to rise throughout all of Austin. The bikeshed extends from a 2-mile to a 4-mile radius. Bikeability in Central Austin not only increases in area but also in granularity. Now that the bicycle plan is fully built out, downtown Austin is extremely bikeable. The eastside of town endures high increases in bikeability most likely due to the Boggy Creek Trail system that integrates into other trails. West Campus and North Campus also increase in bikeability.

The full buildout of the all ages and abilities bicycle network largely increases bikeability throughout all of Austin, especially in the south. Neighorhoods that have highly benefited from these facility investments include: Highland, Windsor Park, Brentwood, Rosedale, Old West Austin, Old Enfield, Bouldin Creek, West Gate, South Manchaca, Franklin Park, and South River City. Potential bikeability of Austin neighborhoods is displayed in Appendix A. New areas of high bikeability also emerge along Airport Blvd north of 45th St and along the East Riverside corridor. Compared to current bikeability, most of Austin, especially South Austin and North of 290 become moderately bikeable. Areas of high improvement occur immediately south of Barton Springs, especially between South Lamar and South 1st. This improvement expands south of Oltorf and continues in fragments all the way to the city's edge.

The recommendation for bicycle and pedestrian facilties to border major arterials allows areas originally suffering from major barriers to become more bikeable. This includes I-35 South, Ben White Boulevard, Mopac, Highway 290, and 183. The intersection of Lockhart Highway and East Ben White Boulevard has improved drastically due to the density of high quality seperated facilties that are planned for the area.

Although most areas have improved in bikeability, the far west still ranks low in bikeability. The areas is extremely hilly and a current ban on development to protect the Edwards Acquifer, has inhibited the interest in bicycle facilty investments for the area. The extreme southern outreaches of the city as well as the airport also feature low bikeability but this should not be much of a surprise as these are also areas with low development patterns and little need for bike facilities.

CORRELATION BETWEEN BIKEABILITY AND RIDERSHIP

The 2014 Bicycle Master Plan aspires to make Austin "a place where people of all ages and abilities bicycle comfortably and safely for transportation, fitness and enjoyment."[29] One organization that will assist the City in achieving its goal is the League of American Bicyclists' Bicycle Friendly Community program. This program sets the standard for what constitutes a strong and authentic bicycling culture and environment. The League of American Bicyclists, also known as The League or LAB, is a national organization that endorses safer roads, stronger communities, and bicycle friendliness. It ranks states and cities on the 5 E's: Engineering, Education, Encouragement, Enforcement, Evaluation, and Planning.

---

[29] City of Austin Bicycle Master Plan Update, 2014.

The 2014 Bicycle Master Plan sets the goal of achieving gold level designation by the League of American Bicyclists by 2015 and platinum level by 2020. In terms of the 5 E's, the City of Austin is doing exceptionally well, excluding ridership. To achieve gold Austin needs to have at least 5.5% of the population commuting by bicycle at least three days a week. Platinum status requires a ridership of 12%. According to the 2013 American Community Survey 5 year estimate, Austin's bicycle ridership is 1.6% and thus needs to significantly increase its bicycle mode share. Bicycle ridership by census tract is included in the appendix.

Primary means of increasing bicycle mode share is the implementation of the all ages and abilities bicycle network, and expansion of encouragement programs to increase levels of bicycling. Figure 15 displays ridership compared to potential bikeability in Austin, Texas. By looking at the relationship between bikeability and actual ridership volumes, we can see which census tracts have the highest potential for increased ridership. Improvement should be focused on census tracts with low ridership but high bikeability potential. Table 6 lists high priority neighborhoods with high bikeability potential and ridership averages of less than 5.5%. Infrastructure investments and educational and promotional programming should be prioritized in these neighborhoods, as they are within the catchment area of 1-3 miles from the center. The City has set a reasonable goal to capture 15% of trips within this distance range.

