digitalconservancy
UNIVERSITY OF MINNESOTA

Deposit Agreement

I represent that I am the creator of the digital material identified herein (“Work”). I represent that the Work is original and that I either own all rights of copyright or have the right to deposit the copy in a digital archive such as the Conservancy. I represent that the regard to any non-original material included in the Work I have secured written permission of the copyright owner(s) for this use or believe this use to be allowed by low. I further represent that I have included all appropriate credits and attributions. I hereby grant to the Regents of the University of Minnesota (“University”), through its University Digital conservancy, a non-exclusive right to access, reproduce and distribute the Work, in whole or in part, for the purposes of security, preservation and perpetual access. I grant the University a limited non-exclusive right to make derivative works for the purpose of migrating the Work to other media or formats in order to preserve access to the Work. I do not transfer or intend to transfer any right of copyright or other intellectual property to the University.

Work(s) to be deposited:
Title: Hennepin County Enhanced Bicycle Network

Author’s Name*:

Quinn Carr — Print

Quinn Carr (signature) — Signature of Author or Authorized Representative

*(See back page for additional names and signatures if there is more than one author)

Name (please print): Quinn Carr
Address: 130 Humphrey School 301 19th Avenue South Minneapolis MN 55455 612-626-8910

Date: May 25, 2015

If the Deposit Agreement is executed by the Author’s Representative, the Representative shall separately execute the following representation.

I represent that I am authorized by the Author to execute this Deposit Agreement on behalf of the Author.

Quinn Carr (signature)
Author’s Representative Signature

digitalconservancy
UNIVERSITY OF MINNESOTA

Date: May 25, 2015

Additional Author's Name: Print and Signatures (s):

Tara Osendorf
Print | Signature

Kevin Karner
Print | Signature

Print | Signature

Print | Signature

Print | Signature

Hennepin County Enhanced Bicycle Network

Authors:
Quinn Carr, Tara Osendorf and Kevin Karner

Instructor:
Professor Greg Lindsey

Clients:
Jordan Kocak and Sierra Saunders from Hennepin County Department of Transportation

May 11, 2017

Table of Contents

Executive Summary

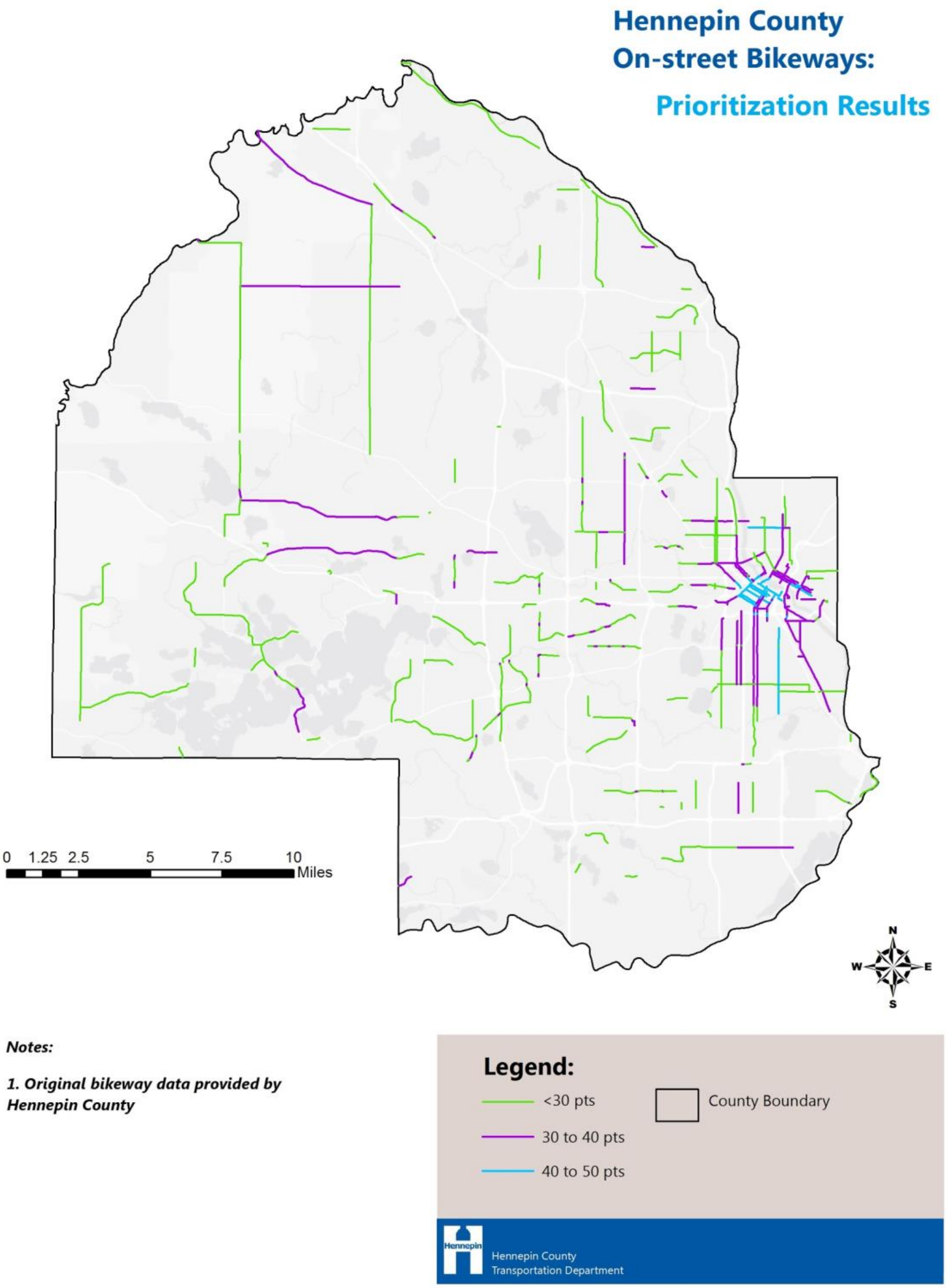
The purpose of this study is to augment the *Hennepin County 2040 Bicycle Transportation Plan* and will inform the next round of system planning in 2017 and beyond. This report provides a flexible process and recommendations for Hennepin County, Minnesota to prioritize facilities for an enhanced bicycle network based on physical, spatial, and social characteristics. In doing so, it identifies a two-step approach for prioritization that uses criteria scoring thresholds and weighting for quantifying and ranking on-street County bicycle facilities. The criteria offer emphasis on goals set out in Hennepin County's bike plan such as safety and comfort, increased ridership, and system connectivity and demand. To the greatest extent possible, the overall process and criteria that are used borrow from existing County plans, public and staff input, and academic research.

Protected bicycle facilities were the focus of this study. Protected bicycle facilities are usually at-grade facilities that are physically separated from traffic by flexible delineators, planters, parking, or other vertical barriers. They are considered comfortable and safe for riders that are interested in bicycling, but generally concerned about safety and comfort issues. These "interested but concerned" riders, as defined by researchers at Portland State University, make up approximately 53% of Hennepin County residents, as stated in their bike plan, and are the target population for future bikeway improvements.

The two-step approach to prioritization focuses its first step on a Level of Traffic Stress Analysis (LTS), and its second on a scoring system that focuses on connectivity and equity measures. The LTS Analysis, first developed by the Mineta Transportation Institute and modified for this study, used a 1 to 4 scoring system to assess elements such as speed, bike lane width, and traffic volumes. LTS 1 was seen as low stress, while LTS 4 was seen as a high stress roadway. The second phase used a variety of measures for connectivity/demand and equity such as distance from activity centers and bikeways, and demographic information addressing criteria including income, vehicle ownership, population of non-driving age and people of color. Once both phases of analysis and scoring were complete, projects were ranked and prioritized for readiness and need for protected bicycle facilities.

Results showed the top 20 bikeway corridors were all located within the downtown core of Minneapolis, which has the highest traffic volumes, highest connectivity, and highest equity concerns. Shown in Figure 1, out of the 257 miles of on-street bikeways examined for prioritization, 17.5 miles scored between 40 and 50 points (6.8%), 84.8 miles scored between 30 and 40 (33%) and 155.3 miles scored less than 30 points (60.4%). A few of the corridors, such as Washington Ave, already have existing plans or construction underway for a protected facility. Recommendations for the County were the inclusion of feasibility measures such as availability of right-of-way, maintenance needs, construction costs and schedules, and stakeholder/public support into the prioritization scoring step alongside connectivity/demand and equity. The flexibility of this approach was also emphasized with respect to changing criteria and thresholds to meet local needs and public input.

Figure 1: Protected Bikeway Prioritization Results



Introduction:

Bicycling benefits public health and safety, reduces transportation costs and fuel consumption, decreases traffic congestion, boosts the local consumer economy, and reduces environmental impacts. Hennepin County's overall vision is for a future where residents live in healthy, safe, self-reliant and mobile communities. In doing so, the county has made it a priority to develop and maintain a robust on- and off-street bike network. Since the 1997 county bike plan, emphasis on biking has been a core piece of transportation policy goals. To date, 55 percent of the original planned network has been completed (Hennepin County 2040 Bicycle Transportation Plan 2015). Recently, plans were updated through a collaboration between Hennepin County and Three Rivers Park District. A 16-month-long planning process of workshops, listening sessions, community events and online surveys resulted in the *Hennepin County 2040 Bicycle Transportation Plan*, published in 2016. The plan outlines several high-level goals and progress metrics centered around ridership increases, sustainability, maintenance, safety and system integration (Appendix 1). In addition, the County and Three Rivers Park District seek to quadruple the number of bike commuters and half the number of per capita bike crashes relative to 2010 levels, bring parity to gender balance of cyclists, add 20 miles of bikeways per year and ensure that at least 90 percent of homes in Hennepin County are within a half mile of an enhanced bike facility.

The purpose of this plan is to augment the *Hennepin County 2040 Bicycle Transportation Plan* that will inform the next rounds of system planning in 2017 and beyond. This plan focuses on identifying a methodology for prioritizing projects that meet the criteria set out by the plan's goals, with particular emphasis on expanding ridership opportunity to more residents of the county, connection with existing routes, and especially increased safety and comfort riding on county infrastructure. This work attempts to make connection to the bike corridor prioritization considerations that were utilized in the *Hennepin County 2040 Bicycle Transportation Plan*, while expanding to new methodological territory.

Existing and Planned Bicycle Network:

The current Hennepin County bikeway system includes a total of 651 miles. Of the network, 394 miles are off-street and 257 miles are on-street facilities. The bike plan identifies 540 miles of new bikeways to add by 2040, including an additional 302 miles of on-street facilities and 238 miles of off-street facilities. Routes were chosen according to their continuity, access to major destinations, network density, overlap with right-of-way managed by the county or park system, as well as concurrence with the Metropolitan Council's Twin Cities Regional Bicycle System Study. The network also includes existing and planned bikeways on roadways that are owned and operated by municipalities and by the Minneapolis Park and Recreation Board. The current on-street network consists of several kinds of designs, both protected and unprotected. On-street facilities include the following (Appendix 2):

- Bicycle boulevards primarily for use on low-volume, low-speed roads. Boulevards are intended to improve safety and comfort to less confident cyclists.
- Paved shoulders for use in more suburban and rural regions with lower volume. While minimal, they can offer a flexible alternative in cases where lanes or trails are not feasible.
- Bike lanes for low-cost improvements when there is right-of-way on an existing roadway. Bike lanes create a dedicated space for bicycling alongside motor vehicle traffic.
- Buffered bike lanes for instances where there is room to upgrade a traditional bike lane with additional striping or buffer space, and there is a concern for blockage of the lane. This application is most appropriate on urban/suburban streets with moderate motor vehicle volumes.

A key part of achieving these goals involves planning and prioritizing an enhanced bicycle network of high comfort, protected bikeways catered towards the largest group of potential users. The engagement process in the 2040 plan yielded a clear preference for bike facilities that were physically separated from traffic. The 2040 identifies these types of protected facilities (Appendix 3, pictures are from the 2040 plan):

- Protected bike lanes: Protected bike lanes are usually at-grade facilities that are protected from vehicular traffic by vertical barriers such as planters, bollards, parking spaces, or medians. They can be either one-way or two-way on either side of the road and provide greater comfort than a painted bicycle lane or painted buffer.

- Cycle tracks: These are usually curb-separated, but adjacent to motor vehicle travel. They sometimes provide additional separation in the form of a boulevard or plants and oftentimes are a different color or material than roadway facilities. They include infrastructure improvements such as specialized traffic signaling or right-of-way for cyclists that increases comfort and convenience.

- Paved multi-use trails: These tend to provide the highest degree of separation from motor-vehicle traffic. High-volume trails provide clear lane of movement for both pedestrians and other non-motorized modes alike. Multi-use trails can be adjacent to roadways or completely separate, with a high level of comfort and safety for users. Trails may include designated lanes for certain modes or additional directional signage where higher user volumes exist. Hennepin County currently has a robust network of off-street and roadway-adjacent multi-use trails which provide designated spaces separate from cars with minimal intersections.

Literature Review:

Several studies have been conducted regarding protected bike lanes within the United States as well as internationally, which have helped inform this research. Existing research has focused on the implementation of protected bike lanes within the larger bicycle network, as well as how they interact with motorized traffic. Primary insights gained from these studies to help guide this prioritization process include a designation of types of cyclists by riding comfort levels and experience, benefits gained from implementing protected bike lane infrastructure, as well as reviews of past planning processes to see if a level of stress analysis or other key methods were used to determine if protected bikeways were necessary.

Cyclist Types

The *Hennepin County 2040 Bicycle Transportation Plan* makes reference to a commonly cited biker typology developed in Portland, Oregon. In 2006, bike coordinator Roger Geller released a paper that attempted to assign cyclist categorizations on a population-wide level. This built upon and advanced a previously used typology used by the Federal Highway Administration, which set design standards around categories of current cyclists, using an ABC system tied to rider skill level—A for advanced bicyclists, B for basic bicyclists, and C for children. This system was fairly general in its design guidelines and was also limited by the focus on existing riders and not the entire segment of the population taking some form of transportation. Again based on an individual's level of comfort with different kinds of bike facilities, Geller developed four categories, ranging from "no way no how," who are either unable or uninterested in biking to cyclists who are considered "strong and fearless," and are undeterred by the majority of roadway, weather, and infrastructure conditions. Geller estimated the proportion of cyclists in Portland as follows:

- **No way no how (33%):** Not interested in cycling as a form of transportation.
- **Interested but concerned (60%)**: Little tolerance for traffic stress with major concerns for safety. Prefer separate from traffic on arterials with protected bike lanes, trails and bike lanes.
- **Enthused and confident (7%)**: Some tolerance for traffic stress. Confidence riders who prefer separation on arterials with protected bike lanes, trails or bike lanes.
- **Strong and fearless (1%)**: High tolerance for traffic stress. Experienced riders who are comfortable sharing lanes on higher speed and volume arterials. Less interested in protected bike lanes and trails.

In a telephone survey conducted in cooperation with the Oregon Transportation Research and Education Consortium, researchers in Portland surveyed a large segment of residents about their comfort level riding on various kinds of streets, both with and without bike facilities. Jennifer Dill and Nathan's report, *Four Types of Cyclists? Examining a Typology to Better Understand Bicycling Behavior and Potential,* closely corroborated Geller's estimates of the proportion of the general population in each group (Dill et al 2012).

The largest group and the majority of riders are a part of the "interested but concerned" group who ride irregularly and selectively, often recreationally, and with varying degrees of experience. This large group prefers off-street paths or protected bikeways that make them feel safe and separate from vehicular traffic. Bike infrastructure that improves their experience will help build confidence and ultimately encourage them to bike more regularly. Non-protected, on-street bicycle facilities by comparison primarily serve the 8% that represent the most experienced two tiers of riders. It stands to reason that a strategy aimed at increasing ridership should focus on engaging these "interested but concerned riders" with facilities that emphasis greater separation from vehicle traffic, either by way of protected on-street facilities or addition of separated trails.

Main Benefits of Protected Bike Lanes

Incorporating protected bike lanes into the larger bike infrastructure of different regions has been shown to create several benefits. One of the main benefits consistently found includes the increased level of rider comfort and safety, particularly user's perception of feeling safe and comfortable using these types of bike lanes. One study incorporating various U.S. cities have demonstrated that without protected bike lanes there are more negotiations required between bicyclists and drivers to adjust what parts of the road they occupy (Bergenthal et al. 2011). These facilities can involve higher mental effort coupled with stresses of being hit by moving or parked cars for bicyclists (Bergenthal et al. 2011). Given this potentially unsafe environment for bicyclists and motorized traffic, several studies have attempted to evaluate perceptions of safety on different types of bike facilities. An online survey conducted in San Francisco, CA showed that perceived threats to safety were significant barriers to bicycling at all experience levels (Sanders 2013). A similar study by Nicolas Foster in Portland, OR used a telephone survey that categorized respondents as different types of bicyclists depending on self-reported experience, levels of comfort in different riding situations and general attitudes towards biking. The Oregon study observed that at least half of all respondents (except the most advanced bicyclists) were at least somewhat concerned about being hit by a motorized vehicle, and these results found approximately 84% of respondents identified as the "Interested but Concerned" group (Foster 2014). Other communities' findings have important implications for Hennepin County's prioritization process of creating protected bike lanes since the largest proportion of County residents (53%) have been found to be in a similar category of "interested but concerned" cyclists, allowing for protected bike lanes to incentivize people to cycle more frequently (Hennepin County 2015). A different study that surveyed bicyclists at specific sites in Austin, TX, Chicago, IL, Portland, OR, San Francisco, CA, and Washington, DC also found that protected bike lanes with more physical separation had the highest levels of perceived comfort (Clifton et al. 2014). Respondents who were surveyed frequently explained that bike lanes were safer after protected elements were added (Clifton et al. 2014). The increased perception of safety and comfort on protected bike lanes has been demonstrated in several different instances, indicating this type of bike infrastructure can help address concerns from Hennepin County residents regarding ridership safety. Protected bike lanes are also allowing for a growing number of riders to be more inclined to at least occasionally bike, increasing rates of bike usage.

Increased rates of bike usage are an additional advantage to installing protected bike lanes. In the multi-city study cited above, it was found that after one year of installing protected bike paths there was a 21 to 171 percent increase in ridership that included new riders as well as riders changing routes to use these specific facilities (Clifton et al. 2014). These are initially promising results from installing more protected bike lanes. Past studies have also found similar trends of increased bike usage. In one study comparing 90 of the largest U.S. cities, a regression analysis found that a 10% higher cyclist fatality rate corresponded to 3.7% fewer bike commuters while a 10% greater supply of bike lanes was associated with a 3.1% greater number of bike commuters per 10,000 people (Buehler Pucher 2011). There appears to be a strong relationship with increased bike ridership and expanded bike infrastructure while cities with higher cyclist fatality rates are experiencing lower levels of bike usage.

In sum, there is a strong argument that protected bike lanes are increasing the perception of comfort and safety for riders while there are higher ridership rates being witnessed after installation of these facilities. The existing literature generally emphasizes having comprehensive bike networks that incorporate other types of bike facilities, and several factors are evaluated to determine the best type of bike facilities for a given area. The next section will explore in more depth what criteria are commonly used to determine where protected bike lanes are appropriate to use. This will help justifying the methods this study uses to prioritize protected bike lanes corridors in Hennepin County.

Local Agency Efforts on Protected Bike Lanes

Bike and pedestrian plans from Hennepin County, as well as other local agency initiatives involving multi-modal transportation and protected bike lane infrastructure, were the foremost resources in understanding assessment and prioritization frameworks in the study. The *Hennepin County 2040 Bicycle Transportation Plan* suggests several considerations to identify priority routes for bicycle facilities, drawing from peer cities and local agencies to identify indicator variables within five broad categories (Table 1). The plan appendix also offers specific datasets to draw from and a recommended scoring system.

