Breaking the Barriers

How Bicycle Boulevards Can Move the City

Jenny Leijonhufvud School of Landscape Architecture The University of Arizona Spring 2009

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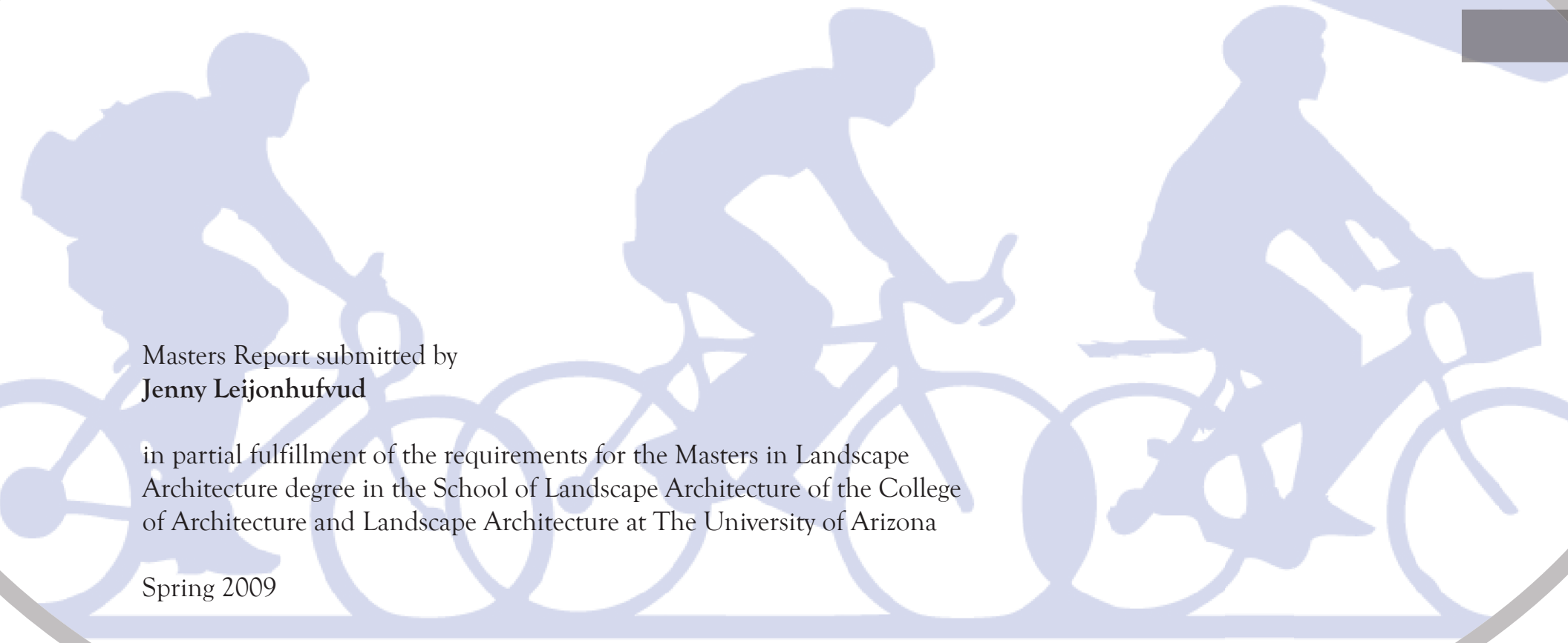

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Abstract

Despite the increasingly apparent costs of car dependence on household finances, health and the environment, most Americans choose to use their car even for very short trips. This choice is most often attributed to barriers such as perceptions of safety or security, convenience and comfort. At the same time, the dearth of good transportation alternatives continues to disproportionately disadvantage groups too young, old or poor to have ready access to a personal automobile.

This work seeks to directly address these identified barriers, and expand the potential for safe and efficient bicycle travel for both transportation and recreation, through the development of a bicycle boulevard network within the City of Tucson.

The final product consist of three parts: a GIS-based model for determining bicycle boulevard suitability corridors and existing barriers; a Design Toolbox to guide the design and implementation of a bicycle boulevard network in Tucson, Arizona, and the conceptual design for two pilot bicycle boulevard routes in the city.