Figure 15: Ridership Correlation to Potential Bikeability

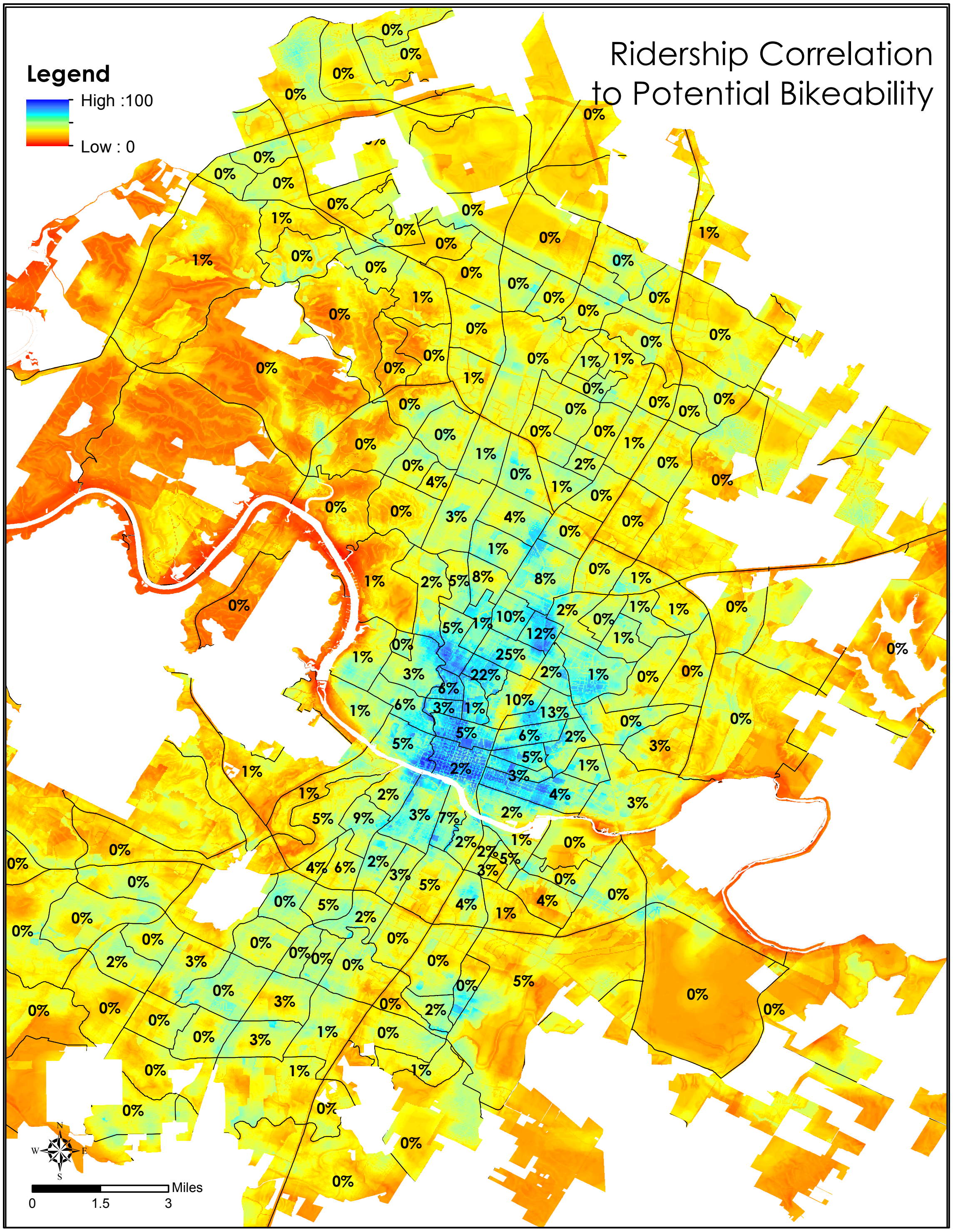


Table 6: Neighborhoods with High Potential Bikeability and Low Ridership

	Neighborhood	**Ridership**
Central	UT	1%
	West University	3%
	Downtown	3.5%
North	Mueller	1%
	Triangle	1%
	Upper Boggy Creek	2%
East	Rosewood	2%
	Holly	3%
	East Cesar Chavez	3%
South	Galindo	2%
	Riverside	2.7%
	Bouldin Creek	3%
West	Windsor Road	1.5%
	Old West Austin	5%

The University of Texas at Austin's surprisingly low ridership reflects the lack of on-campus housing and the means in which census transportation data is collected. If education were interpreted as a form of employment, ridership would most likely be far over 5.5%.

