A Proposal for a Protected Bicycle Route in Tucson, Arizona, Feasibility and Implications for Public Health and Safety

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Abstract

The city of Tucson is well known for its cycling culture and year-round moderate climate. It is a 'Gold' level cycling community according to the League of American Bicyclists. Less known about Tucson is that it can be a dangerous place to ride a bicycle. In an attempt to improve overall cyclist safety, the idea of implementing protected bike infrastructure is explored. With a focus on using protected bike lanes to create a low-stress network for bike movement, this project creates a rubric, and calibrates it against case-studies in New York City, Chicago, and Washington D.C., to analyze the potential streets in Tucson possess to host protected bike lanes.

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Introduction

Central Tucson receives large amounts of bike traffic, with many people commuting and riding recreationally every day (City of Tucson, 2008). In fact, the bike to work rate in Tucson is over 5 times the national average (City of Tucson, 2015). The Tucson metropolitan region consistently scores well in national rankings as a cycling area. Some of its honors include, its designation as the 9th most "Bike Friendly Community" in the US (Walkscore.com, 2015), 7th in the nation for cyclist commuters per capita (LAB, 2013), and it's 'Gold Level' ranking by the League of American Bicyclists' 'Bicycle Friendly Community' rating (LAB, 2015a).

In 2014, 7 cyclists in Pima County were involved in fatal accidents with motor vehicles, and the total reported count of cyclists involved in a crash was 237 (ADOT, 2014). Despite applying for 'Platinum' status (The highest honor given by the League of American Bicyclists), Tucson's most recent application was denied for a number of reasons, the most striking of which being, too many crashes and fatalities. The region has 5 times as many cyclist fatalities when compared to other 'Platinum' communities (McKisson, 2015). As a city with a strong cycling culture, protecting riders can be achieved by implementing protected bike infrastructure. The effects of increasing bicyclist safety go beyond reducing bike-automobile accidents, it can encourage those who bike, to do so more frequently, and encourage those who do not to start (Rhodan, 2014). The City of Tucson commissioned studies to identify bicycle rider volume throughout the city. A spreadsheet from 2008, illustrates an elaborate scheme of data collected about cyclists, including location, gender, age estimate, and other attributes. The three most trafficked areas recorded in Tucson were respectively, the University of Arizona campus, the Urban Core and Downtown (City of Tucson, 2008). A protected bicycle

route through Central-Downtown Tucson could help ensure locals a safe and healthy daily routine.

Proposing protected bike infrastructure is not outlandish, in Tucson there are brief segments of protected bike path that currently exist. Many cities in the United States have committed to installing protected bicycle routes. New York City and Chicago have installed the largest amount of lanes, but over 53 cities, including Tucson, have at least 1 protected bike lane (Peopleforbikes.org, 2016). The extent of the route this project proposes, is what distinguishes it from existing cycling infrastructure in Tucson. The implications on overall public health and safety and assessing the project feasibility in terms of: city permissions, cost-benefit analysis, and public perceptions, will be the main points of observation.

When creating a proposal for implementing bike protected corridors, the optimal route takes into account maintaining proximity to existing highly trafficked bicycle corridors, and chooses locations that can accommodate the installation of new infrastructure. It is also important to address if Tucson is able to support such infrastructure, and what the main limitations are for seeing a proposal in action.

Literary Review

Studies conducted on the topics of cycling for sustainability, and for increased public health are abundant. There are also many studies focused on bike infrastructure with the intention of increasing overall safety for cyclists and comfort (perceived stress) levels. When examining the growth of bicycle culture in cities that have taken action to provide infrastructure for cyclists, it's important to identify the effects the infrastructure has on the perceived stress of the riders.

Factors that affect Rider Volume

There are a variety of factors that influence why people choose to ride bikes as a regular form of transportation. According to Mekuria, Furth, and Nixon (2012), perceived 'stress' is what can be used to approximate how the built environment influences whether or not people are likely to ride. 'Stress' being a subjective indicator, one approach to understanding its influence, is to divide individuals into categories. An in-depth survey of 902 adults in Portland, by Dill and McNeil (2012), classified riders into four categories, intended to apply to all adults regardless of current cycling behavior. The result of these categories are: the "strong and fearless," those willing to ride in all conditions with or without a designated bike lane, the "enthused and confident" the people who are comfortable riding on streets with designated bike infrastructure, the "interested but concerned" those who feel uncomfortable on any urban street regardless of bicycle infrastructure, and the "no way no how" who were described as very uncomfortable on any bike path or were physically unable to ride.