The GIS model relies on data for existing transportation infrastructure, accidents, crime rates, demographics, and popular destinations to determine areas most suitable for routes that create well-articulated linkages and synergy points

The Design Toolbox is both descriptive and prescriptive in establishing guidelines for the future fruition of a coherent bicycle boulevard network, and is meant to underlie and inform future bicycle boulevard design and implementation by the City.

The final Design section articulates the specific design elements of two highly suitable routes that will serve as pilot bicycle boulevard projects, one of which is set to begin construction later this year.

Research Context

The rapidly growing metropolis of Tucson, Arizona in many ways embodies the situation of most western American cities. Built predominantly after wide-spread car ownership in America, the city itself is made to cater to the automobile commuter and consumer. Ubiquitous large parking lots, drive-throughs, driveways, wide multi-lane roads, and the ever-expanding margins of the city are witness to the predominance of this mode of travel. At the same time, increasing congestion, rising costs, and a growing consciousness regarding the negative environmental and health effects of a car-based lifestyle are encouraging a growing reconsideration of transportation choices. While it is increasingly clear that current automobile dependence is both unsustainable and undesirable, the road away from this pattern is less clear.

Re-building our cities as denser, more walkable and transit-friendly environments could help resolve problems long-term, but more immediate solutions are also needed. The question is how to make a city built for cars encourage the already available transportation alternatives of public transit, walking and bicycling, without relying on a prohibitively costly and unrealistic large-scale transformation of the entire city.

A method for understanding and identifying key barriers to bicycle transportation use, as well as addressing these barriers with realistic, focused design solutions, is developed in the document that follows.

Introduction

There are perhaps only a few aspects of society as important as transportation. Good transportation is essential not only for connecting people to jobs, health care, schools, and family, but also for contributing to economic growth and development. Transportation also has fundamental impacts on the landscape. The physical infrastructure of transportation: roads, tracks, sidewalks, highways, paths, waterways and airports, shape all human settlements. It is clear that a village where everyone travels by foot both looks and functions very differently from a town where most trips involve a car. Our transportation choices therefore have far-reaching implications for the way we build our communities, how we spend our time and our resources, and deeply impacts the environment and human health.

In America, the overwhelming majority of all travel involves a personal automobile. According to data collected from the 2001 Nationwide Household Transportation Survey (NHTS), public transit in America captures only 1.76 percent of all personal trips, and about 5.1 percent of all work trips. Bicycling and walking make up approximately another one percent of work related trips. At the same time, only less than one percent of all automobile trips in this country are purely for pleasure (Hanson and Guiliano 2004). Even in sprawling American metropolitan areas, 41 percent of all trips in 2001 were shorter than 2 miles, and 28 percent were shorter than 1 mile (Pucher and Renne, 2003). That means close to 95 percent of all trips taken in this country are in a car, yet almost half of these trips were short enough to be easily accomplished by most people on foot or bicycle. In much of the industrial world, and in the United States in particular, personal automobile use has helped create destructive patterns of inefficient land use, sprawl development, high personal transportation costs, sedentary living, long commutes, congestion, pollution, and fossil fuel dependence that leave many feeling increasingly trapped instead of liberated (Hayden 2003).

Close to 95 percent of all trips taken in this country are in a car, yet almost half of these trips were short enough to be easily accomplished by most people on foot or bicycle.

Although Americans do choose their cars for almost every trip, surveys indicate that Americans want to make changes, but too often find other transportation options are lacking in some regard. The 2003 survey Americans Attitudes Toward Walking and Creating More Walkable Communities found

that 38% of respondents would like to walk to work, and 80% would like to walk more for exercise (STPP 2003). A National Center for Health Statistics poll in 2003 also found that 52 percent of Americans would like to bicycle more, and that if given a choice, 55 percent of Americans would rather walk than drive.