Table 7 lists neighborhoods with medium bikeability and low ridership. These neighborhoods should be kept in mind for future investments. Many of these neighborhoods are slightly outside of the 3-mile boundary but all are within the 9-mile boundary, which the City hopes to capture 7% of all trips.

It is important to note that areas with low bikeability and low ridership still play an important role in the entire bikeway network. Although originating trips may be low due to physical conditions, these areas may still be a route for riders coming from other neighborhoods. The Active Transportation program's restriping program should help eliminate these gaps of connectivity. The program outlines roads to be "right-sized" to include bicycle facilities when the street is resurfaced. A typical rightsizing treatment will morph a street with two lanes in each direction into a street with one lane in each direction, a center turn lane, and one bike lane in each direction. Now the street becomes more complete as it is accessible by more users and funding for this street comes directly out of the general fund.

Table 7: Neighborhoods with Medium Potential Bikeability and Low Ridership

	Neighborhood	**Ridership**
North	Windsor Park	1%
	Allandale	3%
	Crestview	3.5%
	Wooten	0%
	North Austin Civic Association	0.6%
	North Burnett	0%
	North Shoal Creek	1%
East	MLK	0%
	Govalle	1.5%
	Johnston Terrace	3%
South	Montopolis	0%
	Franklin Park	1%
	Pleasant Valley	2%
	South Manchaca	2%
	Dawson	3%
West	West Austin Neighborhood Group	1%

POLICY RECOMMENDATIONS & DISCUSSION

Investing in bicycle infrastructure, especially high quality facilities such as cycle tracks and multi use paths, has proven to positively increase the amount of people who ride a bike. The first multi-academic study on protected bike lanes reports that protected bicycle lanes increase bike traffic by an average of 75% in its the first year.[30] The local new protected facilities on Barton Springs, Bluebonnet, and Rio Grande have experienced bike traffic increases of 58%, 46%, and 126% respectively.[31] Producing a spatial analysis that measures all factors of bikeability enables planners and policy makers to identify areas with the highest potential for investment.

Tight budgets and limited federal funding are bringing scrutiny to transportation spending, thus it is critical that strategic investments are made to improve bicycle transportation in Austin, TX. This analysis clarifies which areas of Austin have the highest potential for bikeability based off of five factors of the built environment. As the City of Austin begins to build out its all ages and abilities network, strategic investments should start in areas with high bikeability potential but low ridership. Areas with medium potential bikeability and low ridership should be targeted next. Both of these areas are prime for well-connected, higher quality bicycle facilities.

Unfortunately this strategy does not properly prioritize the concept of equity since it is based solely off of the current built environment alone. Demographics, income,

[30] Monsere, 2014.
[31] Anderson, 2014.

educational attainment, workforce data, population increases, and car ownership are not taken in regard, but would be advantageous factors to include if this study were to be improved in the future.

This analysis also calls into question the great debate of Ridership vs. Coverage. Cities today are faced with the decision of whether to focus on routes with high ridership or to serve low-density areas. Although this concept has typically been associated with transit, Jarrett Walker questions how cities can balance ridership goals with competing coverage goals. According to Walker, "'coverage' means to respond to every neighborhood's social-service needs and/ or sense of entitlement even if the result is predictably low-ridership."[32] Increasing investments in high service areas are financially and environmentally beneficial, yet they can reinforce the disparities between wealthy and poor neighborhoods. The Ridership Correlation to Potential Bikeability Map demonstrates that there must be a balance between ridership and coverage. All areas with high bikeability potential deserve facilities, yet it's the areas that also have low ridership that should be the recipients of higher quality, separated facilities. These areas have potential, but need stronger reinforcement to achieve higher levels of ridership.