Table 1: Bikeway Corridor Prioritization Criteria, Factors and Elements				
Prioritization Criteria				
Network Connectivity	**Overcoming Barriers**	**Demand**	**Comfort and Safety**	**Other**
• Future population density • Access to jobs • Regional trail connections • Regional bikeway network	• Reported barriers to bicycling per mile • Presence of bikeway system gaps	• Reported bicycle destinations per mile • Requested trip unique origin or destination • Zero car households	• Bicycle crashes per mile • Bicycle crash injuries per mile • Bicycle crash fatalities per mile	• Opportunities with other agencies, new funding • Whether a segment was included in a previous plan • Other undocumented safety issues

In addition to items in Table 1, the plan recommended primary criteria to prioritize protected bike lanes including network connectivity existing Hennepin County and Three Rivers facilities, major activity and transportation centers, and other corridors identified by the Metropolitan Council and cities within the county. The plan also recommends factoring in the ability of a segment to overcome existing gaps, among other potential considerations (Hennepin County 2015). Prioritizing the enhanced bikeways in Hennepin County will require emphasizing some of these considerations from the plan more than others while drawing additional factors from the literature review of past studies.

Additionally, the City of Minneapolis compiled detailed information in their *Protected Bikeway Update to the Minneapolis Bicycle Master Plan* about one process of prioritizing and assessing the need for protected bike lanes. The plan from Minneapolis, which included public survey input gathered over the course of a year, balanced public opinion with data-informed solutions. First, planning staff looked at the spatial distribution of existing and future demand. In doing so, they examined annual average daily traffic (AADT) volumes, land use plans, and defined activity centers/locations generating bicycle traffic. They also established the need for greater separation from motor vehicle traffic, which was determined by AADT, bicycle/motorist crashes, and the location of continuous through-lanes. Finally, they determined the connectivity of the existing and planned bicycle network for the determination of critical gaps and identification of pre-existing protected links.

Table 2: Protected Bikeway Update to Minneapolis Bicycle Master Plan		
Level of Stress Analysis	**Prioritization Criteria**	
Stress Criteria	**Connectivity/Demand Criteria**	**Equity Criteria**
• Average Annual Daily Traffic (AADT) • Speed limit • Bike Crashes • Bike lane width/Parking lane width • Thru lanes	• Proximity to bike facilities • Proximity to transit facilities • Proximity to activity centers • Nearby population density • Estimated daily bike use • Intersection with major barriers	• Income levels • Households without a vehicle • Population of persons of color • Persons of non-driving age (<16 or >65)

In this analysis, they also included low-stress roadways. As secondary criteria, the city considered matters of spatial equity and other contextual factors. While this methodology was not without limitations when it came to actual implementation, it provides a framework for understanding the use of existing data and acknowledging how local officials have taken first steps towards the process of enhanced bicycle network prioritization.

The Ramsey County and the City of Eden Prairie bicycle and pedestrian plans highlight protected bike lanes as one type of bike infrastructure existing in their network of bike paths. While factors around comfort and safety are core components of the prioritization methodologies with the Metropolitan Council, Hennepin County and Minneapolis, these plans are distinctive in their explicit reference to a new system used for understanding the rider experience. Both cite Level of Traffic Stress (LTS) Analysis as an approach to understand the relative need for certain kinds of bicycle facilities, scoring their on and off-street network according to the stress tolerance for their user population. They note this analysis is deemed particularly important since protected bike lanes have a direct impact on bike safety and perceived levels of comfort by riders. Both used modified versions, with Eden Prairie going so far as to develop a parallel system to understand the stress level of their trail system, which makes up the majority of their network (City of Eden Prairie Pedestrian and Bicycle Plan, 2014).

Level of Stress Analysis

Level of Traffic Stress (LTS) Analysis is a recently-developed methodology that understands bicycle networks as the routes between origins and destinations that a rider could take that do not involve sections that exceed their tolerance for traffic stress or their perception of safety from vehicular traffic. This highly influential study was performed by Mekuria, Furth and Nixon (2012) at the Mineta Transportation Institute, in part based on biker typology identified in Portland. In LTS analysis, roadways, trails, and other bicycle infrastructure are rated on a scale from 1 to 4 based on inputs that approximate how riders experience their environment. Level of traffic stress 1 (LTS1), for example, is meant to be a level that most children could safely tolerate. LTS2 is acceptable for "interested but concerned" adults, LTS3 is for the "enthused and confident" segment of the population while LTS4 is a level of stress usually only tolerated by "strong and fearless" riders.

Table 2: Mineta Characteristics of Traffic Stress Brackets

Level of Stress	Comfort Level	Bike Facility Types	Description of Comfort
LTS1	High comfort	Standalone paths, segregated paths or low stress local roads	Comfortable for most children.
LTS2	Medium comfort	Bike sharrows and lanes	Comfortable for mainstream adult population – generally considered to be 60% of the U.S. population who are interested in bicycling but only comfortable, generally, on off-street bikeways or quiet residential streets.
LTS3	Low comfort	Bike sharrows and lanes	Comfortable for "enthusiastic and confident" adult bicyclists generally considered to be 6% of the population and who prefer dedicated bicycling space.
LTS4	Very low comfort	Mixed traffic	Comfortable for only "strong and fearless" adult bicyclists generally considered to be ≤1% of the population and who will generally bicycle regardless of the facility type.

The scoring process employs a "weakest link" logic to determine the score of a segment of on-street bike facilities. Scoring is based around a number of variables, such as how many non-turn traffic lanes are on the road, what the width of the lane or shoulder is, how high the posted speed limit is and at what frequency is the bike lane blocked. The weakest link logic creates a fairly conservative system where a given segment is judged by its most stressful segments, not the average or cumulative total them, noting that “several low-stress links cannot compensate for one high-stress link” if that link will ultimately prove to be the deterrent to use that route.

Table 3: Mineta Criteria for On-Street Facilities

Level of Stress	LTS > 1	LTS > 2	LTS > 3	LTS > 4
Through lanes	1	-	2+	-
Bike lane width	6 ft	5.5 feet or less	-	-
Lane width (parking + bike)	15 ft or more	14 to 14.5 ft	13.5 ft or less	-
Speed limit (with parking)	25 mph	30 mph	35 mph	40 mph+
Speed limit (without parking)	30 mph	-	35 mph	40 mph+
Bike lane blockage	rare	-	frequent	-

The Mineta Transportation Institute level of stress analysis provided an important starting point, but further refinements have been made to this work based on more recent research. In particular, recent literature has cited the importance of also incorporating traffic volumes, bike crash data, and measures of network connectivity (Pacific Northwest Transportation Consortium 2015). Additional methods have been used in Milwaukee, WI and Moscow, ID that may actually predict level of stress more accurately than the method created by the Mineta Transportation Institute; however, these methods are found to be less understandable to bikers, local officials, and general stakeholders while there are data limitations used in these models for many small to medium sized jurisdictions (Vogt 2015).

Methods:

The method of analysis proposed in this report makes an effort to adopt the core elements of the Mineta Transportation Institute’s work while incorporating additional considerations into a scorecard that tie into previous local work on corridor prioritization. This process of using LTS to filter out segments for prioritization by other variables should provide a comprehensive framework that places a premium on rider safety and comfortability, while taking into account system level goals of connectivity and proximity, equity. This process is by no means definitive and is constrained by resources and data quality. As such, this process leaves room for additional ground level analysis that takes into account project-by-project feasibility and community input.

The prioritization consisted of a two-step scoring process of pre-split bikeway segments from Hennepin County bikeway data. The first step involved a pre-assessment step determining the physical need for protected facilities throughout Hennepin County bikeway corridors. To do so, a modified Level of Traffic Stress (LTS) analysis was performed in order to determine the segments of existing on-street facilities that may be underutilized because of traffic conditions, therefore could be improved with addition of further separation. After identifying LTS values for on-street segments, these segments were scored according to the characteristics of each segment and its surroundings. This prioritization included metrics related to equity, network connectivity and demand. Incorporating these other measures helped to take bikeway segments with physical and safety needs and provide a method to acknowledge the actual importance of projects within different corridors.

Similar to the Mineta LTS analysis discussed in the literature review, a list of criteria was determined for classification of traffic stress 1 to 4, with 4 considered the most stressful, and the most in need of additional protection from traffic for cyclists. Consistent with LTS methodology, all off-street and protected on-street networks were automatically applied a less stressful score of one. All other on-street facilities were evaluated according to the following physical characteristics: Average Annual Daily Traffic (AADT), speed limit, bike lane and parking lane width, and the number of through lanes. In doing so, the LTS method outlined by Mekuria, Furth and Nixon (2012) was modified to include traffic volume (AADT) and bicycle accidents, which some criticisms of LTS methodology have pointed out were missing in past work (Wang, Vogt and Palm 2015). Due to data limitations, this modified LTS system drops several scoring components of the original paper, mainly related to intersection design: the length of turn-lane approaches and the presence of crossing islands. Due to the questionable reliability of the parcel dataset that contained land uses, bike lane blockage was also dropped. LTS scoring criteria were defined and assessed as follows (Table 5):

Table 5: Level of Stress (LTS) Scoring Thresholds						
Level of Stress Score	**AADT**	**Speed Limit**	**Sum of Bike Lane and Parking Lane (w parking)**	**Bike Lane Lane Width (w/o parking)**	**Bike Crashes**	**Thru Lanes**
1	Under 3,000	25 mph or less	15 ft. or more	6 ft. +	0 to 10	1
2	3,000 to 9,000	30 pmh	14 or 14.5 ft.	5.5 ft. or less	11 to 30	-
3	9,000 to 15,000	35 mph	13.5 ft. or less	-	31 to 75	2 or more
4	Over 15,000	40+ mph	-	-	76 to 185	-

AADT: Annual average daily vehicle traffic for roadways was available through the Minnesota Department of Transportation. Based on prior LTS implementation studies, speeds were assigned categories from relatively unsafe, high volume roadways to relatively safe, low volume roadways, and given a respective score. Breaks were based on the design criteria for on-street bike facilities in the *Hennepin County 2040 Bicycle Transportation Plan* (Appendix 2) and modified to fit the needs of this study. Through a series of automated and manual joins, this data was imported into the bicycle network dataset provided by Hennepin County.

Speed limit: Posted speed limit values were present in the bikeway dataset provided by Hennepin County. Speed values were broken into four tiers based on the limits established in other LTS analyses. Roadways with posted speed limits above 40 miles per hour received a score of four while low speed sections under 20 miles per hour received a low score of one.

Bike lane/parking width: Borrowing directly from the LTS methodology identified by the Mineta Institute, scoring for this criteria depended on whether or not the roadway has on-street parking or not. In the event that there was on-street parking, the width of the bike and parking lane were added together and assigned a value according to other LTS analyses. If there was no parking, just the bike lane was measured and scored. In either case, more room in either case yielded a lower LTS score. In support of this measure, bike lane width was previously included in the bikeway data model provided by Hennepin County, along with whether or not parking existed on a given segment. Parking lane width was able to be estimated based on county street design guidelines, which vary between seven and ten feet according to estimated traffic volume.

Bike crashes: As discussed, previous LTS analyses excluded the presence of cycling crashes, which are perhaps a more direct measure of riding safety than any roadway design factor. Bike crash data has historically been maintained by the Minnesota Department of Transportation and the Department of Public Safety. In this analysis, coordinate locations for reported over the past decade were collected, mapped, joined to Census Tract boundaries and split into groups based on the segmentation method Jenks Natural Breaks. Breaks were assigned values with more crashes yielding a higher score.

Through lanes: By virtue of being less confined, streets with multiple lanes are generally considered more turbulent than those with single lanes, encouraging higher speeds and more unpredictable movement from vehicles. Roadways with multiple lanes also create a potential conflict when cyclists, on the right hand, attempt to make left hand turns. Here, this is approximated by the number of non-turn lanes on a given road where roadways with more than two "through lanes" are given an LTS3 with anything lower given an LTS1. While through lanes are not recorded directly by the county, the number of segments with only one through lane were small enough to be "ground truthed" with programs like Google Maps.

Once these components were given scores, the "weakest link" logic consistent with other applications of LTS, was used to determine the overall score for that particular segment. Using weakest link logic takes a conservative approach to scoring. Given the large emphasis on safety and comfort in enticing riders, this method provided the broadest base of corridors to be further prioritized, rather than taking an average value. An averaging system was tested and compared as an alternative and, by comparison, only yielded nine segments at LTS3 and none as LTS4. After this analysis, every on-street bikeway segment was left with a score between 1 and 4. Segments with a 1 or 2 were assumed relatively "low stress" and were assigned a multiplier or 0.75. Meanwhile, "high stress" LTS 3 and 4 segments were given multipliers of 1 and 1.25 respectively, which would later be applied to (secondary) prioritization scores.

The focus in the secondary scoring phase was not on safety, but rather on social benefits and community demand and needs, as well as integration with the existing system. Criteria were established by factors previously used by the City of Minneapolis and Hennepin County in past prioritization efforts, as well as criteria established in past studies and measures discussed in focus groups with Hennepin County staff. For the purpose of consistency, these measures were also individually given a score between 1 and 4, similar to the LTS analysis, and often were split into "yes" and "no" categories and given a 1 for a lower priority score or a 3 to give a higher priority because of certain characteristics.

Descriptions of secondary prioritization criteria are in Table 6. Based on background research, conversations with County staff, and an assessment of data availability, secondary scoring criteria was formed and categorized into three general groups: connectivity and demand, equity, and feasibility. Only the first two groups were scored, while feasibility was intended to be left open to case-by-case analysis, taking into account such factors as presence of right-of-way, environmental barriers, cost considerations, or maintenance requirements in the future. This is an important acknowledgement that will heed the success of the implementation of future projects. Connectivity and demand criteria consist of nearby population density, estimated daily bike use, proximity to activity centers such as job centers, schools and parks, proximity to existing bike coverage and regional trails, alignment with the Regional Bicycle Transportation Network (RBTN), intersections with major barriers and proximity to transit. Equity measures include aspects of income, age, persons of color, and vehicle ownership. High stress and high need create high priority.

Table 6: Connectivity and Demand Scoring				
Score	1	2	3	4
Nearby Population Density (per/mi2)	< 5,000	5,000 - 10,000	10,000 - 15,000	> 15,000
Estimated Daily Bike Use	< 35	35 - 95	95 - 195	> 195
Intersection with Job Centers	No	-	Yes	-
Proximity to Schools (mi)	> 0.25	-	< 0.25	-
Intersection with Parks	No	-	Yes	-
Proximity to Existing Bike Coverage (mi)	> 1	-	< 1	-
Intersection with Met Council RBTN	No intersection	Intersection any RBTN	Along Tier 2 Corridor	Along Tier 1 Corridor
Proximity to Planned/Existing Regional Trail (mi)	> 0.25	-	< 0.25	-
Intersection with Major Barrier	No	-	Yes	-
Proximity to Transit Stops (mi)	> 0.25	-	< 0.25	-

Population density: The most intuitive metric for demand is likely how many people live in a given unit through which a bike facility passes. These data were collected from the 2015 American Community Survey (ACS), mapped 4 groupings, and scored accordingly. In this case, low scores would go to sparsely populated areas at the county fringe.

Estimated daily bike use: The City of Minneapolis, Hennepin County and Three Rivers Park District participate in annual bike counts across sections of their facilities. These counts take place at specific bikeway cross-sections. Since many bikeway facilities haven't been counted, existing count locations were extrapolated. Using the inverse-distance weighting function, counts from 2014 and 2015 can be predicted and smoothed across the county to come up with estimated daily use. These estimates were then assessed for expected general trends. A crude approximation, the extrapolation yielded expected results.

Proximity to activity centers: To estimate traffic demand, bikeway segments were scored according to whether they pass by or through one of several different kinds of activity centers. Activity centers were defined as job centers, schools and parks. If a segment passes through a job center or park, they received a higher score, if not then it received a lower score. If an on-street segment is within ¼ of a mile from a school, it received a high score. For consistency with other kinds of binary measures in the scorecard, high scoring segments would be considered a 3, and low scores a 1. Thresholds for the three proximity categories are shown in Table 6.

Proximity or alignment with bike facilities: Three separate measures were used to weight proximity to bikeways. First, proximity to existing bike coverage addresses intersections with "low stress" level 1 or 2 LTS bikeways. This is important in addressing safe connections and tries to respond to the Hennepin County Bike Plan's goal of supplying enhanced bike facilities within a mile of 90% of households. In this scoring process, existing LTS 1 facilities were given a one mile buffer. If a potential protected bikeway fell within a gap area, it was given a higher prioritization score. Another scoring measure looked at a segments intersection or alignment corridors identified by the Metropolitan Council's Regional Bicycle Transportation Network, with higher scores given to segments that aligned with a Tier 1 and Tier 2 corridors. The last bikeway measure looked at proximity to planned or existing regional trails compiled in a state-maintained dataset. Since regional trails are generally off-street, low-stress facilities, these are important connections and are known to be well-used and to generate regional bike demand. Intersection with a planned or existing trail yielded a higher value than if there was no contact.

Intersection with a major barrier: Major barriers, for the purpose of this scoring criteria, were determined to be all principal arterial roadways. Following the themes of comfort, safety, and connectivity, this measure helped to identify obvious gaps and obstacles and assigned a higher score to those bikeways with any sort of major barrier and a lower score for those without a major barrier, as those would be less likely to need a more protected facility.

Proximity to transit stops: Using data provided from the Metropolitan Council and Metro Transit, a 0.25 mile buffer was applied to all transit stops within Hennepin County. Transit connections improve the overall connectivity of the local and regional bike network and allow for trips without a personal vehicle to be longer and more comfortable for users who may otherwise be unwilling to get to certain destinations.

Transit connectivity increases mobility, and was therefore given a "yes" value of 3 if a bikeway was within the 0.25 mile buffer of a transit stop, and a "no" value of 1 if it were located outside of that buffer.

All demographic data used to determine equity measures was collected from the 2015 American Community Survey (ACS) and mapped in GIS by census tract geography. Maps illustrating these relationships can be found in Appendix 6. Bikeway layers were overlaid and each average equity variable was spatially joined to bikeway segments. Analysis was completed in a spreadsheet and joined to spatial data. Scores were joined with bikeways for each criteria based on the following thresholds.