Low-Stress Networks

Low-Stress Networks are cycling networks, that as their name implies cause low amounts of discomfort to their users, and overall attract the widest possible amount of the population. Simply put, a low-stress network provides routes between origin and destination that do not require cyclists to exceed their tolerance for traffic stress, and do not involve large amounts of detour (Mekuria, Furth, and Nixon, 2012).

Reducing Stress

The majority of people in the Portland study (60%), fell into the "interested but concerned" category. 43% of this group of people said that they would likely ride a bicycle if there were a physical barrier between bikes and automobiles (Dill and McNeil, 2012). This is an enormous amount of potential riders, whose main objection to riding is feeling uncomfortable about their safety. Bikeways with the lowest level of traffic stress between intersections are those physically separated from motor traffic (Mekuria, Furth, and Nixon, 2012). Creating an environment that that encourages this group to ride, i.e. installing protected bike lanes, could immensely increase the volume of overall riders, and that increased ridership includes a multitude of positive effects for the public.

Benefits of Increased Ridership

Riding a bicycle recreationally, or for transportation, can be a very positive action. In regards to health, individuals who exercise 30 minutes a day are at a lower risk of having high triglyceride levels, less likely to be obese, and are more likely to have lower blood pressure (Gordon-Larsen, Boone-Heinonen, Sidney, Sternfeld, Jobs, and Lewis, 2009.). People who commute via bicycle have remarkably lower levels of exposure to pollutants like benzene, which pose a risk to health, when compared to those who commute by car (Chertok *et al.*, 2004). While using the same route in an urban environment, car drivers were exposed to more pollution than cyclists (Rank, 2001). Commuting by foot or bike is correlated with a reduced cardiovascular risk of 11% (Hamer and Chida, 2007). Those who rode bicycles to work were 40% less likely to die, regardless of the amount of physical activity that they did outside commuting, according to the follow-up of a study on 30,000 individuals (Andersen, 2000).

From an economic perspective, bicycling just makes sense. The National Cooperative Highway Research Program (2005) found that individuals who choose to walk or ride just 30 minutes a day, will save between $19 and $1,175 from reduced car maintenance and health care costs, not to mention the average household in the US spends three months' pay per year just on transportation (Center for Neighborhood Technology, 2009). According to Sevick *et al.* (2000), it costs three to four times more to enroll a sedentary adult into a fitness program than to teach them how to integrate moderate-intensity physical activity, like bicycle riding, into their life. Retailers might fear that if someone has commuted there by bicycle, then they are likely to buy less. Clifton *et al.* (2012) showed that while it was true that bicycle commuters tend to make smaller purchases, they also visited retailers more frequently, and spent the same amount of money per month as those who drove. A last thing of note, a 2013 ADOT study found that out-of-state bicycle tourism helped create 721 jobs and brought in $88 million for Arizona annually (ADOT, 2013).

The inspiration for many to commute via bike is environmental concern. Atmospheric CO_2 levels are at the highest ever recorded, 404.83ppm as of a March 2016 reading on Mauna Loa (NOAA, 2016). The U.S. transportation sector emits more CO_2 than any other country's entire economy (Pedroso, 2008). Unger, *et al.* (2010) identified motor vehicles as the greatest contributor to atmospheric warming. With climate change now more than ever a pressing issue, individuals may feel inspired to do their part in reducing greenhouse gas emissions and start commuting by bicycle. Norway has fully realized this and in an initiative reduce pollution, their government plans to spend nearly a billion dollars on bicycle infrastructure, between now and 2030, with the aim of having zero growth in car use (O'Sullivan, 2016).

People for Bikes

The benefits of increased ridership are clear. But what is being done to jump start the effort? Under the domain name 'PeopleForBikes.org' a community of bicycle orientated people have compiled an overwhelming amount of resources to support the blossoming of initiatives with the intention of improving conditions for cyclists at a national scale. The Green Lane Project is a program they have created with the intent of aiding in the implementation of low-stress bike networks for leading cities. A major staple in creating low-stress bike networks is the protected bike lane. To back up their claims, the organization does not shy away from providing reputable full-length reports, statistics and inventories, on the benefits of having protected bike lanes.