Another important aspect of planning that is touched on, yet could be improved upon is Mobility vs. Accessibility. The land use methodology and factor map score land use areas based on an estimation of originating and destination trips generated per zoning code. What fails to be fully incorporated, is the relationship of one land use's proximity to another. As a hypothetical, all neighborhood office land uses are given a score of 6. Yet, if a residential land use is not within 3 miles, than the office is not as accessible by bicycle and should be given a lower score. A Jobs to Housing balance ratio could

[32] Brasuell, 2014.

complement the Land Use Factor map as it would show areas with great access and poor access to nearby businesses and services.

Although many of the policy recommendations are in strict regard to investments in bicycle facilities, education, and promotion, the City of Austin should continue to activate long-term Smart Growth and New Urbanist policies. Various land use factors such as density, regional accessibility, mix, and roadway connectivity have a serious impact on travel behavior.[33] As the City of Austin re-writes its land development code, it is critical that the new code proactively implements Imagine Austin and fortifies the realization of the plan, a compact and connected city consisting of complete neighborhoods that offer high accessibility to jobs and amenities.

[33] Litman, 2015.

Chapter Six: Conclusion

As Austin begins to invest in its all ages and abilities network, it is important for transportation planners and policy makers to fully understand how the current built environment affects bicycle commuting. Precedent studies have revealed that the presence of bicycle facilities, connectivity of the street network, land use types, topography, and physical barriers are key indicators of bikeability. By mapping each factor using spatial analysis in ArcGIS, this study reveals how competing factors of varying importance affect bikeability throughout Austin.

The Current Bikeability Map presents a raster analysis of areas most and least conducive to cycling in Austin. Currently, a bike shed of two miles exists around the Capital building. Although many central neighborhoods receive high scores, the highest areas of bikeability are exhibited downtown around Lady Bird Lake due to the hike and bike trail and the density of the network in that area. The grid-like street network, relatively flat terrain, and mixed land use types also contribute to the relatively high scores north of the lake. Unfortunately the windy roads, hilly terrain, and low-density land uses hinder South Austin's bikeability. Regardless, bikeability decreases dramatically as neighborhoods extend further from the city center.