Table 7: Equity Considerations

Score	Individual Mean Income	Population of Non-Driving Age (<16 or >65)	Population Persons of Color	Households without a Vehicle
1	> $80,000	< 15%	< 10%	< 10%
2	$40,000 - $80,000	15 - 30%	10 - 30%	10 - 30%
3	$20,000 - $40,000	30 - 45%	30 - 50%	30 - 60%
4	< $20,000	< 45%	> 50%	> 60%

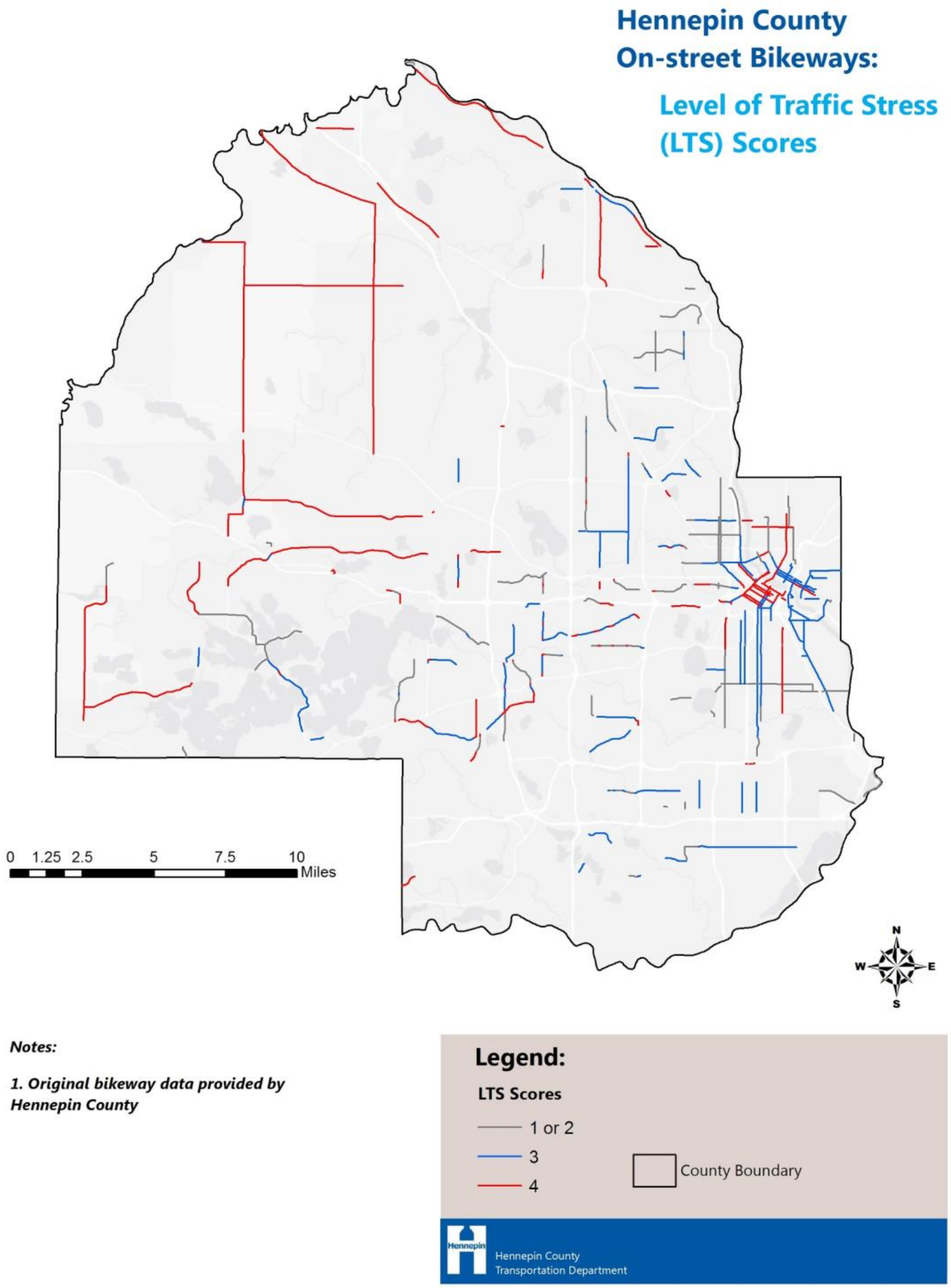
Once all secondary criteria were given a score 1 to 4, all scores were summed and the result was multiplied by the value assigned to that segment's LTS score. Once results were available, the team assessed smaller segments and identified longer, more complete corridors with multiple high scoring segments. Final scores saw a high of 50 points, and priority was addressed on 10-point intervals, with 40 to 50 points considered top priority bikeway corridors, 30 to 40 points seen as second priority, and anything less than 30 points to be considered "not a priority for protected bikeway construction or updates" during the present time.

Results

Results are presented here in two sections, echoing the analysis. The first round of analysis resulted in a map of areas in need of physical safety improvements based on the calculated LTS of each bikeway segment. The second round focused on scoring social and demand characteristics and prioritization of future project locations, and combined with results and multipliers from the first phase, final priority corridors for enhanced bikeways were determined.

As shown in Figure 1, the LTS analysis yielded expected results with the highest stress, LTS4 corridors found in downtown Minneapolis where there are high traffic volumes and the largest number of bike crashes and the outer fringes of the county where speeds are high, and bike facilities are less likely to be present. Other high stress LTS3 corridors were scattered mostly throughout first ring suburban communities. A map of the results of this section are found below (Figure 1).

Figure 1: Hennepin County LTS Scores



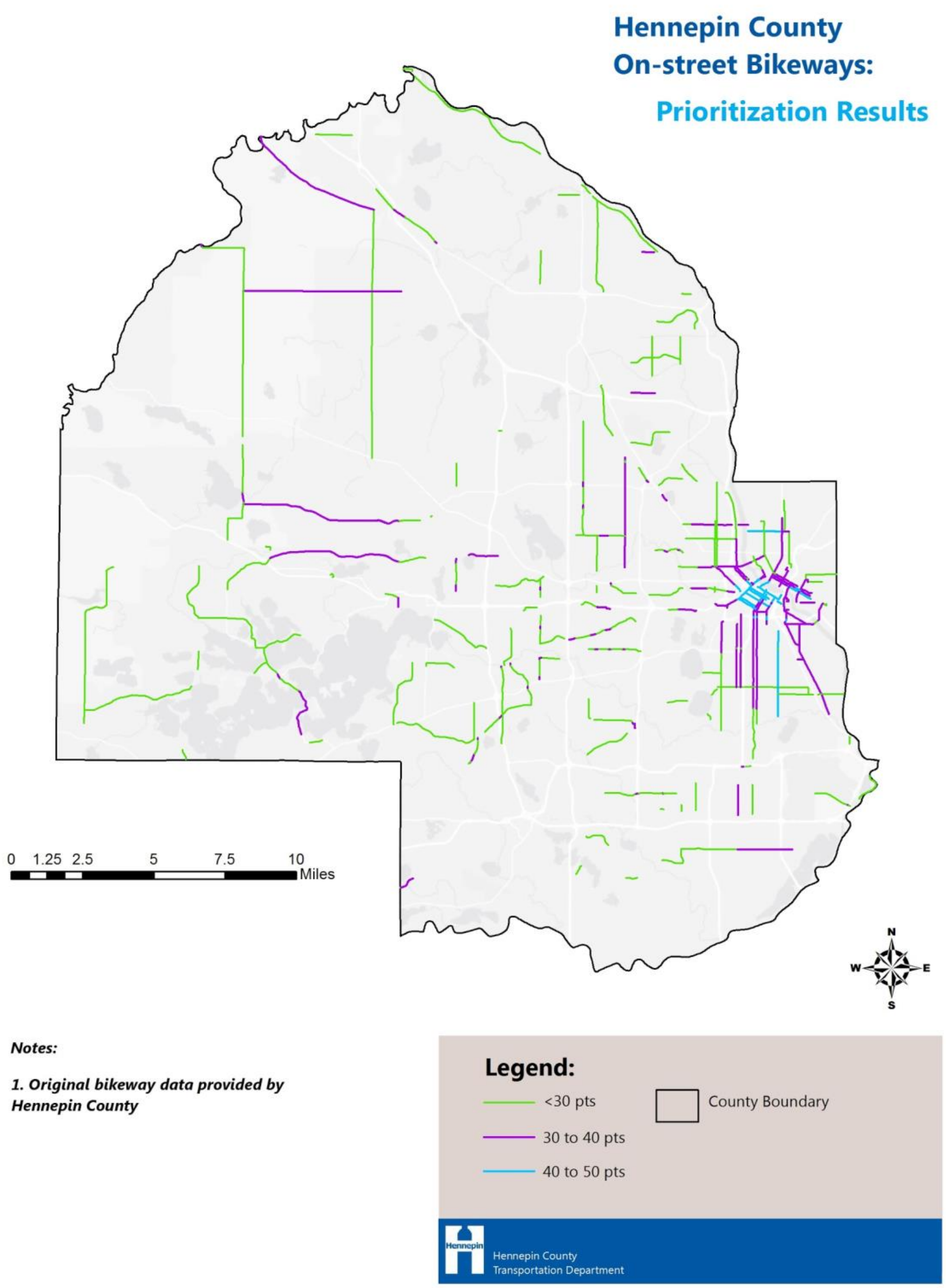
Given the purposefully inclusive nature of this part of the analysis due to the “weakest link” methodology, LTS 3 and 4 facilities were frequent and used to impact the second phase of the analysis with their larger applied multipliers. Of the 257 miles of facilities examined, the LTS corridors skewed towards LTS 3 and 4. The full breakdown showed 104.5 miles of LTS 4 segments (40.6%), 86.9 miles of LTS 3 (33.8%), and only 66.1 miles of LTS 2 (25.7%). There were not LTS1’s in the system.

Once prioritization criteria were scored, summed, and assigned their appropriate multipliers, corridors were left with a score, the highest ranking at 50 points. Figure 2 shows the final results. As discussed above, the top prioritized bikeways were those that scored between 40 and 50 points. The following list displays the top 20 prioritized bikeway corridors from the culmination of the LTS analysis and the prioritization scoring process, in no particular order due to the inherent uncertainty in the ranking system and necessity of the application of feasibility measures:

- Park Ave S
- Hennepin Ave
- Portland Ave
- Washington Ave
- 17th Ave S
- 10th St S
- 9th St S
- 7th St N
- 6th St S
- 4th St S
- 4th St SE
- 3rd St S
- 2nd St S
- University Ave SE
- 11th Ave
- 3rd Ave S
- 22nd Ave NE
- 1st Ave NE

- Central Ave NE
- Riverside Ave

Figure 2: Hennepin County Prioritization Results



Corridors scoring between 30 and 40 points were also seen as high priority bikeway corridors for consideration of protected facilities, and it should be noted that a number of these corridors are not located in the direct downtown core, with some even spread to outer suburbs. Given the existing demand and connectivity, as well as severe traffic and equity considerations in the urban core, it is no surprize that those corridors considered "high priority" would be located close to downtown. Additionally, given that enhanced bikeways are relatively new to the region, downtown segments would be a reasonable place to begin implementation. However, this second tier 30 to 40 group is important to acknowledge in future efforts and long-range planning processes.

In summary, out of the 257 miles examined for prioritization, 17.5 miles scored between 40 and 50 points (6.8%), 84.8 miles scored between 30 and 40 (33%) and 155.3 miles scored less than 30 points (60.4%).

Analysis and Discussion

The bikeways recommended for incorporating protected facilities and the prioritization process created for installing these types of facilities should guide future implementation efforts in Hennepin County. In addition to highlighting the top priority bikeways based on the conducted analysis, it is important to consider how different thresholds and criteria might have changed the results of this prioritization process. This is especially important to consider if future changes to the process want to be made. Additional components to creating these protected bikeways will also be discussed including "ground-truthing" that looks at site-specific factors, effective community engagement, and evaluating the effectiveness of new protected bikeways after installation.

Adjusting the Scorecard

As the prioritization process is used in upcoming projects to install protected bikeway facilities, there should be flexibility to make adjustments to the scorecard process. The GIS tools created to prioritize the bikeways across the county should be easily adjustable moving forward. Hennepin County will have to consider how this scoring process integrates with issues around feasibility and changes to the general bikeway infrastructure in the county. For example, corridors that may have a lower designated priority from this scoring process could have bikeways installed before higher priority infrastructure due to new funding resources available or projects initiated by stakeholders. Or conversely, a higher priority corridor could become a lower priority after community feedback is negative or if the community would prefer working on different infrastructure projects. These types of events can change the scoring process itself or more factors will be incorporated outside of this scoring process. Overall, a flexible scorecard process that does not hinder the work of Hennepin County staff will be crucial.

Additional Considerations

In various protected bikeway initiatives there have been additional considerations that help prioritize where and how to install these facilities. One of the common approaches found to help guide implementation of protected bikeways includes having community engagement be incorporated into the process. There is generally public outreach in various instances through community meetings, surveys at protected bikeway facilities as well as online, providing educational materials as well as presentations on intended plans for protected bikeways (Delaware Department of Transportation 2015, Massachusetts Department of Transportation 2015, San Francisco County Transportation Authority 2009, City of St. Paul 2015). These past cited efforts for bicycle planning incorporated community engagement mainly before implementing any new facilities; however, there are potential benefits to receiving feedback on bicycle facilities after installation to measure general use, whether or not people use these bikeways correctly, and if new people are biking as a result of the protected bikeways. Hennepin County appears to be doing largely similar engagement efforts, but there may be the potential for more on-site feedback at protected bikeway facilities, and more robust bike count data could be used to compare different facility types or to see if bike use changes after specific site improvements.

In the feasibility of protected bikeways implementation it could be useful to consider "ground-truthing" aspects of implementation. This could include considerations such as facility site design, funding availability, project opportunities as well as stakeholders. The Massachusetts Department of Transportation provides an insightful guide considering different site designs for separated bike lanes by considering how curbside activity, intersections, maintenance and signals would affect the biking and motorized traffic experience (Massachusetts Department of Transportation 2015). It is clear that different cycling conditions can lead to a variety of bikeway designs. Future protected bikeway projects could attempt to use past designs to implement desired qualities for a specific facility. Other feasibility considerations such as funding availability, project opportunities and stakeholders will certainly have an impact on implementing protected bikeways. These were all items considered to some extent during meetings with Hennepin County staff while several other municipalities with bike plans had discussed these topics. Themes that were frequently mentioned in these other plans include attempting to gain support from stakeholders on projects through engagement during planning phases, incorporating smaller plans into the larger, often regional plans, and considering site designs that can be cost-effective or more practical (Delaware Department of Transportation 2015, Massachusetts Department of Transportation 2015, San Francisco County Transportation Authority 2009, Seattle Department of Transportation 2014). These are all important considerations in terms of creating new protected bikeways that should be thoughtfully incorporated into future work in tandem with using this developed scorecard prioritization process.

Conclusion

Determining an approach to begin prioritizing Hennepin County's enhanced bicycle network was largely influenced by public input gathered throughout the development of the *2040 Hennepin County Bicycle Plan.* It was also affected by input from Hennepin County staff, local plans and academic research, and data availability for analysis. With a two step system, results incorporated both safety and traffic stress, as well as spatial and social characteristics of the system contributing to community and network needs. Results yielded a small, primarily urban area of prioritized corridors, providing greater safety, connectivity, and equity efforts to an area of the county where a large amount of bicycling occurs, and many physical and social needs are apparent. However, the results also provide corridors outside of the urban core for consideration for protected facilities, and acknowledge the potential need for updated or improved enhanced bikeways throughout the entire county.

This analysis is the first step to the improvement and implementation of protected and enhanced bikeways throughout Hennepin County's bikeway network. Through the flexibility of this tool and its capacity to incorporate and alter existing criteria and threshold values, it is customizable to changing County needs and goals. Feasibility criteria will be important in implementation and overall success of the enhanced network, and it is important that results are strengthened through the inclusion of variables such as right-of-way, maintenance needs, construction costs, and stakeholder/public support. Overall, the use of incorporated deliverables such as the geodatabase of all geospatial data included in report analysis and appendices are for the purposes of continued work and alterations for the highest level of effectiveness of this tool.

This details of this report are best implemented alongside the most current data and forecasts. For that reason, it is recommended that the database continue to be updated, edited, and adapted for up-to-date purposes.

References

Buehler, Ralph, and John Pucher. "Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany." *Transport Reviews* 28.4 (2008): 495-528. Print.

Dulaski, Daniel M., Dan P.E. Bergenthal, Peter G. Furth, and Shannon Brown. "More Than Sharrows: Lane-Within-A-Lane Bicycle Priority Treatments in Three U.S. Cities." (2011): 1-14. Print.

Foster, Nicholas. "Predicting Bicyclist Comfort in Protected Bike Lanes." Portland State University, 2014. Web. 1 May 2017.

Lusk, Anne C., Peter G. Furth, Patrick Morency, Luis F. Miranda-Moreno, Walter C. Willett, and Jack T. Dennerlein. "Risk of Injury for Bicycling on Cycle Tracks versus in the Street." *Injury Prevention*. BMJ Publishing Group Ltd, 01 Apr. 2011. Web. 01 May 2017.

Mekuria, Maaza C., Peter G. Furth, and Hilary Nixon. "Low-Stress Bicycling and Network Connectivity." *Springer Reference* (2012): 1-67. Web. 1 May 2017.

Monsere, Christopher, Jennifer Dill, Nathan McNeil, Kelly Clifton, and Nick Foster. "Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S." Civil and Environmental Engineering Faculty Publications and Presentations, 2014. Web. 1 May 2017.

Sanders, R. L. Examining the Cycle: How Perceived and Actual Bicycling Risk Influence Cycling Frequency, Roadway Design Preferences, and Support for Cycling Among Bay Area Residents. Dissertation, University of California Transportation Center, University of California, Berkeley, 2013.

Schoner, Jessica E., and Daniel M. Levinson. "The Missing Link Bicycle Infrastructure Networks and Ridership in 74 US Cities." (2012): 1-19. Y American Association of State Highway and Transportation Officials, 2012. Web. 1 May 2017.

United States. City of Eden Prairie. *Pedestrian and Bicycle Plan*. Public Works, 2014. Web. 1 May 2017

United States. City of Minneapolis. *Bike Master Plan*. City of Minneapolis, 2011. Web. 1 May 2017.

United States. City of Minneapolis. *Protected Bikeway Update to the Bicycle Master Plan*. City of Minneapolis, 2015. Web. 1 May 2017.

United States. City of St. Paul. *Saint Paul Bicycle Plan*. N.p., 18 Mar. 2015. Web. 1 May 2017.

United States. Delaware Department of Transportation, comp. "Deleware Avenue Bikeway Two Way Separated Bike Lane Feasibility Study." (n.d.): n. pag. Deleware Department of Transportation, 2015. Web. 1 May 2017.

United States. Hennepin County. *Hennepin County 2040 Bicycle Transportation Plan: Making Bicycling Safe and Comfortable*. Hennepin County Department of Transportation, 14 Apr. 2015. Web. 1 May 2017.

United States. Massachusetts Department of Transportation, comp. "Separated Bike Lane Planning & Design Guide." (2015): n. pag. Web. 1 May 2017.

United States. Ramsey County. *Ramsey County Pedestrian and Bicycle Plan*. Ramsey County Department of Transportation, 14 Apr. 2015. Web. 1 May 2017.

United States. San Francisco County Transportation Authority. “San Francisco Bicycle Plan” 26 June 2009. Web. 1 May 2017.

United States. Seattle Department of Transportation. “Seattle Bicycle Master Plan” April 2014. Web. 1 May 2017.

Vogt, Rachel. "Exploring the Relationship between Bicycle Level of Traffic Stress and Reported Bicycle Collisions." Oregon State University Civil Engineering, 26 Oct. 2015. Web. 1 May 2017.

Appendix 1: Hennepin County 2040 Bicycle Transportation Plan Goals

Topic	Goals	Indicators
Sustainability	Implement bikeways and support facilities as an essential tool in realizing environmental, social and economic sustainability.	Increase in number, quality and prominence of bicycle support facilities offered by employers, housing developments, retail establishments and others in the private sector.
Ridership	Promote the bicycle as a mode of transportation that is practical, convenient, and pleasant for commuting, health and exercise, and outdoor recreation.	Bicycling among women, children, older adults, low income and ethnic groups increases to a level proportionate to their population.
Bikeway System	Collaboratively build an integrated county bicycle system that allows bicyclists of varying skills to safely, efficiently and comfortably connect to and between all destinations within the county.	The Twin Cities region, including Hennepin County, counties to be recognize as a world class bicycling region.
Maintenance	Protect the county's and the park district's investments in the bikeway system and reduce seasonal hazards through partnerships.	Protect the county's and the park district's investments in the bikeway system and reduce seasonal hazards through partnerships.
Safety and Comfort	Create a safe and comfortable county bikeway system.	Resident satisfaction with bicycling conditions improves (fewer reported issues, feedback through surveys, 311 systems, media, etc.)