Protected Bike Lanes: Definition and Benefits

A protected bike lane can be created differently to best suit a situation, but three characteristics of a protected bike lane according to the Green Lane Project are: first, physical separation exists between motor vehicle traffic and bicyclists. This can be any vertical separation like plastic posts, bollards, parked cars, curbs, etc. So long as the separator is something more than a painted line. Second, the lane is exclusively for cyclists, except for mixing zones where necessary. Lastly, the lane is on or adjacent to the roadway and is not an "off-street pathway." It is okay for the protected bike lane to be separated by landscaping or a median, but it must run parallel to a roadway (Peopleforbikes.org, 2014).

As for the use of the term "protected bike lane" the project claims that this name conveys to people a reassuring feeling of safety (reducing stress), is technically precise, is non-alienating (compared to the term "separated bike lane"), and is easily modified to express form

(e.g. “Bollard-protected bike lane, or “Curb-protected bike lane”) (Peopleforbike.org,2014). Protected bike lanes can be used for unidirectional or ‘two-way’ travel, and can exist on one side, both sides, or through the middle of a road (with traffic on both sides).

Leading by Example

Washington D.C. and New York City were the first two cities in the United States to start building protected bike lane networks. According to census figures released in 2014, the rate of bike commuters in both of these cities has doubled from the years 2009-2014. This has been attributed to their successful bike sharing programs, growing painted line networks, protected bike lanes, and burgeoning bicycle culture (Anderson *et al.*, 2014). Protected bike lanes provide safer and less stressful logistics for individuals to commute by bicycle. When New York City installed a protected bike on its 9th Avenue, it established that there was a 57% drop in injuries to bicyclists, and 84% less cyclists riding on sidewalks (NYC DOT, 2012). Two studies, one published in the Journal for Injury Prevention and the other by the American Public Health Association, found that protected bike lanes reduced the rate of injury to bicyclists at intersections by 75% (Harris *et al.*, 2013), and saw 90% fewer injuries per mile on streets with protected bike lanes (Teschke *et al.*, 2012), when compared to streets and intersections without protected bicycle infrastructure. A Portland State University study done in 2014 found that 96% percent of people surveyed said they felt safer riding in a protected lane (Monsere *et al.*, 2014*).*

Beyond safety, the cost of rent for New York City apartments along pedestrian and bicycle paths increased by 71% in 2010 (NYC DOT, 2011), and when surveyed, 72 percent of the residents of Toronto were in support of having protected bicycle lanes (Rider, 2011). In

Washington D.C. and New York City, the first two cities in the United State to start building protected bike lanes, the Census recorded a doubling in rates of bike commuting from 2008-2013 (US Census Bureau, 2013). The bottom line is, protected bike lanes increase cyclist safety, increase cyclist perception of safety (also reducing stress), encourage stronger ridership, are good for businesses and are desirable to the public.

Bikeleague.org

The League of American Bicyclists (LAB) is a non-profit organization that represents bicyclists. Their mission is "to lead the movement to create a Bicycle Friendly America for everyone." They run programs in the United States to help accomplish this mission. The Bicycle Friendly America (BFA) program, which provides useful information for states, communities, universities, and businesses to improve bicycling conditions. Each year the organization assesses every state, and then provide customized feedback along with a ranking at each level (state, community, university, and business).

Tucson has applied for 'platinum' status before, most recently Tucson was denied for three reasons. The first being, there are not enough individuals commuting by bicycle, when compared to other 'platinum' cities the average bike commuting rate is more than 10% lower in Tucson (McKisson, 2015). The second reason was that Tucson's bicycle-motor vehicle crash rate was far too high, nearly 5 times higher than other 'platinum' communities (McKisson, 2015). Lastly, the League declared that Tucson did not have enough dedicated routes, it also strongly recommended considering innovative solutions like protected bike infrastructure (McKisson, 2015). This rationale makes a strong case that Tucson could become a 'platinum' bicycle community with the aid of protected bike lanes.

City of Tucson

The City of Tucson is interested in bicycles; they conduct regional bike counts to collect data on bicycling trends. The city has also implemented a Bicycle Boulevard Program (shared roadways) to help cyclists safely navigate the city, developed the Loop (100+ miles of shared-use-path), and have installed 2 small segments of protected bike lane in Tucson. Their approach to bicyclist safety has been one that is more pragmatic in nature, and less about increasing cyclist safety at whatever cost.