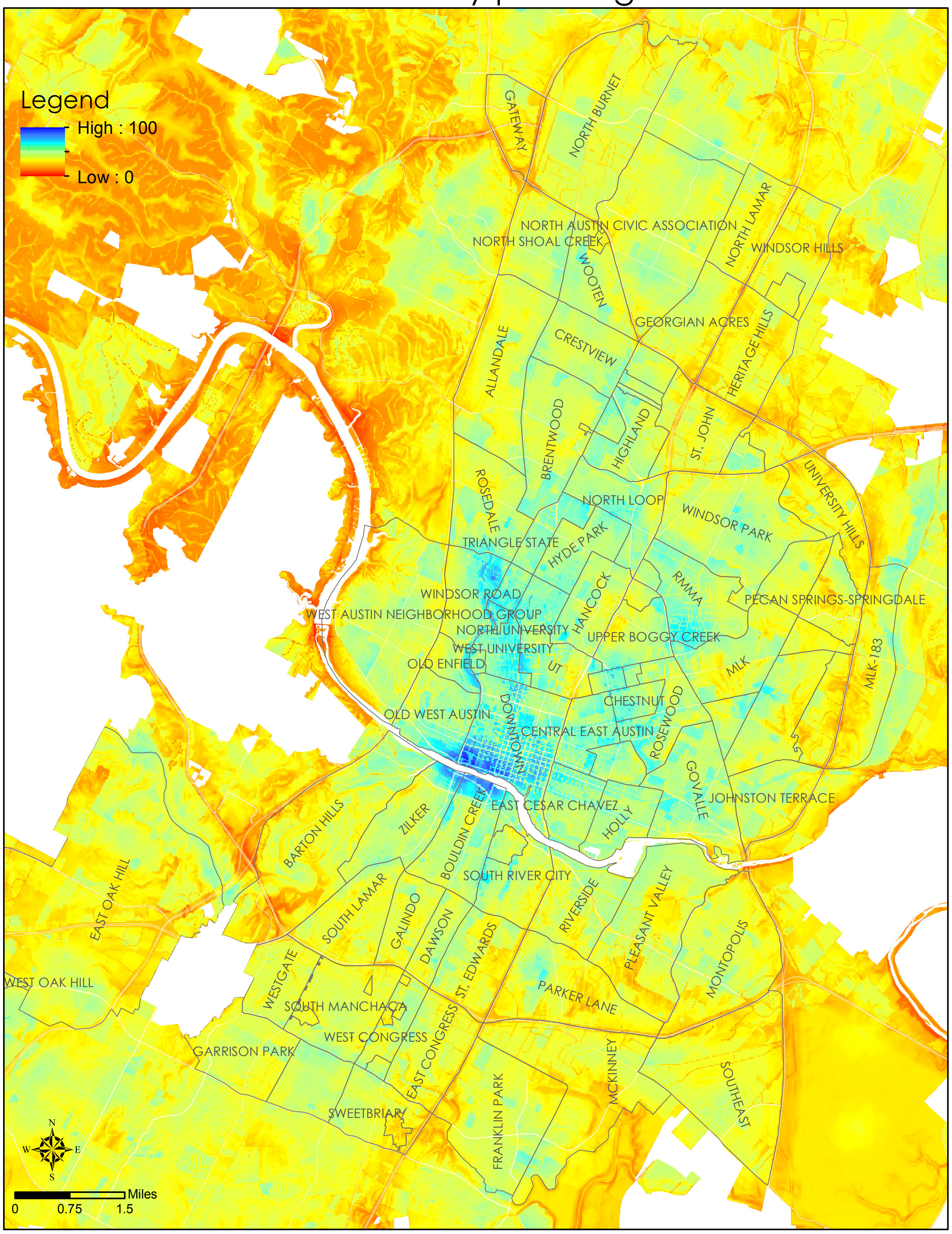
Adding the recommended bicycle facilities from the 2014 City of Austin Bicycle Master Plan exposes the potential bikeability that could be obtained by bicycle infrastructure investments. Implementation of the bicycle master plan has a substantial impact on the bike network as it not only expands bikeability, but also improves the granularity. The bikeshed flourishes from two miles to a four-mile radius and areas that received low scores in bikeability now receive moderate scores. The addition of new dense, high quality facilities enables the south to be more bikeable and the north to be extremely bikeable.

Immediate policy recommendations were informed by comparing potential bikeability to current ridership. Census tracts that have the highest bikeability, yet lowest ridership are prominent areas for future infrastructure investments. In addition to bicycle specific investments, this study reinforces the need for long-term land use policy changes. Austin's sprawling, low-density land use planning practices not only impede bikeability but have largely contributed to immense congestion. In order to reach its vision of becoming a compact and connected community that fosters different mobility choices, the City of Austin needs to re-write its land use code to be less restrictive and more embracing of higher density land uses.