Appendix 2: Hennepin County On-Street Facility Types and Design Guides

On-Street Bike Facility Characteristics by Type and Design			
Bicycle Boulevard	**Shoulder**	**Bike Lanes**	**Buffered Bike Lanes**
• Urban/suburban context • Low separation from motor vehicles • Appropriate for low traffic volumes • For posted speed limits 25 - 30 mph • Local or collector roads • Suitable for 'interested but concerned' experience level and highermed	• Suburban/rural context • Low separation from motor vehicles • Appropriate for low to moderate traffic • For posted speed limits 35 - 55 mph • All kinds of street segments • 5'-8' minimum width • Suitable mainly for 'strong and fearless' riders	• Urban/suburban context • Low to moderate separation from motor vehicles • Moderate traffic volumes • Speed limit varies • Minimum width 5' when adjacent to parking • Mainly suitable for 'enthusiastic and confident' riders and up	• Urban/suburban context • Moderate to high separation from motor vehicles • Moderate to high vehicle traffic • Speed limit varies • Minimum 5' adjacent to parking • Most suitable for 'enthusiastic and confident' riders and up

Source: Hennepin County 2040 Transportation Plan

Appendix 3: Hennepin County 2040 Off-Street Facility Designs

Protected Bikeway Characteristics by Type and Design		
Protected Bikeways	**Cycle Tracks**	**Multi-Use Trails**
• Urban context • High separation from motor vehicles • High vehicle traffic volumes • Speed limit varies • Minimum width 5' with 3' buffer (one-way) • Minimum width 10' with 3' buffer (two-way) • Best for interested but concerned group • Also serves enthusiastic and confident, strong and fearless groups and older children	• Urban/suburban context • High separation from motor vehicles • Moderate to high traffic volumes • Speed limit varies • Minimum width 5' with 2' clear zone on each side (one-way) • Minimum width 10' with 2' clear zone on each side (two-way) • Best for interested but concerned group • Also serves enthusiastic and confident, strong and fearless groups, as well as children	• Urban/suburban/rural context • High separation from vehicles • Minimum width 8' with 2' clear zone on each side (two-way) • Best for interested but concerned group and children • Also serves enthusiastic and confident, strong and fearless groups • Riders may be less well-served if the trail is poorly maintained, has a soft surface, takes indirect route, or has high pedestrian volumes

Source: Hennepin County 2040 Transportation Plan

Appendix 4: Initial Possibilities for LTS and Priority Scorecard

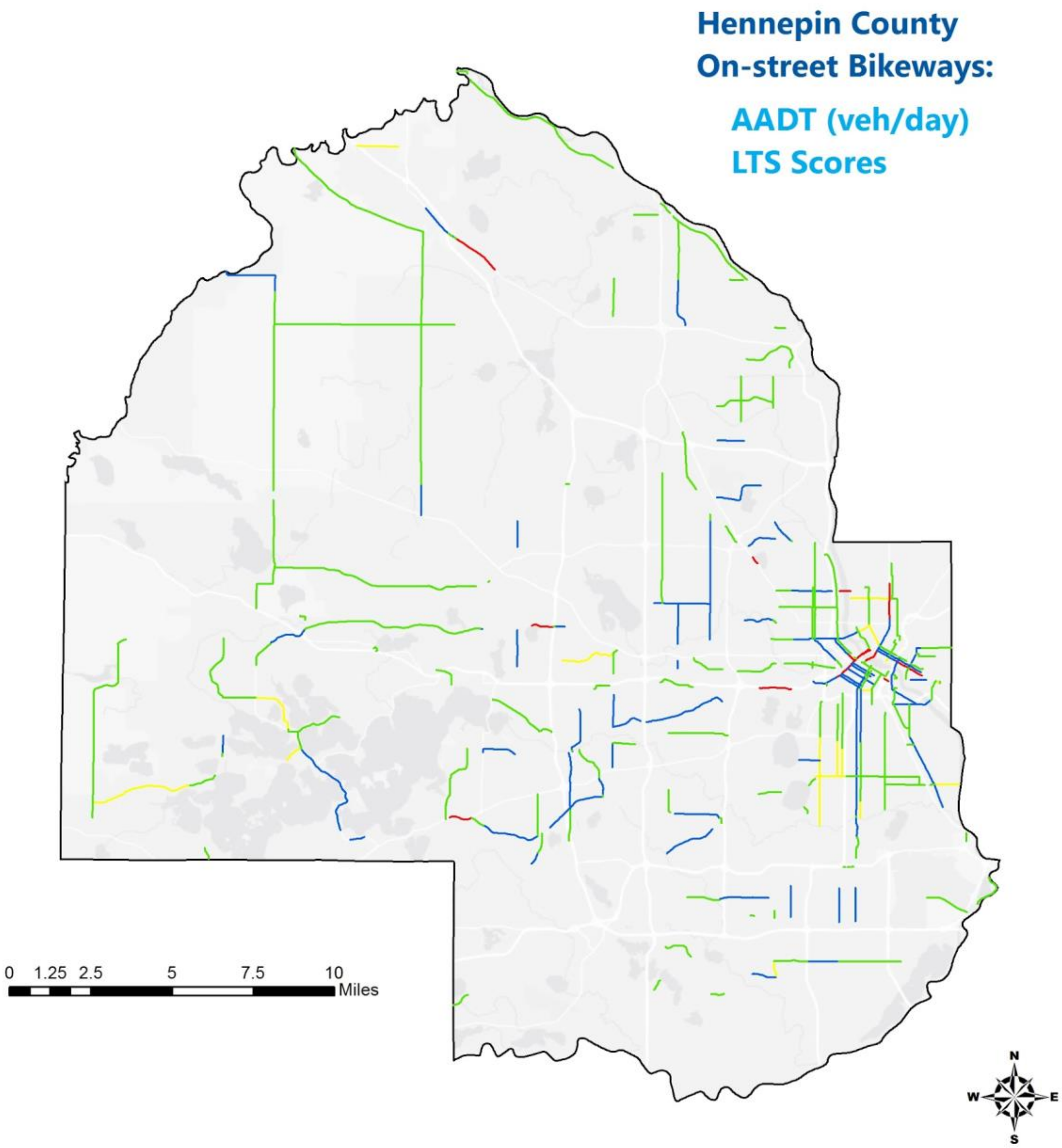
Possible Measure of Safety	Attributes	Votes
AADT	The average annual daily traffic is a measure of traffic volume recorded by the Minnesota Department of Transportation. It is embedded in segments of roadway data. For the purpose of a stress analysis, it can be divided into two tiers--those that are above 6,000 vehicles a day and those below 6,000 vehicles a day.	6
Speed limit	Speed limit is recorded within the centerline roadway data maintained by Hennepin County, broken up into segments according to where the speed limit changes. For the purpose of a stress analysis, intervention would be necessary in any segment of road where the speed limit was above 35 miles per hour.	6
Intersection control type	Intersection control type includes the presence of all intersections, as well as stop signs and stop lights, is maintained by Hennepin County.	4
Density of bike crashes	Bike crash data is maintained by the Minnesota Department of Transportation as geocoded points that can be queried according to severity and date. This could be further aggregated through cluster analysis or heat mapping.	3
Lane width	Lane width for segments of road with on-street bike facilities is maintained within the attribute information of the Hennepin County Bikeway shapefile. Lane width remains one manner of approximating the degree of separation from traffic that a rider feels.	0
Number of lanes	Information of how many lanes of traffic exists as an attribute within the bicycle network information maintained by Hennepin County. As a simple Y/N attribute, this can easily be queried.	2
Parking lanes	The presence of on-street parking exists as an attribute within the bicycle network information maintained by Hennepin County. As a simple Y/N attribute, this can easily be queried.	3
Existing protected bike facilities	The presence of existing protected on-street and off-street bike facilities is maintained by Hennepin County is maintained by the city.	4
Car crashes	The density of car crashes could be	NA
Bike lane blockage	Look at zoning, land use, or parcel property type to derive commercial vs. non-commercial zones. Create a field in the bike route line indicating whether the route passes through a commercial zone (per MTI report, bike lanes in commercial areas are subject to frequent lane blockages)	NA

Possible Measure of Connectivity	Attributes	Votes
Estimated daily bicycle trips	The estimated daily bicycle trips were conducted through a series of counts at specific sites, then applied to specific road classifications. This could be segmented according to a pre-established statistical method such as Jenks Natural Breaks.	4
Proximity to other bike lanes	The data exists as a line file, where proximity could be determined through a buffer analysis.	4
Proximity to regional attractions	While not entirely complete, the regional activity center dataset has been maintained by the Minnesota Department of Employment and Economic Development. The Job and Activity Centers describe contiguous areas where there are at least 1,000 jobs and the employment density is at least 10 jobs per net acre. The data also includes some regionally significant manufacturing and distribution centers that have at least 1,000 jobs but densities less than 10 jobs per acre. The data exists as a polygon file, where proximity could be determined through a buffer analysis.	4
Population density	This can be calculated at the Census Block level using the most recent data available from American Community Survey. Population density tiers could be calculated into quadrants using a pre-established method such as Jenks Natural Breaks.	1

Possible Measure of Equity	Attributes	Votes
Percent of people of color	This can be calculated at the Census Block level using the most recent data available from American Community Survey. Many of the guidelines around classification of concentrated areas of people of color have been established by the regional planning authority.	1
Percent population below federal poverty line	This can be calculated at the Census Block level using the most recent data available from American Community Survey. Many of the guidelines around classification of concentrated areas of people of color have been established by the regional planning authority.	2
Percent of households without a vehicle	This can be calculated at the Census Block level using the most recent data available from American Community Survey. Percent of households without a vehicle could be calculated into quadrants using a pre-established method such as Jenks Natural Breaks.	3

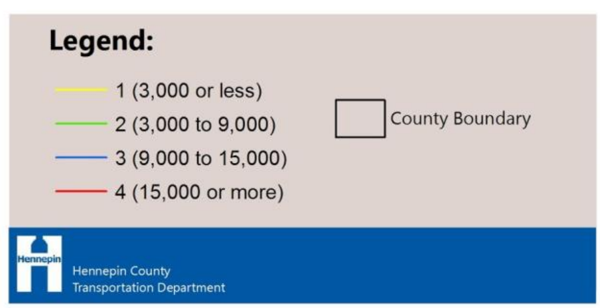
Possible Measure of Feasibility	Attributes	Votes
Right of way	This could be conceived as a simple yes or no, whether the county owns the road or land near the road so that an upgrade could be completed.	3
Cost Considerations	Cost considerations could factor in the timing of whether the upgrade of a segment was done in coordination with other road maintenance projects, such as road or pathway resurfacing.	2
Environmental barriers	The presence of non-crossable land features that would prevent the development of an on-street or off-street network could be determined through generalized land use categories that are maintained by the Metropolitan Council.	0
Maintenance considerations	Cost considerations about things like snow removal, street cleaning or other trail improvements.	3

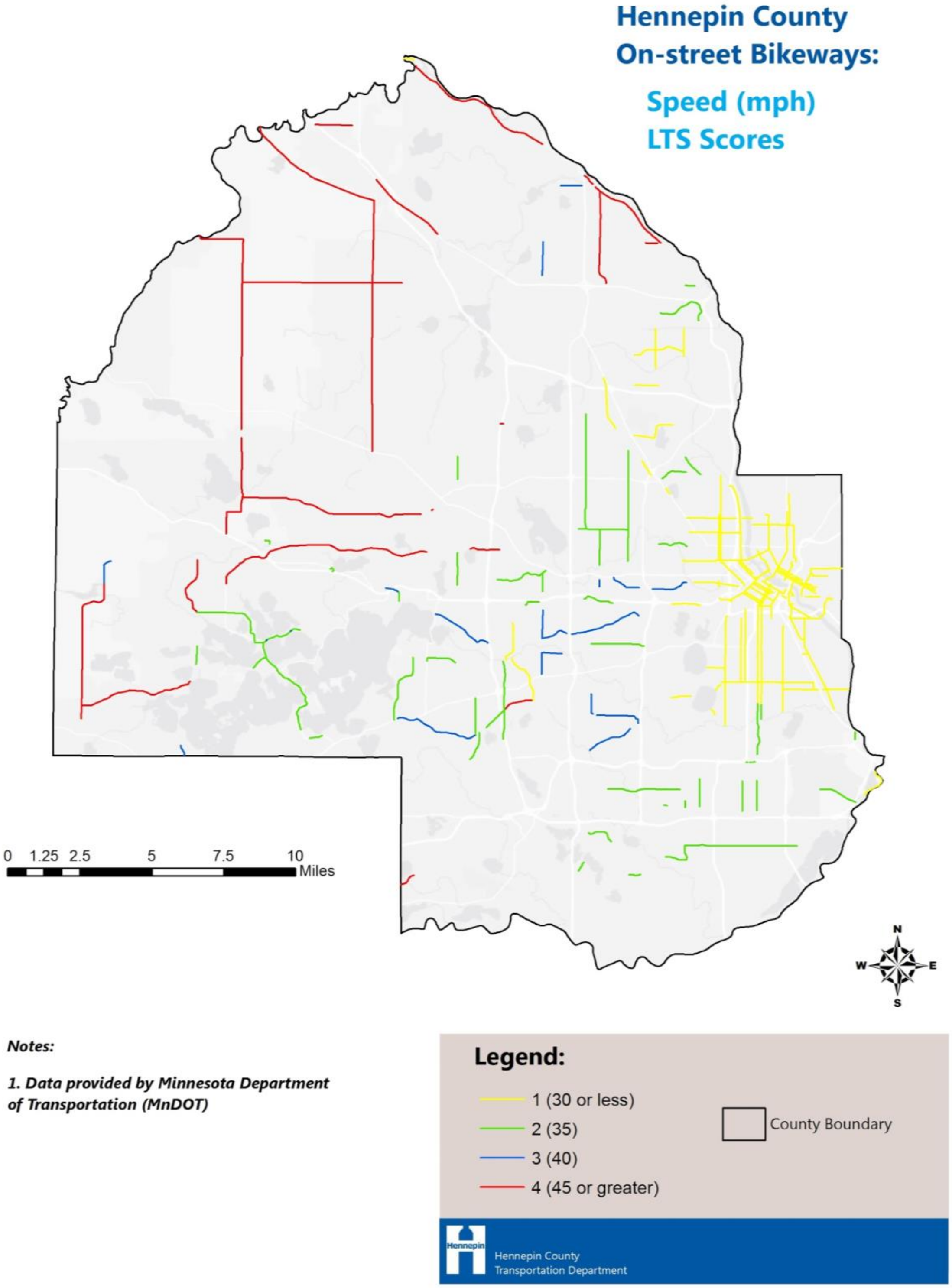
Appendix 5:
LTS Maps



Notes:

1. Data provided by Minnesota Department of Transportation (MnDOT)



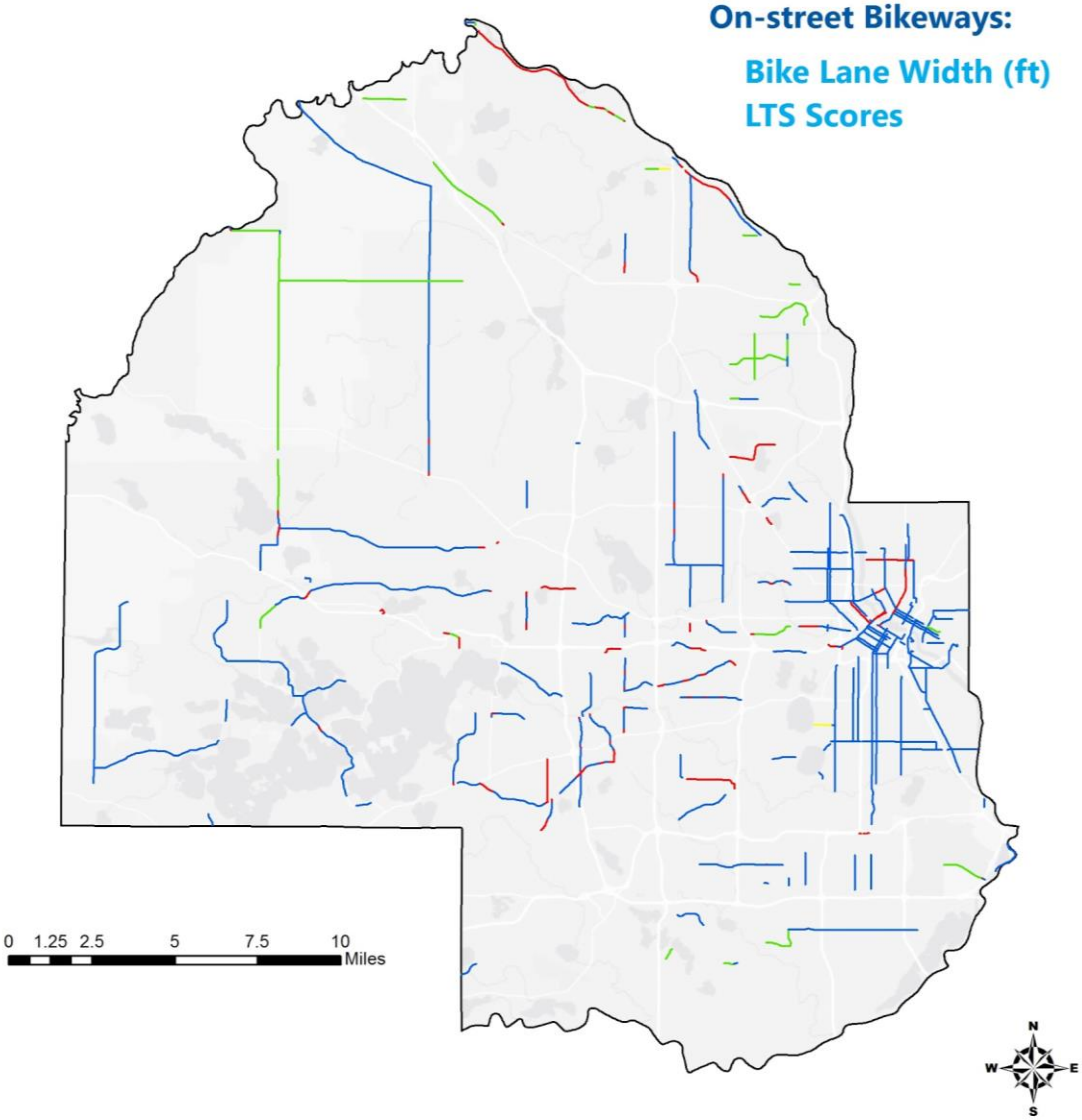


Notes:

1. Data provided by Minnesota Department of Transportation (MnDOT)

Hennepin County On-street Bikeways:

Bike Lane Width (ft)
LTS Scores



Notes:

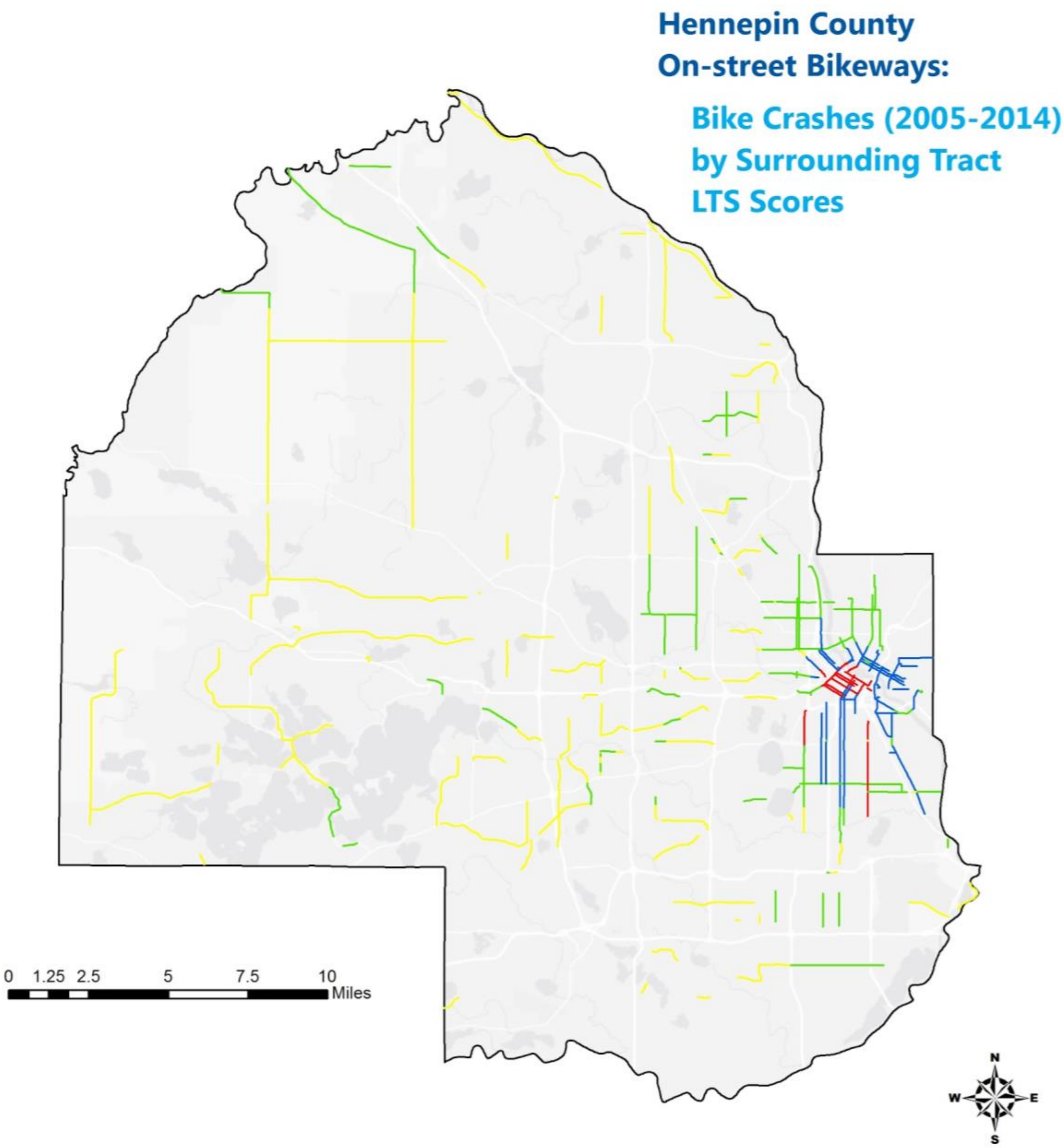
1. Data provided by Minnesota Department of Transportation (MnDOT)