Funding a Protected Bike Route in Tucson

Across the United States it would appear making bicycle and pedestrian investments are a still low in priority when compared to the amount of money spent on automobiles. Of the entire amount of federal transportation dollars spent, only 1.3% are spent on bicycle and pedestrian exclusive facilities (Advocacy Advance, 2014). A shift in policy could help create more protected bike infrastructure. At a state level, in 'An Analysis of Problems and Priorities in Transportation Planning' by Advocacy Advance, it was found that one of the most important things state DOTs can do is be more transparent. They recommended coordinating more data on a statewide basis and providing more project descriptions. Without increased public funding for projects, it may become worth it for communities to seek out private funding to protect their cyclists.

Methodology

Research and analysis of other protected bike lane projects is the main point of study. Previous projects can give an impression to the limitations and hurdles a project may undergo, utilizing data from other projects is effective in addressing the challenges that will come with

implementing a protected bike lane in Tucson. To answer the question, which streets make good candidates for having protected bike lanes? It was necessary to create a rubric to aid in the process of selection. The rubric scores a 1-mile segment of which the origin is a location that receives a lot of bike traffic (University, Downtown, etc.). The score is dependent on three conditions, type of street, room available on the street, and the number of intersections.

In the urban framework, there exists a hierarchy among streets. For example, an arterial street is one that serves to carry longer-distance flows between important centers of activity, and is laid out as the backbone of an urban traffic network (Neuman, 1992). By definition, from the Pima County Subdivision and Development Street Standard from 2005, Collector roads collect traffic from local roads and distribute them to the arterial roads. Then residential collector roads are the lowest on the hierarchy and typically have a 25 mph speed limit and carry the lowest volume of traffic (Pima County, 2005). On the rubric, the type of street can earn up to 3 points. 1 point for a residential street, this is because neighborhood politics can make these the most difficult streets to introduce infrastructure. 2 points for an arterial street and 3 points for a collector street. The lower traffic volume of the collector street means less noise and pollution exist here than an arterial street, and the city has more grounds to install infrastructure than on a residential street.

Type of Street	Arterial	Collector	Residential
Score	2	3	1

The second factor taken into consideration, is the width of the street. Wider streets make it easier to find the room necessary to install a protected bike path by avoiding private property or without making changes to sidewalks. Wider streets also allow for wider bike lanes

which reduces stress of riders (Mekuria, Furth, and Nixon, 2012). A typical lane for automobile traffic will be between 10' and 12' ft. in width (Federal Highway Administration, 2014). A typical urban bike lane will be around 5' in width (Azbikelaw.org, 2010). So for a street with two-way traffic and a bike lane, we can assume a width of 30' ft. For streets with a center turn lane, or other automobile lanes, an additional 10 feet should be applied to the estimate per lane. For scoring, a two-way street that is wider than 30' will earn 3 points (or for streets with additional lanes, wider than estimated). Between 28' and 30' will earn 2 points, and streets that are less than 28' in width will earn 1 point. Residential streets will be held to the same standards.

Width of Street	Large >30 ft.	Medium 28' – 30' ft.	Small <28 ft.
Score	3	2	1

The last factor that was taken into consideration for the rubric, was the number of intersections. All intersections are taken into consideration, but arterial or collector street intersections pose the greatest risk. Arterial streets that lack low-stress approach and safe crossing, are barriers to low-stress connectivity (Mekuria, Furth, and Nixon, 2012). Many intersections carry such high volume of traffic that it is generally not an option to assume that traffic can be rerouted around bicycle infrastructure. There are steps that can be taken to help ensure cyclist safety at intersections, like Dutch-style intersections (see appendix A), but generally speaking, low-stress routes will have fewer intersections.

# of intersections	3+	2	1 or less
Score	1	2	3

Complete Rubric

Type of Street (Arterial, Collector, Residential)	Points (Residential 1, Arterial 2, Collector 3)
Width of Street (Large (30'+), Medium (28' – 30'), Small (<28'))	Points (Small 1, Medium 2, Large 3)
Intersections (3+, 2, 1 or less)	Points (3+ (1pt.), 2(2pt.), 1 or less (3pt.))
Cumulative Score	**Score (1-9)**

After developing a rubric to address the feasibility of installing protected bicycle lanes, by assessing one-mile segments of road, it can be applied to six case studies. Three segments in cities across the United States which possess substantial protected bike infrastructure (New York City, Washington D.C., and Chicago), and three segments in Tucson. The segments in Tucson were selected by the author both from anecdotal and statistical evidence of their potential value in creating a low-stress network in urban Tucson.