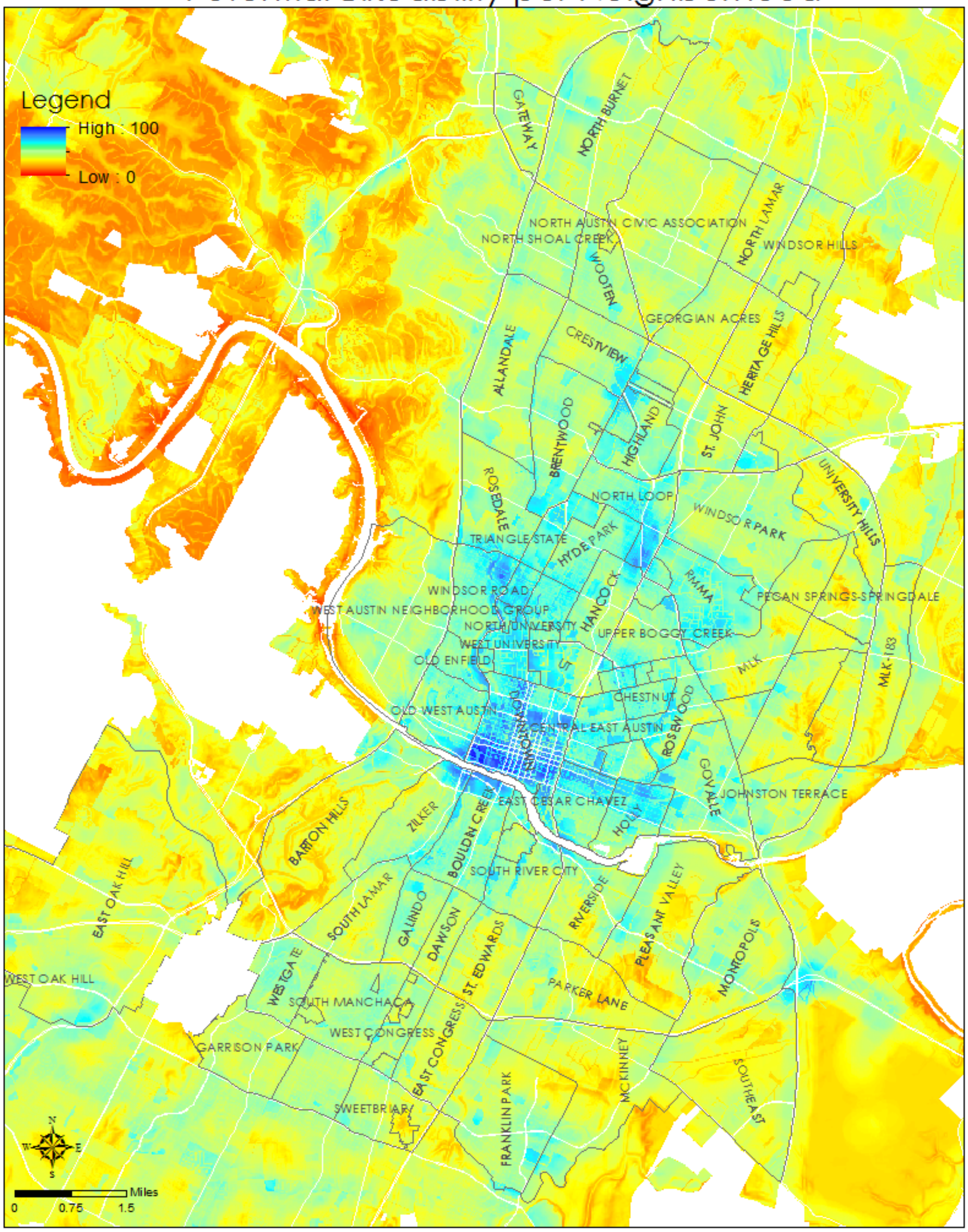
Bicycle transportation improvements are a cost-effective strategy to combat congestion within the City of Austin. An extremely innovative and forward thinking master plan has recently been passed to strengthen the current system and mobilize more bicycle trips. Now it is up to state and local officials to invest in the build out of the all ages and abilities network. Hopefully, this spatial analysis will guide planners to strategically target investments that optimize the impact on existing and future cyclists.