Legend:

- 4 (Under 4)
- 3 (4 to 6)
- 2 (5 to 6)
- 1 (6 or more)

County Boundary

Hennepin County
Transportation Department



Notes:

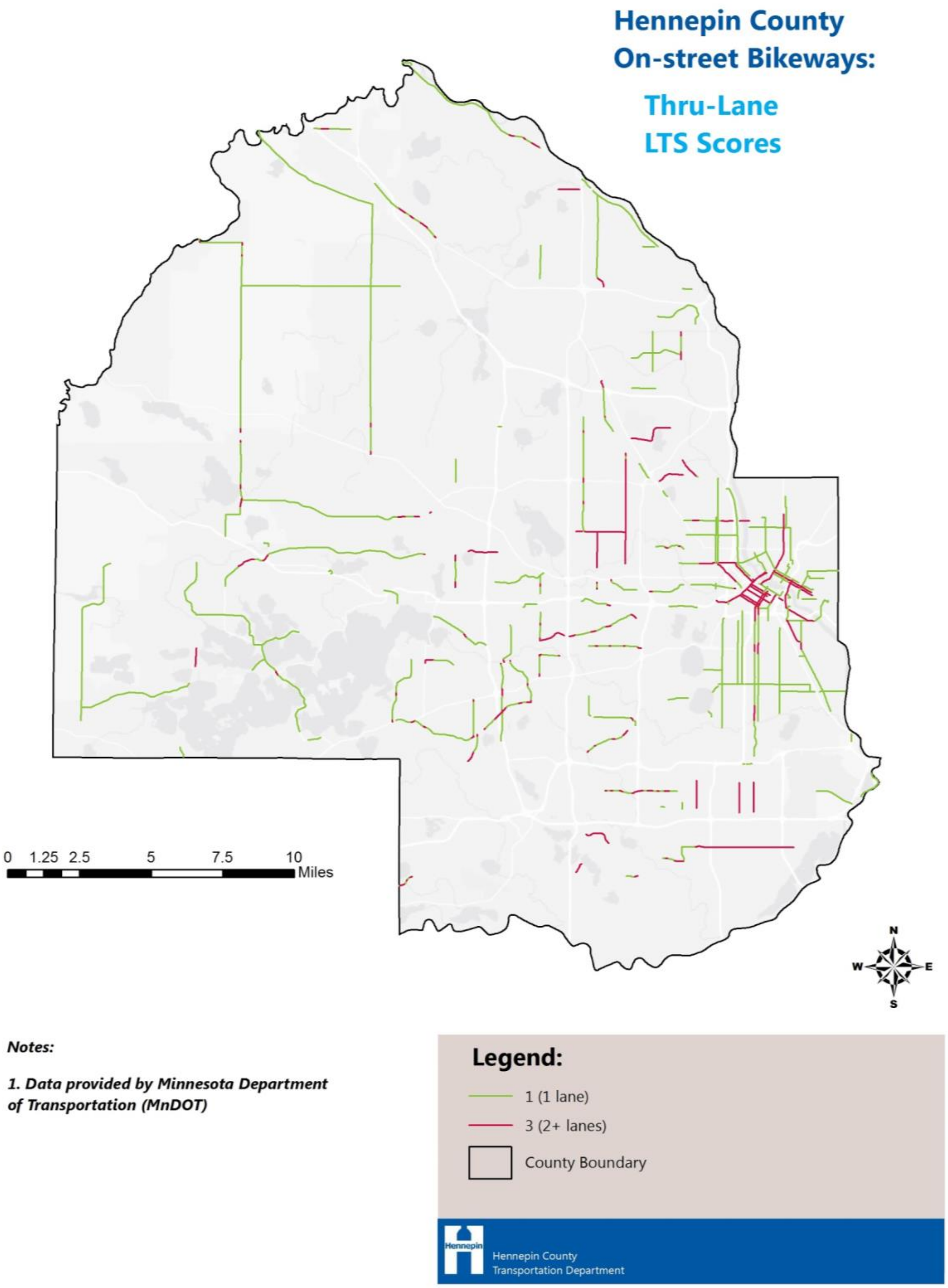
1. Crash data provided by Minnesota Department of Transportation (MnDOT)

Legend:

1 (Up to 10)
2 (10 to 30)
3 (30 to 75)
4 (75 or more)

County Boundary

Hennepin County
Transportation Department



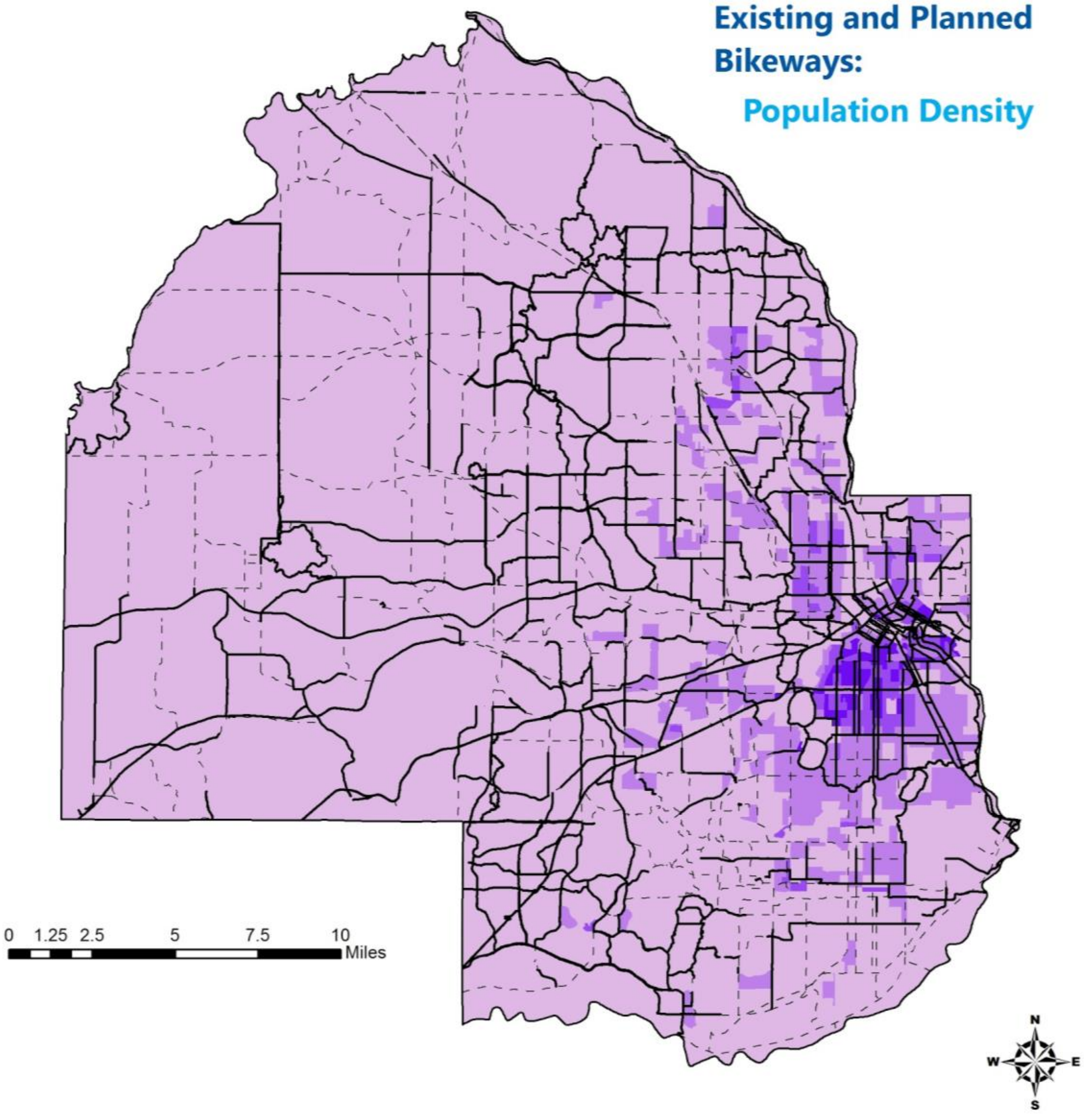
Notes:

1. Data provided by Minnesota Department of Transportation (MnDOT)

Appendix 6:
Connectivity Criteria Maps

Hennepin County Existing and Planned Bikeways:

Population Density



Notes:

1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

Legend:

Existing Bikeway

Planned Bikeway

County Boundary

Population Density (per/sqmi)

< 5,000

5,000 - 10,000

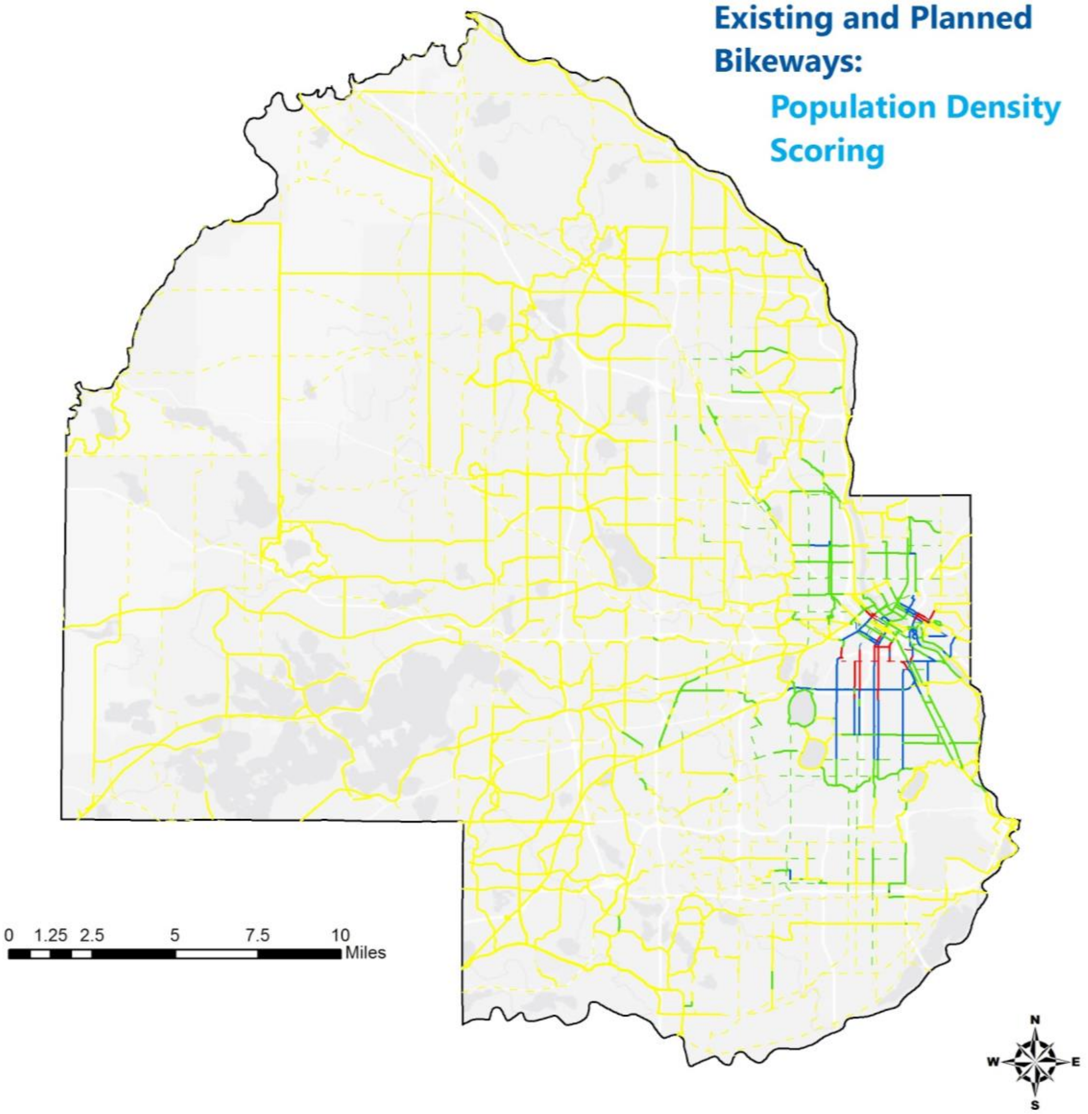
10,000 - 15,000

< 15,000

Hennepin County
Transportation Department

Hennepin County Existing and Planned Bikeways:

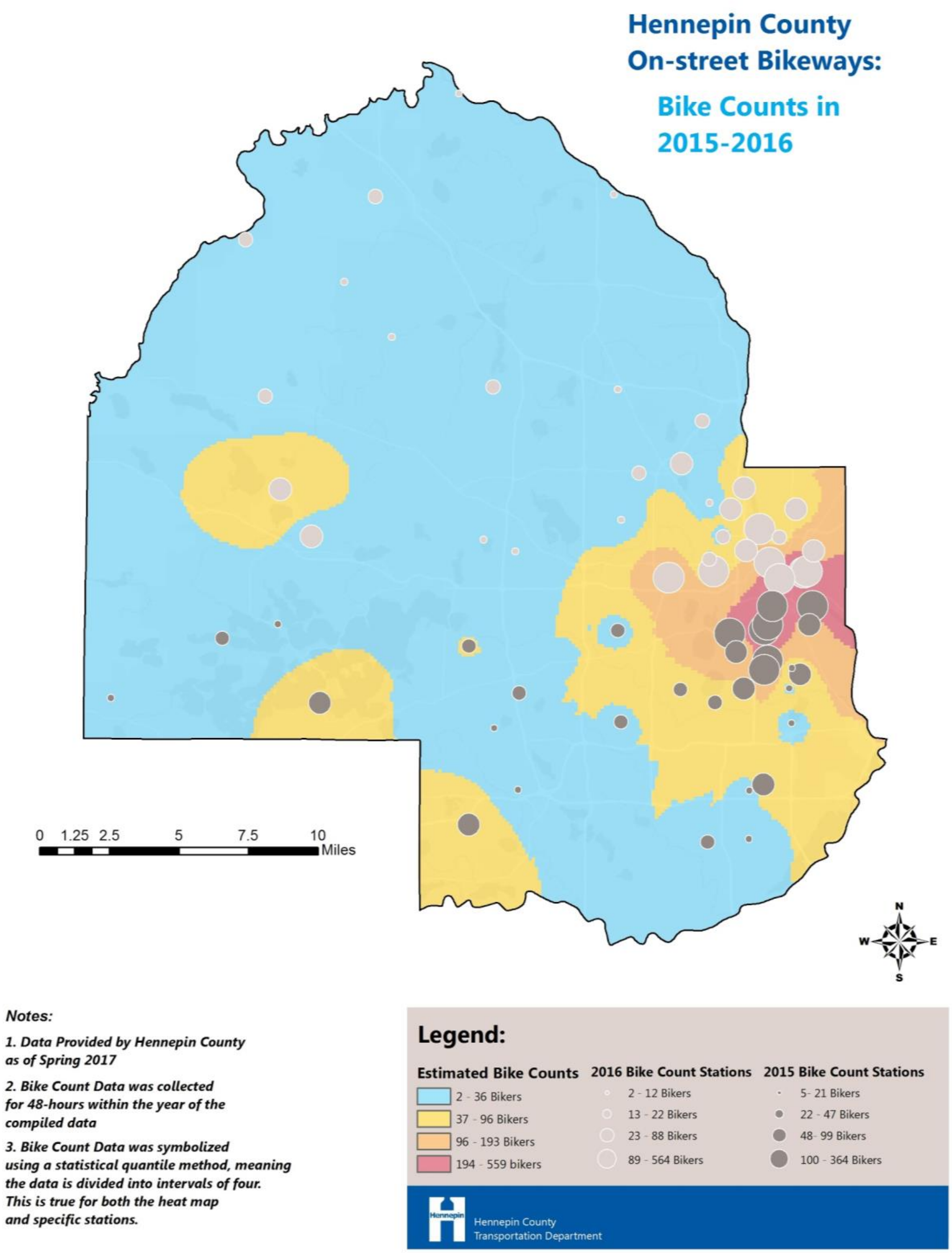
Population Density Scoring

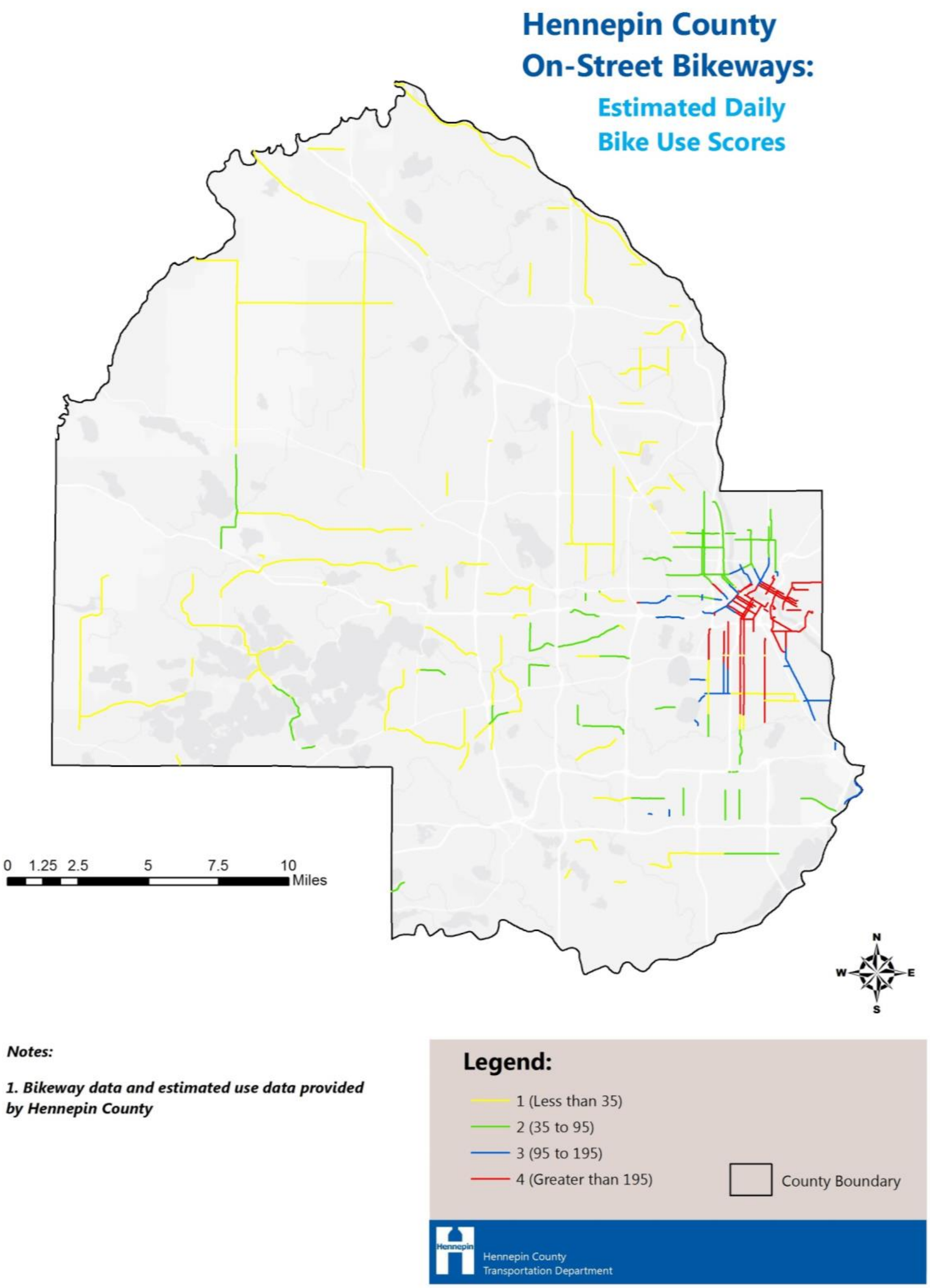


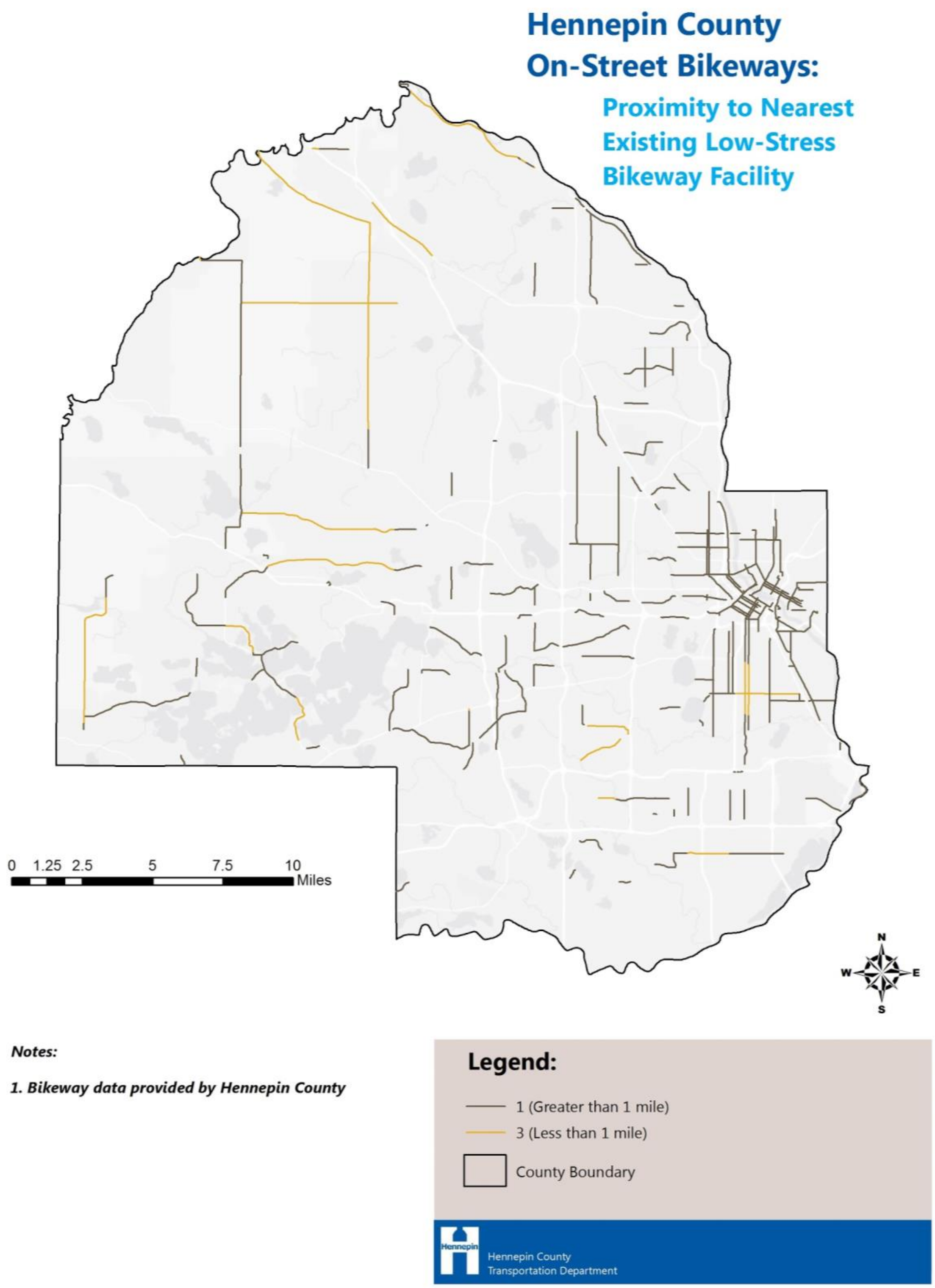
Notes:

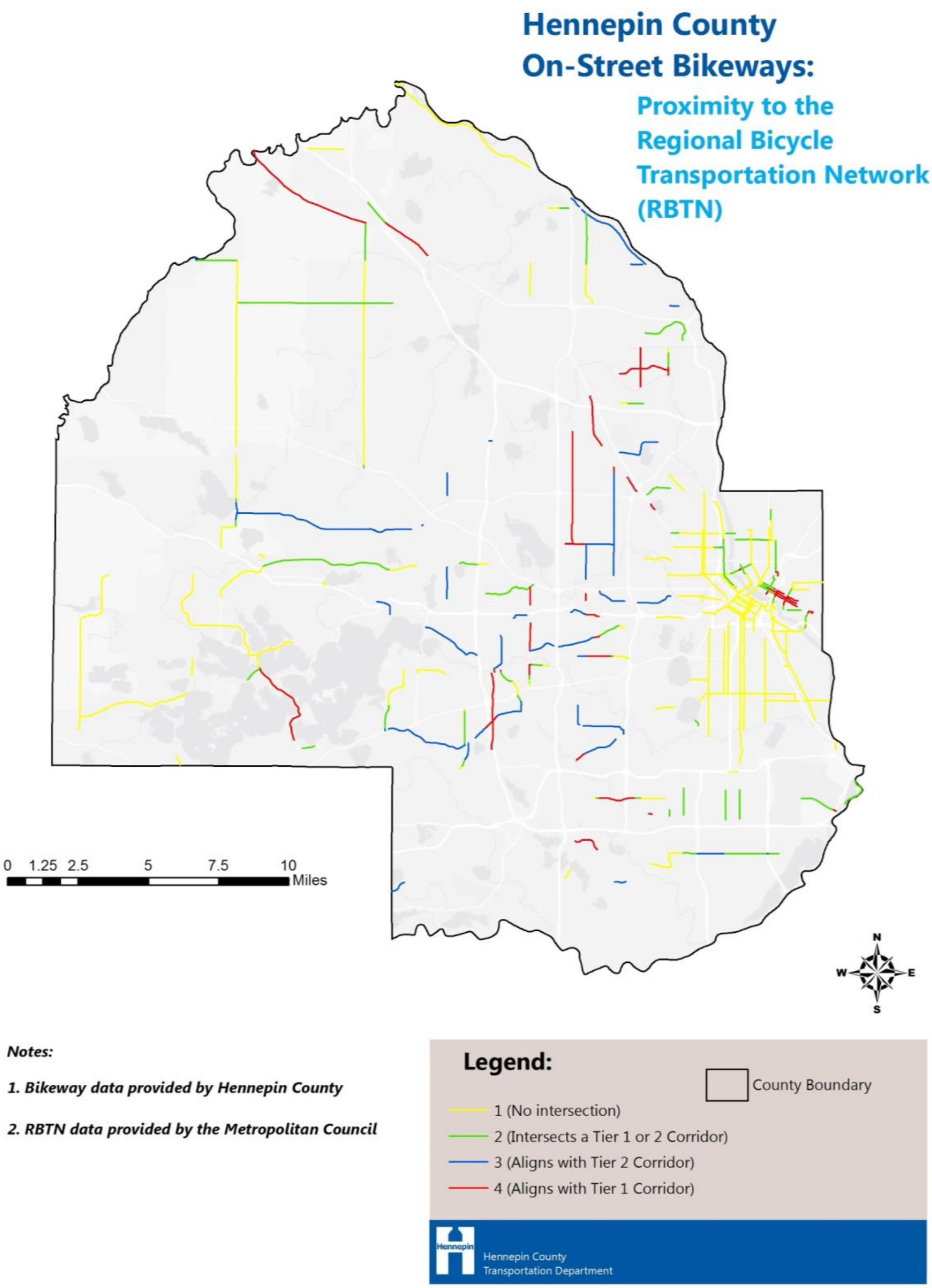
1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015


Hennepin County
On-street Bikeways:
Bike Counts in
2015-2016
0 1.25 2.5 5 7.5 10
Miles
N
W
E
S
Notes:
1. Data Provided by Hennepin County as of Spring 2017
2. Bike Count Data was collected for 48-hours within the year of the compiled data
3. Bike Count Data was symbolized using a statistical quantile method, meaning the data is divided into intervals of four. This is true for both the heat map and specific stations.
Legend:
Estimated Bike Counts
2 - 36 Bikers
37 - 96 Bikers
96 - 193 Bikers
194 - 559 bikers
2016 Bike Count Stations
2 - 12 Bikers
13 - 22 Bikers
23 - 88 Bikers
89 - 564 Bikers
2015 Bike Count Stations
5- 21 Bikers
22 - 47 Bikers
48- 99 Bikers
100 - 364 Bikers
Hennepin
Hennepin County
Transportation Department


Hennepin County
On-Street Bikeways:
Estimated Daily
Bike Use Scores
0 1.25 2.5 5 7.5 10
Miles
N
W
E
S
Notes:
1. Bikeway data and estimated use data provided by Hennepin County
Legend:
1 (Less than 35)
2 (35 to 95)
3 (95 to 195)
4 (Greater than 195)
County Boundary
Hennepin
Hennepin County
Transportation Department


Hennepin County
On-Street Bikeways:
Proximity to Nearest
Existing Low-Stress
Bikeway Facility
0 1.25 2.5 5 7.5 10
Miles
N
W
E
S
Notes:
1. Bikeway data provided by Hennepin County
Legend:
1 (Greater than 1 mile)
3 (Less than 1 mile)
County Boundary
Hennepin County
Transportation Department



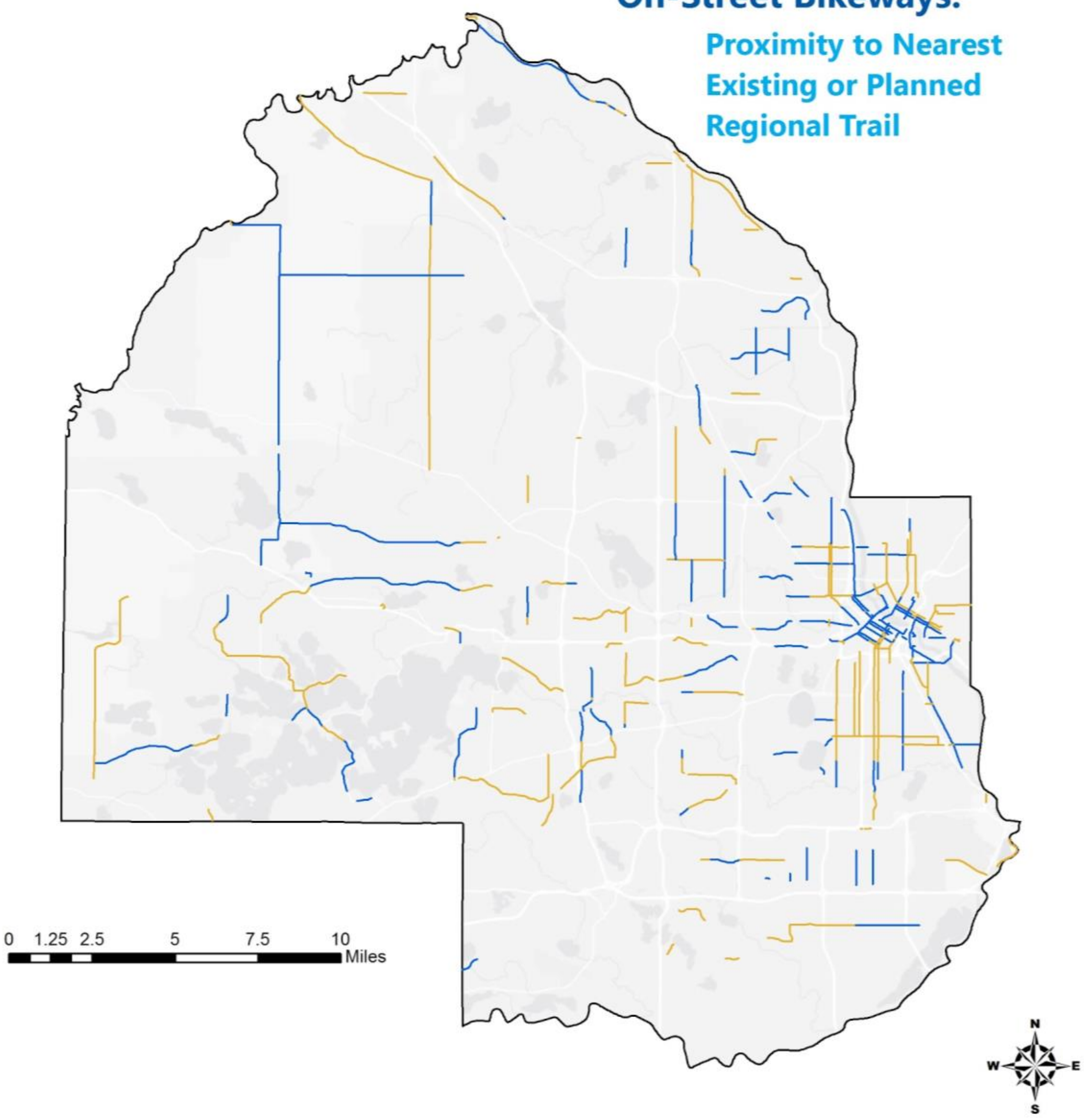
Notes:

1. Bikeway data provided by Hennepin County

2. RBTN data provided by the Metropolitan Council

Hennepin County On-Street Bikeways:

Proximity to Nearest Existing or Planned Regional Trail



Notes:

1. Bikeway data provided by Hennepin County

2. Regional trails data provided by the Metropolitan Council

Legend:

1 (Greater than 1/4 mile)

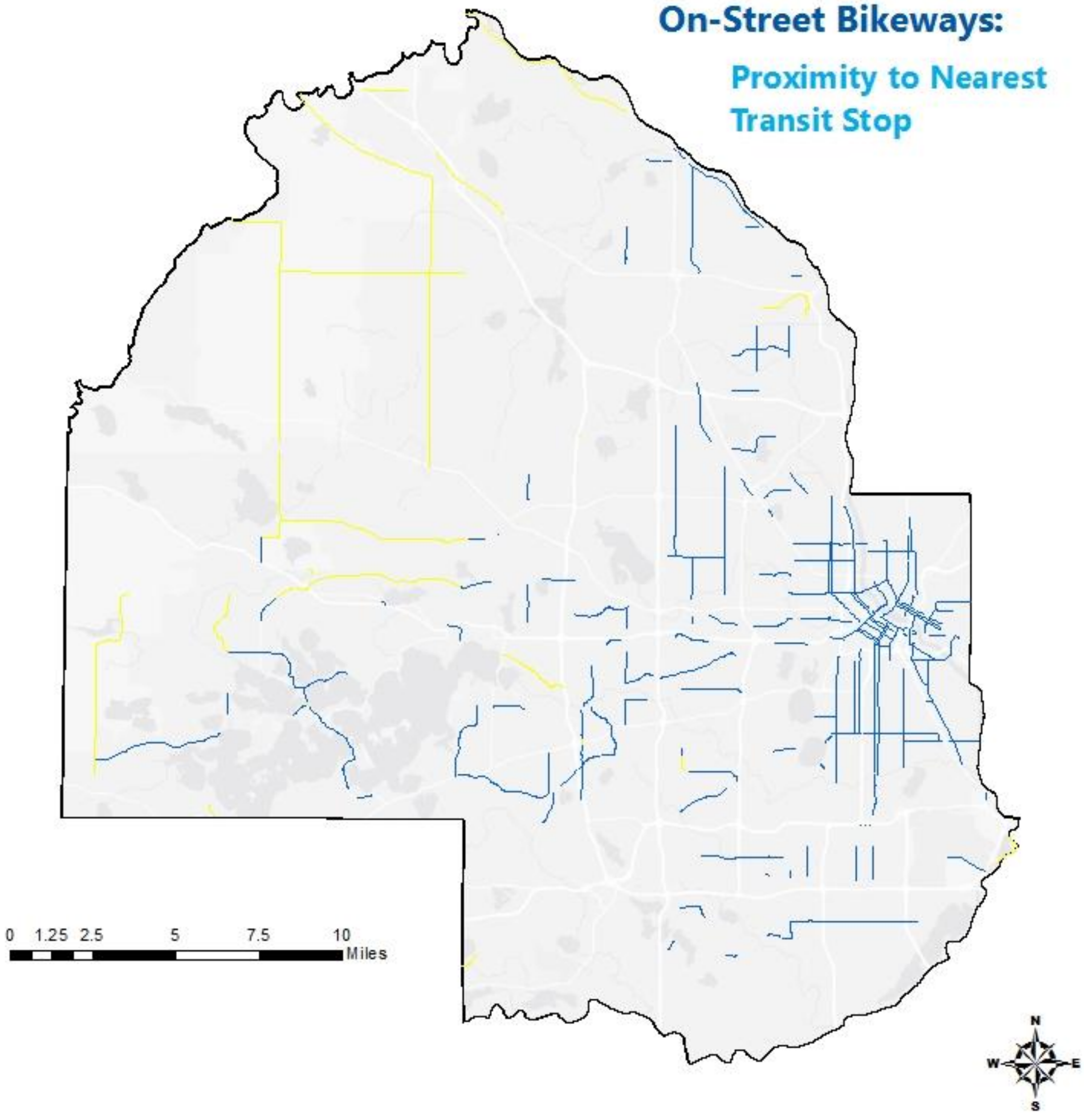
3 (Less than 1/4 mile)

County Boundary

Hennepin County
Transportation Department

Hennepin County On-Street Bikeways:

Proximity to Nearest Transit Stop



Notes:

1. Bikeway data provided by Hennepin County

2. Transit data provided by Metropolitan Council, Metro Transit

Legend:

1 (Less than 1/4 mile)