Analysis and Discussion

New York City

New York City has taken great initiative to increasing cyclist safety by installing a groundbreaking 46 individual segments of protected bike lane, of which the average length is 1.2 miles, and the longest 5 miles (Peopleforbikes.org, 2016). According to the New York City Department of Transportation Protected Bike Lane Analysis published in 2014, they had installed 30 miles of protected bike lanes since 2007, crashes with injuries were reduced 17%, pedestrian injury was down 22%, cyclist injuries decreased even as bicycle volume had increased, number of total injuries were down by 20%, the average risk of a serious injury decrease by 75% from 2001 to 2013, compared to similar corridors, streets with protected

bicycle lanes saw greater increases in retail sales, and trees had been added along project areas, enhancing neighborhoods (Trottenberg, 2014).

Vernon Boulevard between 46th Ave, and 38th Ave, Queens, NY is a 1-mile segment along a 3.3-mile stretch of protected bike lane (Peopleforbikes.org, 2016). It was built in 2015, is on one side of the road and provides two-way traffic for bicycles (Peopleforbikes.org, 2016). This location works well for the one-sided design due to it being near the waterfront and lacking intersections (see Figure 1). Cyclists are protected from automobiles with a combination of plastic bollards and concrete jersey barriers (Peopleforbikes.org, 2016).

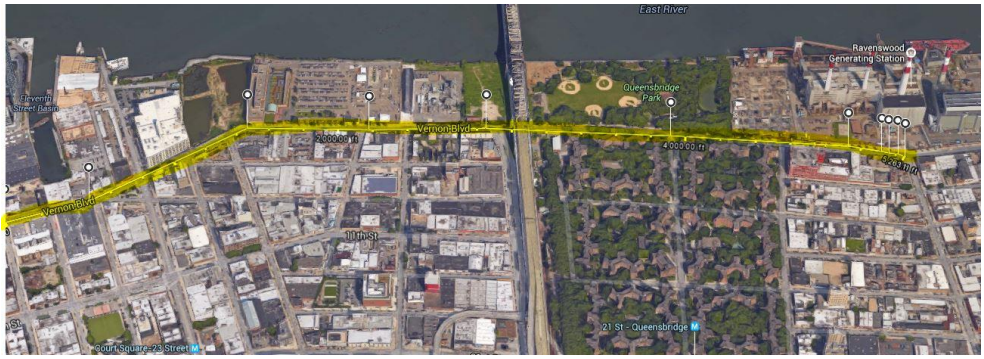

Figure 2. Vernon Boulevard, Highlighted: 46th Ave to 38th Ave. Source: Google Maps

This segment on Vernon did well on the 'Intersection' portion of the rubric, scoring 3 points. Having only one intersections allows for smooth travel along the protected bike lane and has little effect on automobile traffic. In the width category Vernon scores 3 points, for measuring 45 feet across and being a standard two-way street without a turning lane. Finally, Vernon Blvd. is a collector street earning it another 3 points. Earning 9/9 points, Vernon Boulevard is a perfect example of a great street in which to install protected bicycle infrastructure.

Type of Street (Arterial, Collector, Residential)	Collector, **3/3**
Width of Street (Large (30'+), Medium (28' – 30'), Small (<28'))	Large, **3/3**
Intersections (3+, 2, 1 or less)	1 or less, **3/3**
Cumulative Score Vernon Boulevard (46th Ave to 38th Ave)	**Score 9/9 (100%)**

Chicago

Chicago has been busy installing and planning low-stress bicycle networks. The Chicago Streets for Cycling Plan 2020, a plan published in December 2012 by the Chicago Department of Transportation, details a 645-mile bicycle network with the intention of providing the ability to ride safely and comfortably. The plan was developed with parameters to create a network that provides bicycle accommodations no more than .5 miles from every resident, provides greater number of bikeways where population is densest, and increase infrastructure where rider volume is high and establish infrastructure where ridership is low with the hope that it grows. The reason they have put forward such a plan is that the city's Department of Transportation recognizes that bicycling will improve the physical health of its citizens, reduce transportation costs, and increase economic development – all around creating a more attractive city for current and future residents/employers.