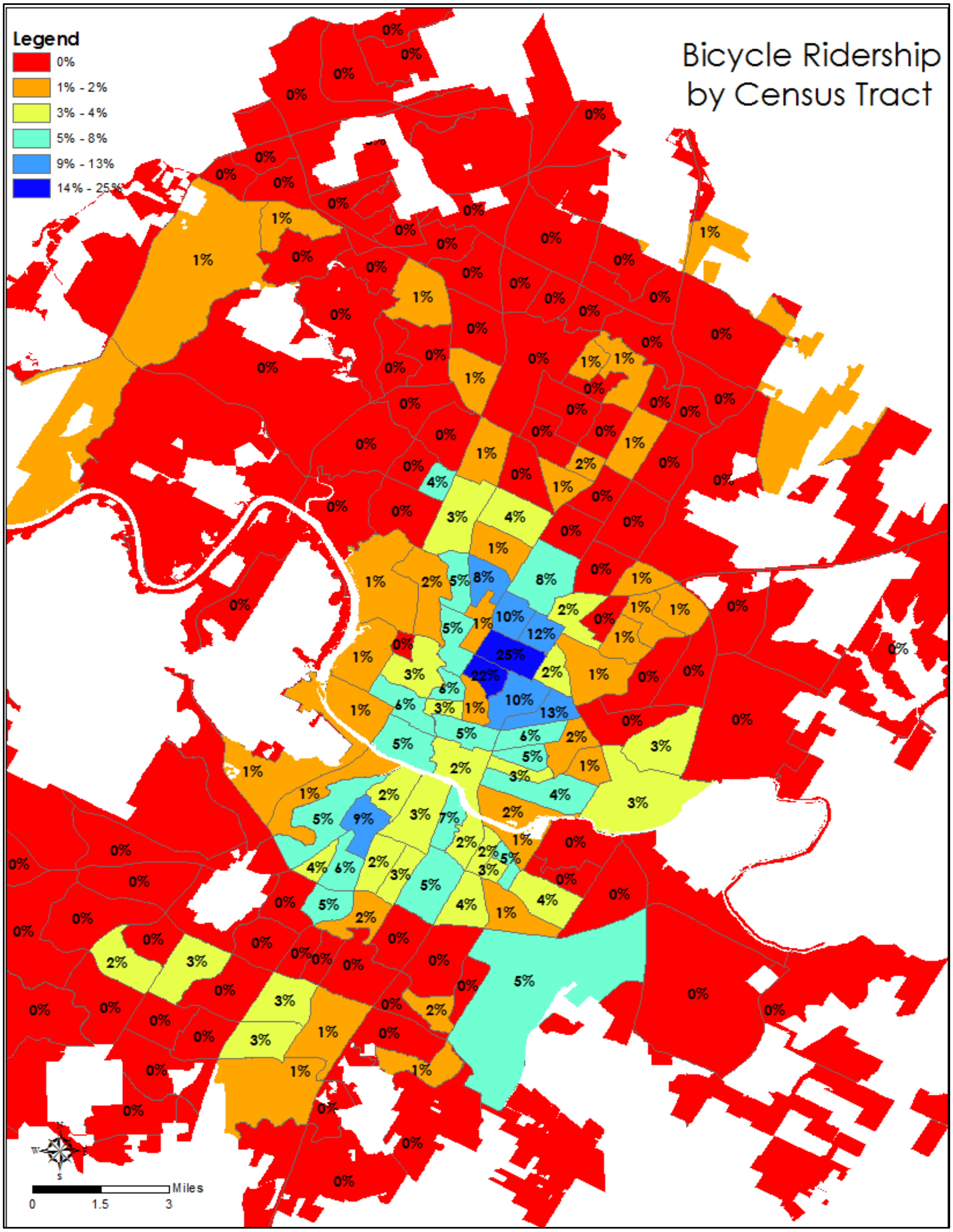
Appendix

Current Bikeability per Neighborhood



Potential Bikeability per Neighborhood




Bicycle Ridership
by Census Tract
Legend
0%
1% - 2%
3% - 4%
5% - 8%
9% - 13%
14% - 25%
Miles
0
1.5
3

Bibliography

Brasuell, James. *Great Debate: Transit Ridership vs. Transit Coverage*. Planetizen. http://www.planetizen.com/node/71454. 29 Sept 2014.

California Planning Roundtable. *Deconstructing Jobs-Housing Balance*. N.P, California Planning Roundtable, 2008.