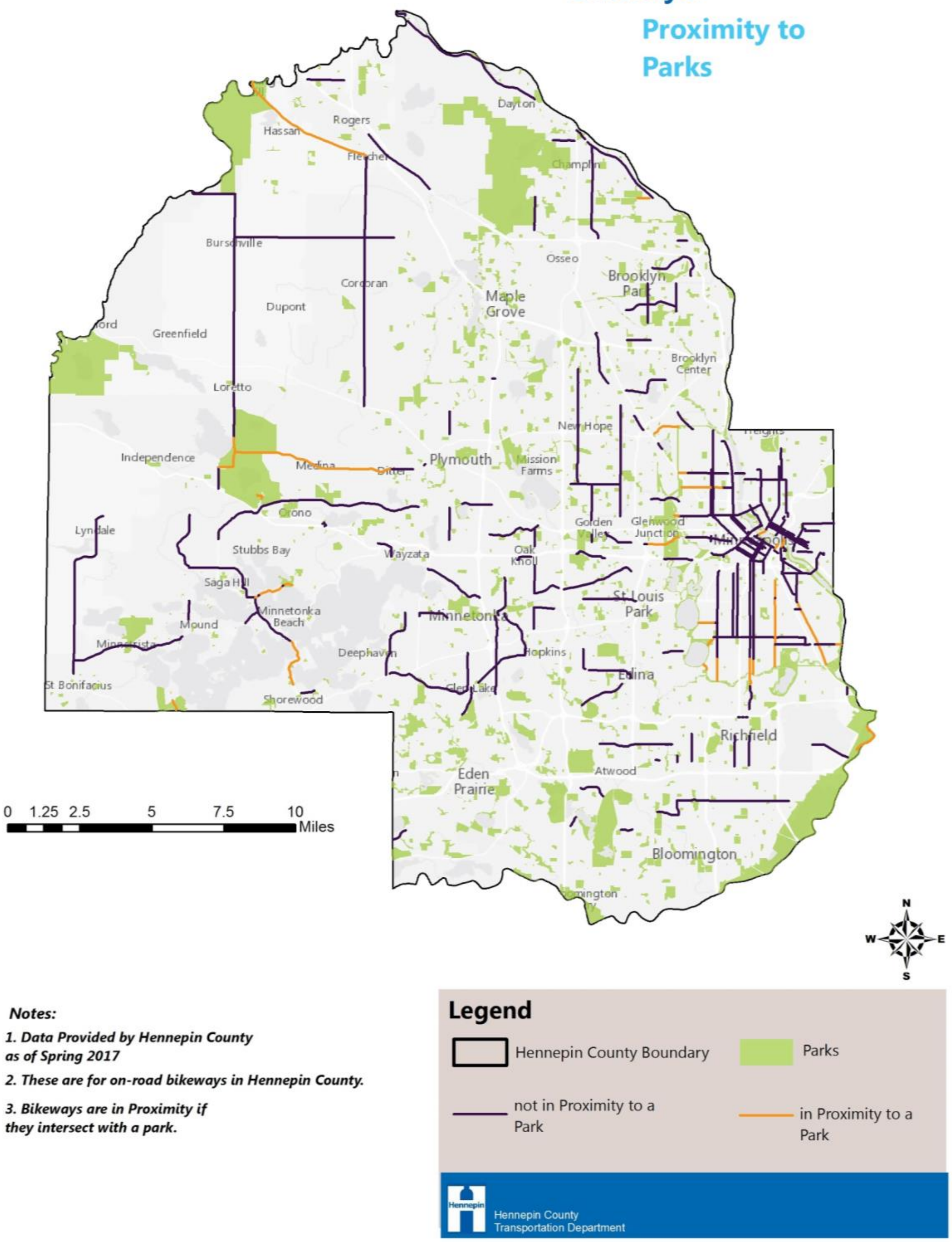
3 (Greater than 1/4 mile)

County Boundary

Hennepin County
Transportation Department

Hennepin County On-Street Bikeways:

Proximity to Parks

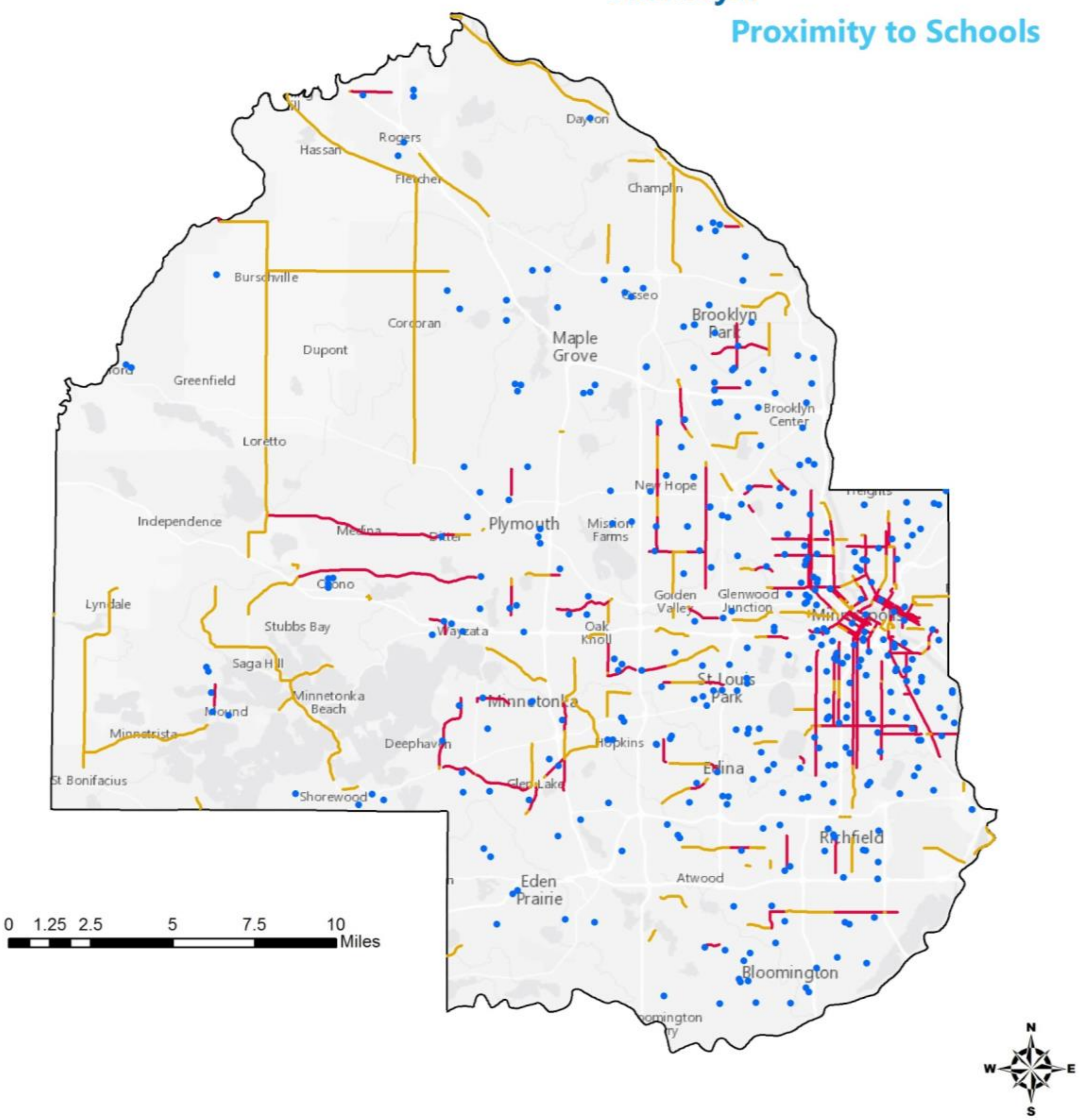


Notes:

1. ***Data Provided by Hennepin County as of Spring 2017***
2. ***These are for on-road bikeways in Hennepin County.***
3. ***Bikeways are in Proximity if they intersect with a park.***

Hennepin County On-street Bikeways:

Proximity to Schools

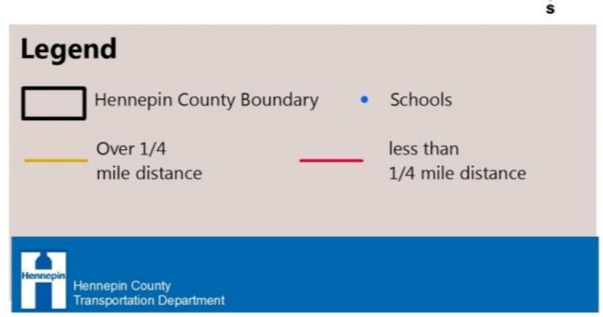


Notes:

1. Data Provided by Hennepin County as of Spring 2017

2. These are for off road bikeways in Hennepin County.

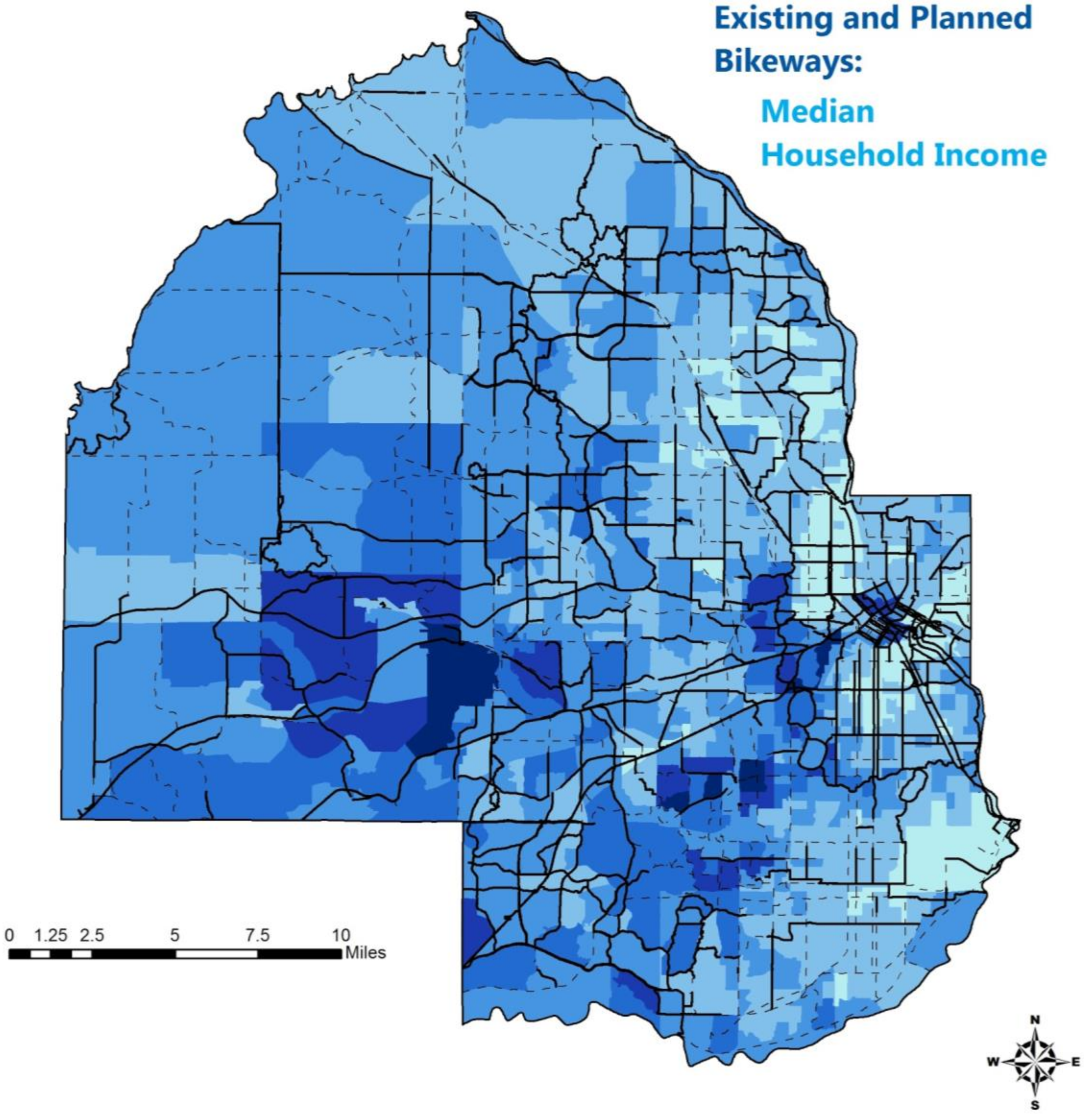
3. Bikeways are defined as being in proximity if they are within 1/4 mile radius from a school.



Appendix 7:
Equity Criteria Maps

Hennepin County Existing and Planned Bikeways:

Median Household Income



Notes:

1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

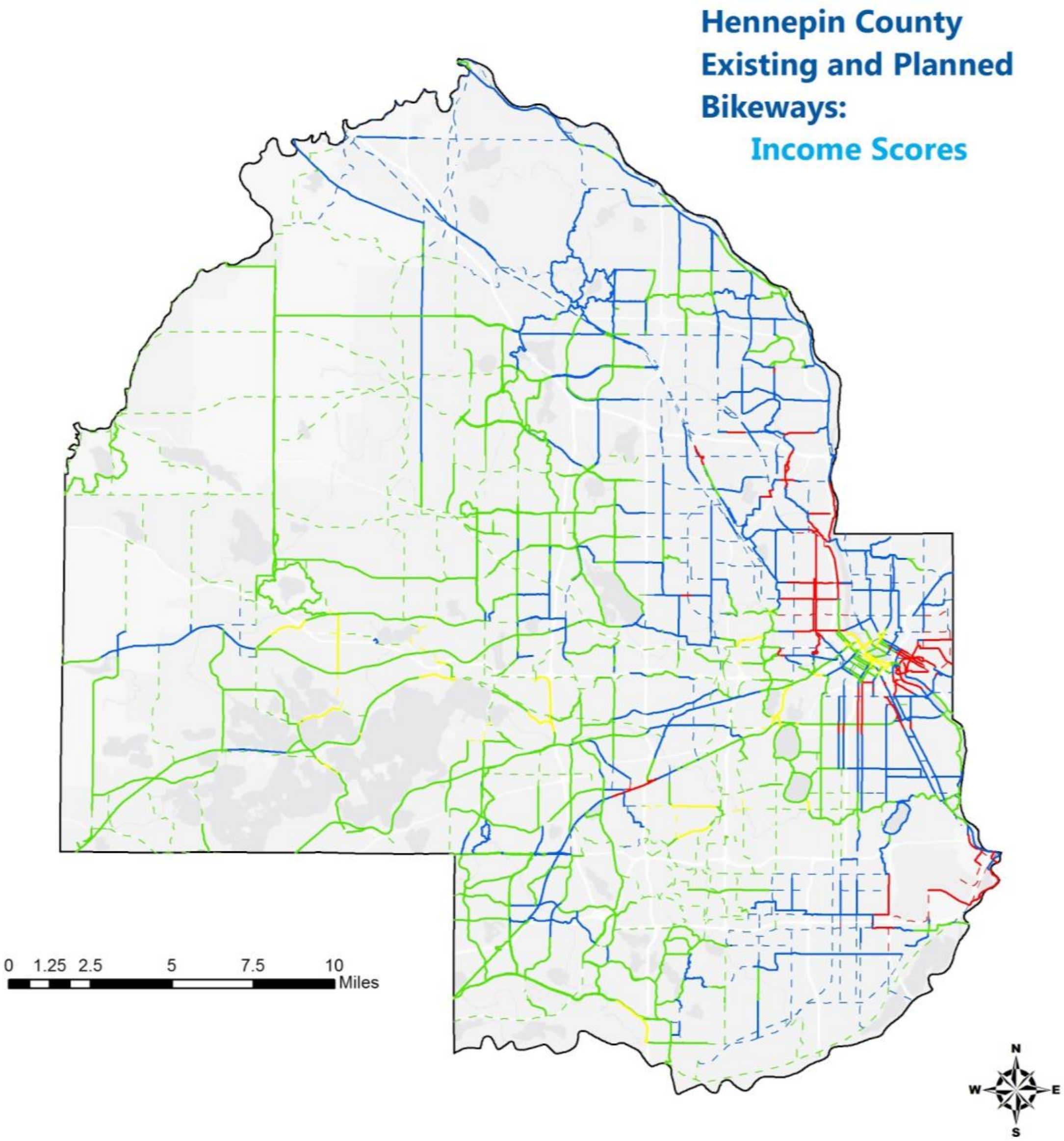
Legend:

- Existing Bikeway
- Planned Bikeway
- County Boundary

Median Household Income

- < $20,000
- $20,000 - $40,000
- $40,000 - $60,000
- $60,000 - $80,000
- $80,000 - $100,000
- <$100,000

Hennepin County
Transportation Department



Notes:

1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

Legend:

Existing Facility

Planned Facility

County Boundary

Score:

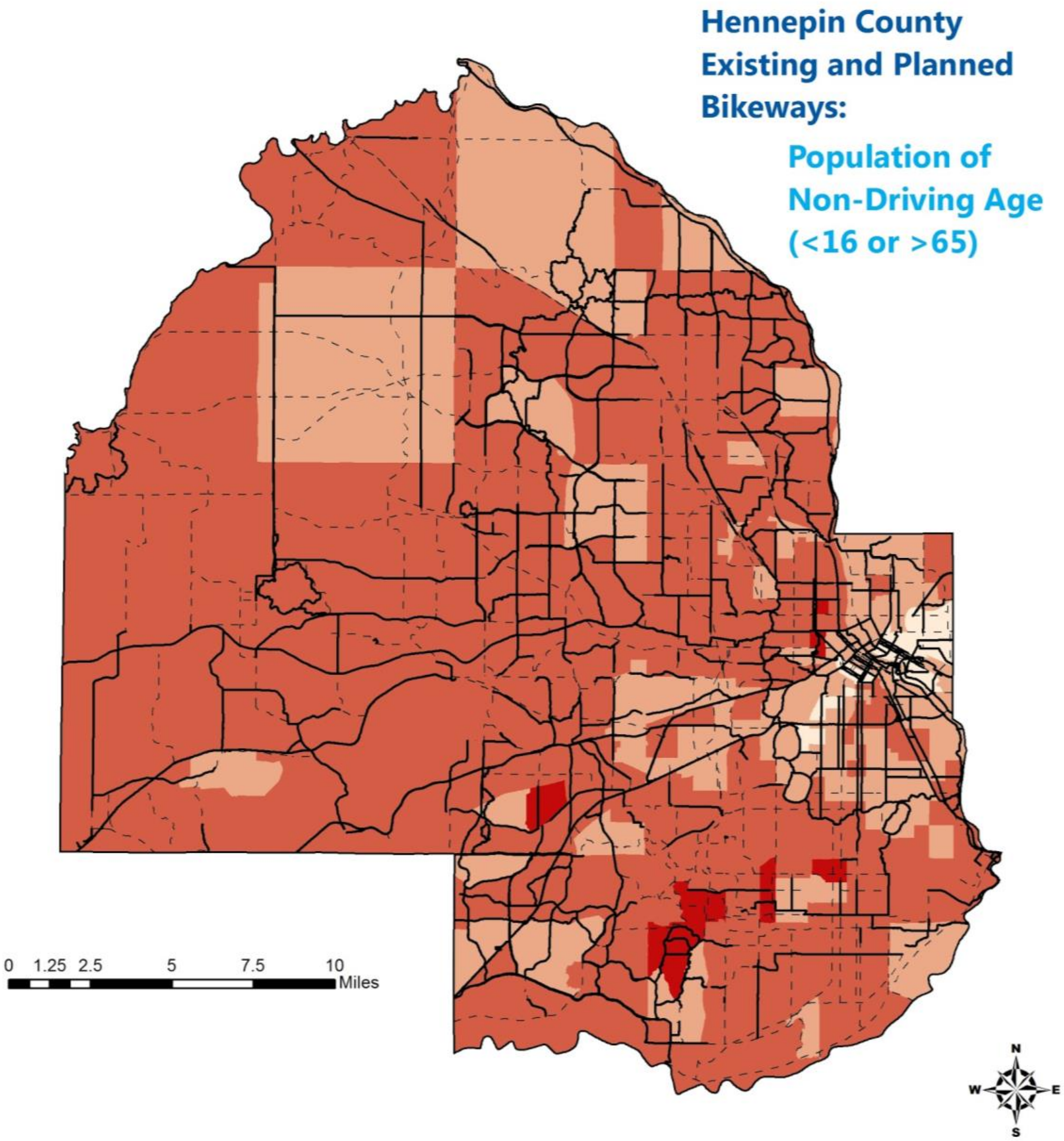
1

2

3

4

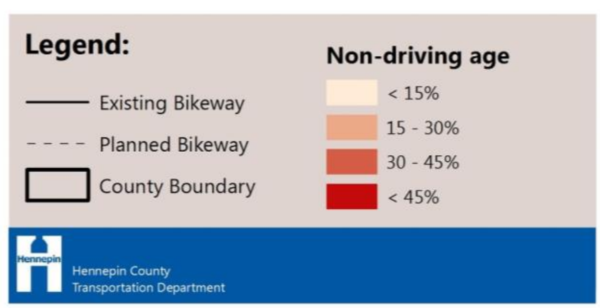
Hennepin County
Transportation Department



Notes:

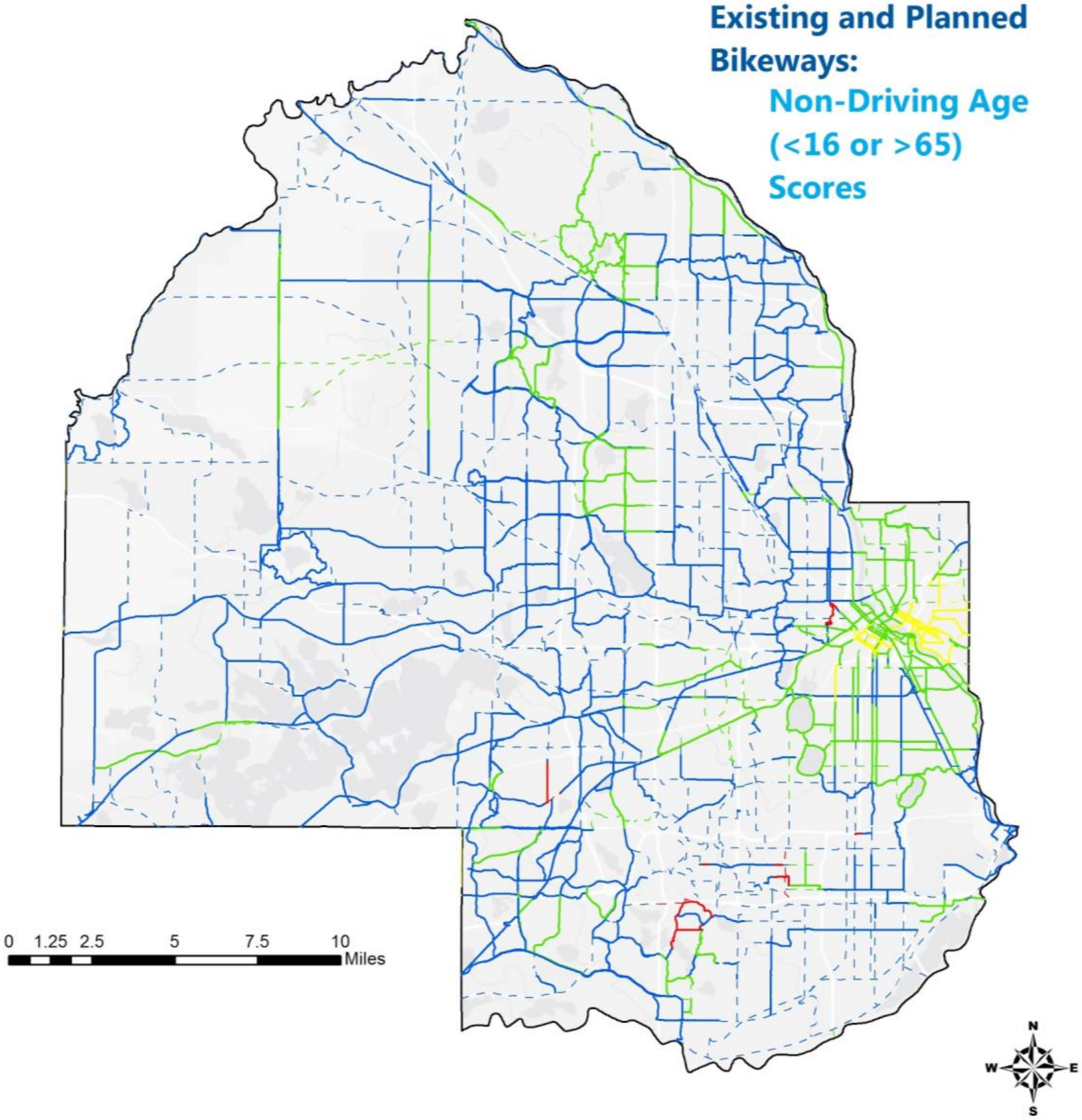
1. ***Bikeways Data Provided by Hennepin County as of Spring 2017***

2. ***Demographic data from 5-year American Community Survey data 2015***



Hennepin County Existing and Planned Bikeways:

Non-Driving Age (<16 or >65) Scores



Notes:

1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

Legend:

Existing Facility

Planned Facility

County Boundary

Score:

1

2

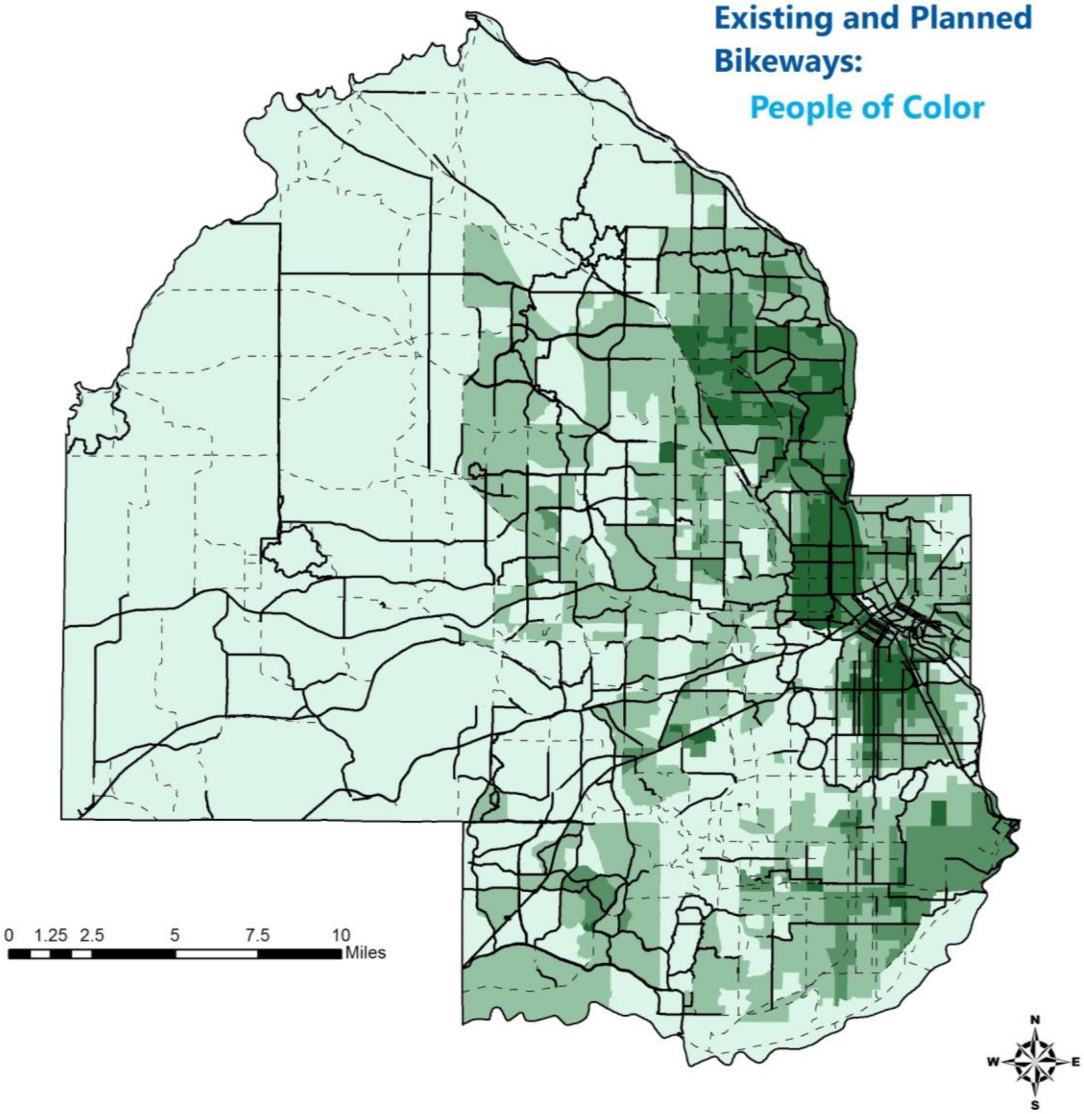
3

4

Hennepin County
Transportation Department

Hennepin County Existing and Planned Bikeways:

People of Color



Notes:

1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

Legend:

Existing Bikeway

Planned Bikeway

County Boundary

People of Color

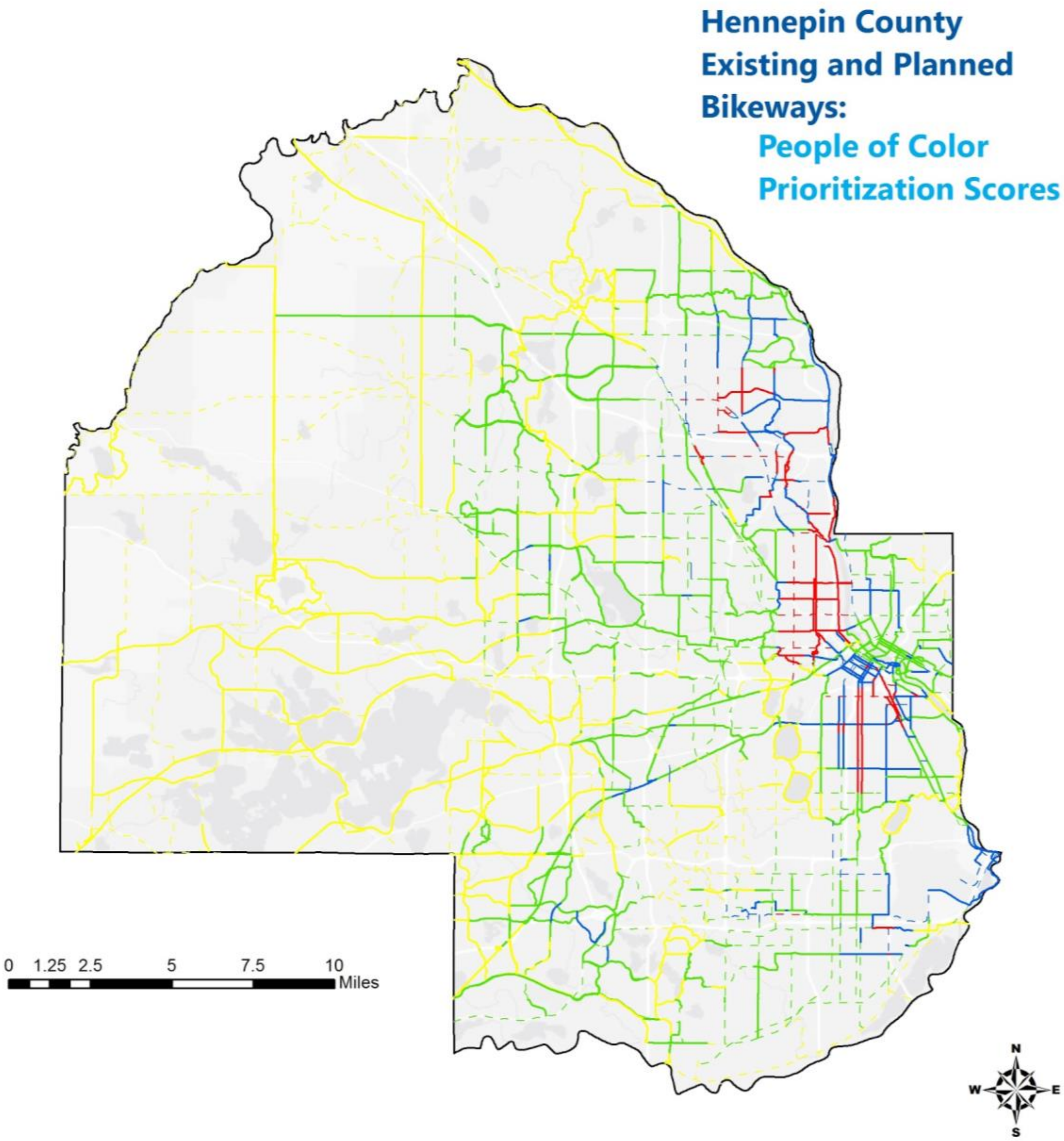
< 10%

10 - 30%

30 - 50%

> 50%

Hennepin County
Transportation Department



Notes:

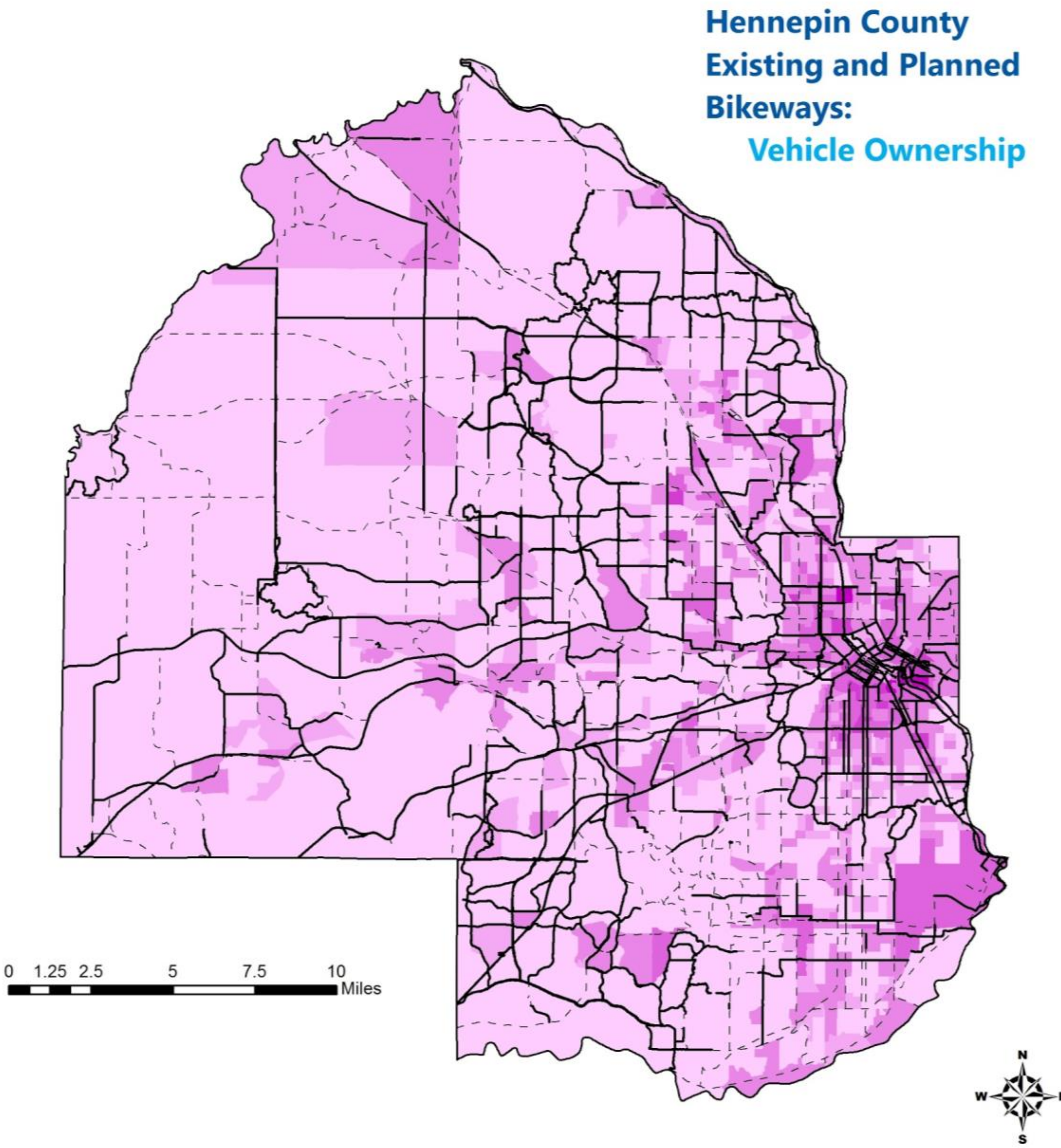
1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

Legend:

		Score:	
——	Existing Facility	yellow line	1
- - -	Planned Facility	green line	2
☐	County Boundary	blue line	3
		red line	4

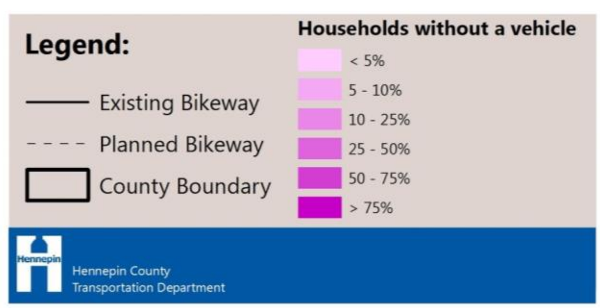
Hennepin County
Transportation Department



Notes:

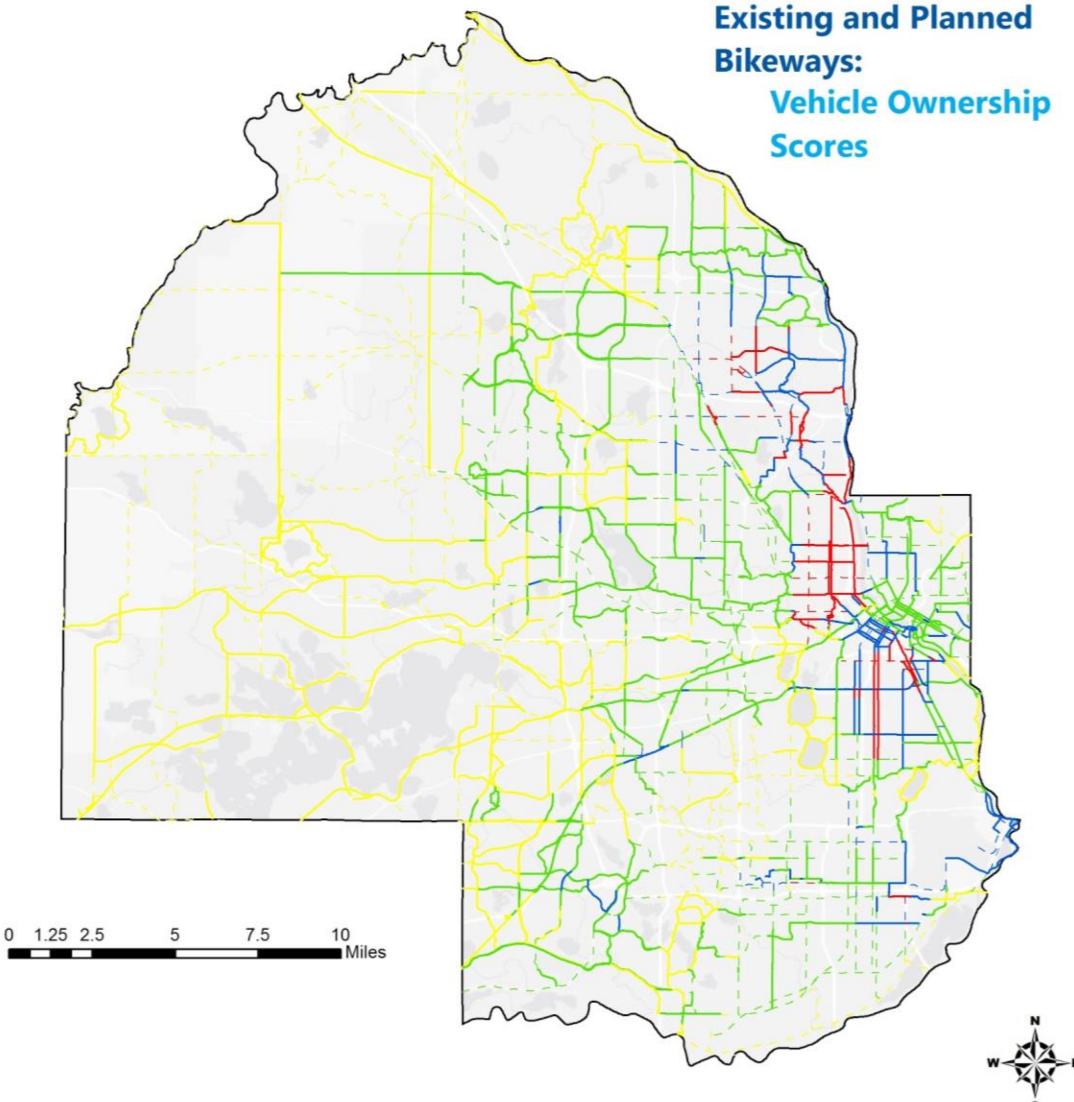
1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015



Hennepin County Existing and Planned Bikeways:

Vehicle Ownership Scores



Notes:

1. Bikeways Data Provided by Hennepin County as of Spring 2017

2. Demographic data from 5-year American Community Survey data 2015

Legend:

- Existing Facility
- Planned Facility
- County Boundary

Score:

- 1
- 2
- 3
- 4

Hennepin County
Transportation Department