To date Chicago has installed 28 separate protected bike lanes with an average length of 0.77 miles, a maximum length of 2 miles, and a total of 21.6 miles (Peopleforbikes.org, 2016). Last year (2015), Chicago installed 2.85 miles of protected lanes and upgraded a few of its

existing barrier-protected lanes to concrete separation (CDOT, 2015). Something of note about the Chicago Department of Transportation publications is that they define protected bikes lanes differently than Peopleforbikes.org, they include buffer-protected lanes as well as barrier protected lanes. In this project the Peopleforbikes.org definition, protected bike lanes are only considered barrier protected lanes, is exclusively used when referring to protected bike lanes.

South Dearborn St. between West Polk St. and West Wacker Dr. was the segments of protected bike lane chosen in Central Chicago (Peopleforbikes.org, 2016). It was built in 2012, runs a total length of 1.25 miles, supports two-way bike traffic and is on one-side of the street (Peopleforbikes.org, 2016). Bicyclists are separated from the street by flexible delineators and parked cars (Peopleforbikes.org, 2016).

Figure 3. South Dearborn St: Polk St. to Wacker Dr. Source: Google Maps

The South Dearborn St. segment scored 1 point in the intersection category, with a total of 11 intersections. The location in Chicago amongst dense population and a tight grid system, it's understandable why there are so many intersections. Considering there are management strategies that can be used to increase cyclist safety at intersections (see Dutch Junction in

Appendix A), this does not necessarily make the segment a bad location for a protected bike lane. As for width, Dearborn is a one-way street with 3 lanes designated for automobile traffic, following the rubric that would mean any width above 40' ft. qualifies this street for 3 points. With a width of 50' ft. Dearborn earns all 3 points. Lastly, Dearborn is a collector street earning it 3 points in the street type category, and a total of 7/9 points possible.

Type of Street (Arterial, Collector, Residential)	Collector, **3/3**
Width of Street (Large (40'+), Medium (38' – 40'), Small (<38'))	Large, **3/3**
Intersections (3+, 2, 1 or less)	11, **1/3**
Cumulative Score Dearborn St., Polk St. to Wacker Dr.	**Score 7/9 (78%)**

Washington, D.C.

The District of Columbia is a perfect setting for cyclists. It covers a relatively small area and commuting by bicycle can be one of the quickest ways to travel. In fact, many people do commute by bicycle in Washington D.C., bike commuting is in excess of 10% of total commuting trips, and providing safe, continuous, and protected bicycle infrastructure has become one of district's transportation administration's current goals (DDOT, 2015).

Between the Whitehouse and the Capital Building, Pennsylvania Ave. between 15th and 3rd streets, the district has built a protected bike path lane that is roughly one mile in length, supports two-way traffic, uses flexible delineators to separate automobile traffic from bicycles and was originally installed in 2010 (Peopleforbikes.org, 2016). After the Washington DDOT installed the Pennsylvania Ave. two-way cycle track, data concluded that there was over a 200

percent increase in bicyclist volume during peak afternoon hours, the volume of motor vehicles remained relatively constant, pedestrians say the encounter fewer cyclists on sidewalks, and cyclists report feeling safer while riding on 15th street (DDOT, 2012).

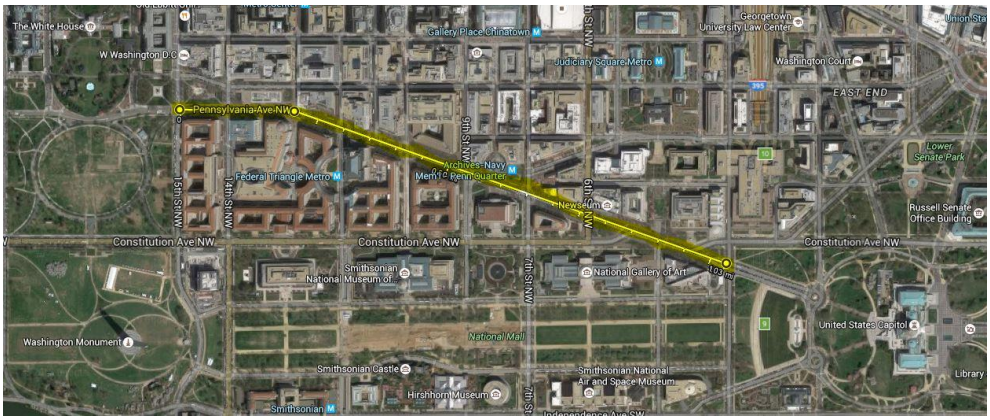

Figure 4. Pennsylvania Avenue, 15th St. to 3rd St. Source: Google Maps

Applying the rubric to Pennsylvania Ave., it earned 2 points for being an arterial street that hosts a large volume of car traffic. It earned 1 point in the 'width' category, measuring 80 feet across this is small for a street that hosts 8 lanes of car traffic and a protected bike lane. As for intersections there are 12, earning it 1 point. Some of the intersections counted are not full crossings, but since the lane is in the middle, cars turning left will have to cross the bike lane leaving a chance for collision.