Cervero, Robert and Michael Duncan. *Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing?* The Journal of American Planning Association, Autumn 2006, p475-490.

Cervero, Robert and Michael Duncan. *Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Areas*. American Journal of Public Health, Vol. 93, No. 9, 2003. P1478-1483.

City of Austin. *Chapter 2: Bicycle System*. 2014 Bicycle Master Plan Update. https://austintexas.gov/sites/default/files/files/Final_-_Ch._2_-_Bicycle_System.pdf

Dill, Jennifer and Theresa Carr. *Bicycle Commuting and Facilities in Major US Cities*. Transportation Research Record 1828, TRB, National Research Council, Washington, D.C. 2014. P 116-123.

Dill, Jennifer and John Gliebe *Understanding and Measuring Bicycling Behavior: A Focus on Travel Time and Route Choice*. Oregon Transportation Research and Education Consortium. 2008.

Dill, Jennifer and Kim Voros. *Factors Affecting Bicycle Demand: Initial Survey Findings from the Portland, Oregon Region*. Transportation Research Record: Journal of the Transportation Research Board, No. 2031, 2006. Pp. 9-17

Geller, Roger. *Cycle Zone Analysis (CZA): A New Bicycle Transportation Planning Tool. Developed for the Update of Portland's Bicycle Master Plan*. Presentation at Probike Prowalk, 2008.

Geller, Roger and Mia Birk. *Cycle Zone Analysis- Draft*. Emailed from Roger Geller. 2008.

Giuliano, G. *Is Jobs-Housing Balance a Transportation Issue?* Transportation Research Record, no. 1305, pp. 305-312. San Francisco: The University of California Transportation Center. 1991.

Handy, S., Xing, Y., Buehler, J. *Factors Associated with Bicycle Ownership and Use: A Study of Six Small U.S. Cities*. Transportation Springerlink. 2010.

Hartzell, Anne. *Minneapolis, Portland, and San Francisco Top Walk Score Ranking of Most Bikeable Cities*. Bike Score Launch Press Release. 14 May 2012.

Iseki, Hiroyuki and Matthew Tingstrom. *A New Approach for Bikshed Analysis with Consideration of Topography, Street Connectivity, and Energy Consumption*. Elsevier 48. 2014, p166-77.

Kockelman, KM. *Travel Behaviour as Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from San Francisco Bay Area*. Transportation Research Record: Journal of the Transportation Research Board, No. 1607, 1997. P116-125.

Litman, Todd. *Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior*. Victoria Transport Policy Institute. 17 April 2015.

McCormack, E., G.S. Rutherford, and M.G. Wilkinson. *Travel Impacts of Mixed Land Use Neighborhoods in Seattle, Washington*. Transportation Research Record, 2001. P 25-32.

Parast, Adam B. *Bikeability Analysis: Seattle and Portland*. *Seattle Transit Blog*. www.seattletransitblog.com/2010/04/20/portland-and-seattle-bicycle-analysis/ 20 April 2010.

Parsons Brinkerhoff Quade and Douglas, Inc. *The Pedestrian Environment*. Vol. 4A, Portland OR: 1000 Friends of Oregon. 1993.

Pucher, J., Dill, J., Handy, S. *Infrastructure, Programs, and Policies to Increase Bicycling*. Preventative Medicice, Volume 50, Supplement, January 2010. Pages S106-S125.

Reilly, M., Landis, J. *The Influence of Built Form and Land Use on Mode Choice: Evidence from the 1996 Bay Area Travel Survey*. University of California Transportation Research Center. Institute of Urban and Regional Development, University of California, Berkeley. IURD WP. 2002-4(1).

Winters, M., Brauer, M., Setton, E. Teschke, K. *Mapping Bikeability: A Spatial Tool to Support Sustainable Travel*. *Environment and Planning* B: Planning and Design 40 2013. P865-883.

Winters, M., Cooper, A. *What Makes a Neighbourhood Bikeable: Reporting on the Results of Focus Group Sessions*. Prepared for Translink. November 2008.