Type of Street (Arterial, Collector, Residential)	Arterial, **2/3**
Width of Street (Large (90'+), Medium (88' – 90'), Small (<88'))	Small, **1/3**
Intersections (3+, 2, 1 or less)	12, **1/3**
Cumulative Score Pennsylvania Ave. 15th St. to 3rd St.	**Score 3/9 (33%)**

Tucson

Applying the rubric in Tucson, segments where chosen for their proximity to the urban core and University, which according to the City of Tucson's 2009 bike count, received the highest volume of bicyclists.

Volume Rank	Location	VOLUME
1	Park & University	900
2	3rd St/Campbell	856
3	Mountain/Helen	724
4	6th St/Highland Ave	540
5	2nd Street/Highland Ave	533

Figure 5. Top 5 Cyclist Locations according to the 2009 Metropolitan Bicycle Count. Source: City of Tucson

6th St., Campbell to Country Club Rd.

Type of Street (Arterial, Collector, Residential)	Collector, **3/3**
Width of Street (Large (50'+), Medium (48' – 50'), Small (<48'))	Medium, **2/3**
Intersections (3+, 2, 1 or less)	10, **1/3**
Cumulative Score 6th St., Campbell Ave. to Country Club Rd.	**Score 6/9 (67%)**

Figure 6. 6th St., Campbell Avenue to Country Club Rd. Source: Google Maps

This segment, that travels east from the University, scored 2 points for being an arterial street, 2 points for having a width of 48 feet, and 1 final point for having 10 intersections. 6th St. possesses no bicycle infrastructure currently; a route could be made in continuation of this segment to safely connect cyclists from the University to businesses at the El Con mall.

Park Avenue, Helen St. to Water St.

Type of Street (Arterial, Collector, Residential)	Collector, **3/3**
Width of Street (Large (30'+), Medium (28' – 30'), Small (<28'))	Large, **3/3**
Intersections (3+, 2, 1 or less)	14, **1/3**
Cumulative Score Park Avenue, Helen St. to Water St.	**Score 7/9 (78%)**

Figure 7. Park Avenue, Helen St. to Water St. Source: Google Maps

Heading north from campus, a protected bike lane on Park Avenue would contribute a more protected option for cyclists, than the current best northbound low-stress option (taking Mountain Ave). Providing a route on Park could add incentive to provide safe crossing infrastructure at the Park Avenue and Speedway Boulevard intersection, which Bikecolli.com reports having 6 motor vehicle to bicycle collisions (Bikecolli.info, 2016). Park accumulated 7 out of 9 points on the rubric, earning top score in all categories except for number of intersections. Having 14 intersections, Park scored poorly in that category, a reoccurring issue with bicycle routes on Tucson's urban grid.

5th St., Euclid Ave. to Main Ave.

Type of Street (Arterial, Collector, Residential)	Residential, **1/3**
Width of Street (Large (30'+), Medium (28' – 30'), Small (<28'))	Large, **3/3**
Intersections (3+, 2, 1 or less)	13, **1/3**
Cumulative Score 5th St., Euclid Ave. to Main Ave.	**Score 5/9 (56%)**

This segment could serve as a protected alternative route to using University Boulevard west of the University of Arizona. It is primarily on a residential street, thus this route could face opposition from the neighborhood, but it is plenty wide at 50 ft. 13 intersections along the segment do not help its cumulative score.

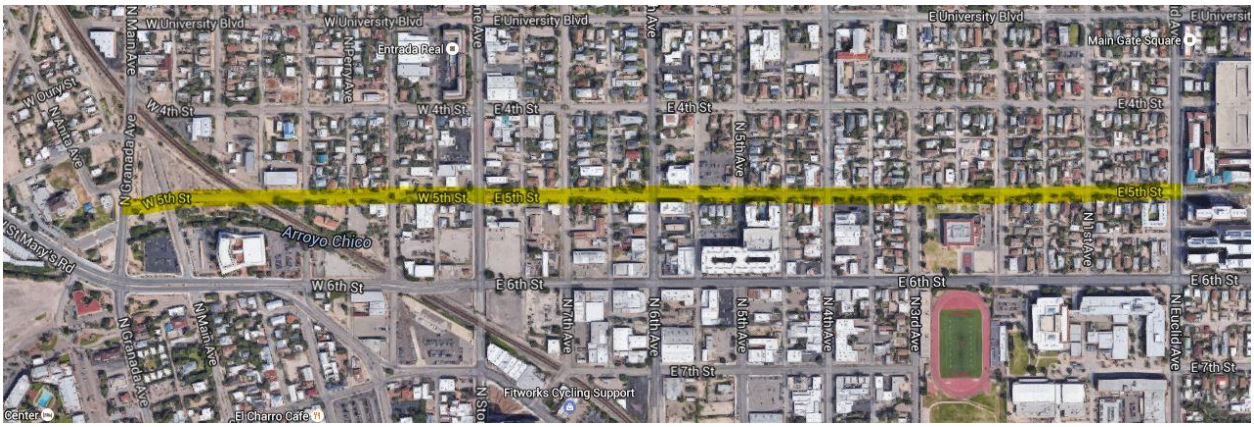

Figure 8. 5th St, Euclid Ave. to Main Ave. Source: Google Maps

Shortcomings of Implementing Bike Infrastructure in Tucson

When discussing the feasibility of introducing any protected bike infrastructure, there are many limitations worth noting. The first major hurdle for any project is securing funding. While insufficient funding is an issue, there are pragmatic solutions, like what the City of Tucson is currently doing, that help address bicyclist safety. In theory, a protected bike lane does not have to cost much more than a normal bike lane. Using plastic bollards or jersey barriers are examples of relatively low cost infrastructure. Jersey barriers provide substantial protection and are simple to install or remove, they could be used in testing routes or permanently.

Figure 9. Jersey Barrier Protected Bike lane in New York City. Source: Streetsblog.org

Another point of discussion when aiming to create a protected bicycle network is, if installation of protected bike routes is to be done in phases, it would be worth creating a system of priority to address areas that are currently most dangerous for bicyclists. Creating the system could be accomplished using collision data along with the rubric developed in this capstone project. Adapting the rubric could address other applications as well, for example applying it to segments of other lengths, or incorporating more data, from newer methods of surveying or more frequent bicycle counts, could create more dynamic routing that could respond to changes in cycling behavior.

Conclusion

In order to maximize bicyclist safety and increase ridership it would be wise for Tucson to continue developing a low-stress bicycle network that includes protected bicycle lanes. This would continue to express the city's interest in being well known for its cycling culture and potentially earn "Platinum" status from the League of American Bicyclists. The rubric utilized by this project is meant to aid in the analysis and drafting of a protected bike route by ranking 1-mile segments. This approach is practical because projects of this nature will be undergone in phases. When this topic was discussed with a city planner, securing funding seemed to be one of the largest limiting factors, a change in policy could help ensure larger allocations of funds for local and regional cycling infrastructure.

Overall there truly is an abundance of information available about the topics discussed in this capstone. As far as limitation to this project go, city governments could be more explicit about their spending and source of funding, this could help further political changes and create greater understanding of why pragmatic solutions are often the best ones, or why there just

really is not enough money invested into cycling infrastructure, but a larger limitation was a lack of technological savvy to create more complex computer models and/or rubrics.

In a continuation of this project it would be advantageous to develop more complex forms of modeling to understand where investment in cycling infrastructure will yield the most net-benefits. Utilizing technology, like heat mapping, that records cyclist movement, could be a more accurate way to collect data than bicycle counts. Bicycle crash records, like those hosted on 'Bikecolli.info' would be worth incorporating into models for route development, then routing could be based off how dangerous a location is along with how practical, and low-stress the route would be (factors addressed in this capstone).

Appendix A

Safe Intersections (Dutch Cycling Infrastructure)

The Netherlands has long been a pioneer when it comes to bicycle infrastructure. Using relatively simple methods they have dramatically increased cyclist safety at intersections by providing infrastructure. The Dutch Junction prevents cars from hitting cyclists while making right turns, makes the entire process of turning easier for a cyclist, and also forces greater visibility of the cyclist from the automobile lane.

The Dutch Junction. Source: Bicycledutch

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