At the same time, car-based development can mean isolation and dependence for non-driving populations such as the elderly, the poor, children, youths, and the disabled (AARP, 2005; Hillman and Adams, 1995; O'Brien, 2001). Nationwide, over 90 percent of individuals on public assistance do not own a car (Brown, 2007). In 2000, households making less than $25,000 per year made up 22.5 percent of all households, but their travel comprised only 15.2 percent of all vehicle miles (Hanson and Giuliano, 2004). In communities where driving is prioritized, the inability to drive limits access to essential components of economic, social and physical well-being such as jobs, schools, and health care. These numbers indicate that an investment in reducing barriers to the affordable and more readily accessible modes of walking, bicycling and alternative transportation, implies greater equity and opportunity to non-drivers.

Personal automobile use has helped create patterns of inefficient land use, sprawl development, high personal transportation costs, environmental degradation, sedentary living, long commutes, congestion, and fossil fuel dependence.

Automobile dominated transportation also effects our environment in a number of ways. Fossil fueled vehicles emit a slew of damaging pollutants, including fine particulates that have damaging effects on human health, and carbon dioxide, which has been linked with global warming. In 1997 vehicles in the United States accounted for 20 to 25 percent of worldwide transportation emissions of greenhouse gasses (Transportation Research Board, 1997). Not only do fossil fuel vehicles emit a large number of pollutants, transportation facilities such as roads, highways and parking lots cover a large portion of urban surface areas. These large, exposed surfaces absorb, then re-radiate heat, and help create the urban heat island effect. These swaths of impervious surface also affect watersheds, and liquid, solid and gaseous pollutants that settle on these surfaces are carried as runoff into watercourses.

In addition to environmental benefits, catering to preferences, and providing for equity, walking and bicycling more can also have great health benefits for the individual. Public health research has shown that incorporating physical activity into daily transportation behavior has clear health benefits. The World Health Organization concluded in 2000 that public transportation is associated with higher levels of physical activity, and lower levels of obesity. Leading medical journals have shown that walking and cycling for daily transportation as the cheapest, safest, and most realistic way to increase the physical activity of Americans, and reduce the multitude of negative health effects of sedentary lifestyles (Hanson and Guiliano 2004).

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There are of course good reasons why we choose our cars for transportation. Accessibility and mobility are the key. These are the two main concepts of transportation planning, as accessibility refers to the number of access points available within a distance or travel time, whereas mobility refers to the ability to move between any two given points (Hanson and Giuliano, 2004). The great advantage of the car, and the reason it is so popular, is that it offers both high levels of accessibility and mobility. Automobiles, moving within an infrastructure that is made for them, provide versatile, adaptable and comfortable freedom of movement not only between two points, but also among any number of places all in relative privacy and comfort. While cost and journey time considerations increasingly act to reduce the relative advantages of the automobile, a

competitive alternative transportation system must find a way to offer comparable or superior levels of accessibility and mobility.

At the same time, it is important to remember that transportation solutions requiring enormous public and private investments are by their very nature unable to change anything very quickly. In the 1970's and again in the 1990's rail transit was viewed as the solution for problems from long commuting times to pollution, but the enormous investments required left that solution largely untested in most cities (Hanson and Giuliano, 2004). Now some speculate that alternative fueled vehicles will make all the environmental objections to automobile dependence obsolete, but even perfectly clean vehicles would not resolve problems with sedentary lifestyles, sprawl, road infrastructure, impervious surfaces, congestion, heat islands, and equity. Although

Even a perfectly clean automobile would not resolve existing problems with sedentary lifestyles, sprawl, road infrastructure, impervious surfaces, congestion, heat islands, and social equity.

large investments in developments such as rail service and cleaner vehicles are certainly important, smaller, faster and less expensive changes also play a vital role in effectively changing the system.

As proposed below, part of the solution necessarily lies in identifying what elements of alternative transportation systems are limiting their use, then targeting those barriers specifically. Partial solutions to the big problem of automobile dependence may therefore be found in small, realistic changes to the existing city fabric. The research outlined below builds on increasing connectivity between modes through mobility hubs, and increasing safety and convenience of biking and walking through the development of a well-articulated bicycle and pedestrian boulevard network that utilizes existing street infrastructure.

Research Program and Study Parameters

In order to determine where and how to improve alternative transportation infrastructure, it is necessary to understand how the facilities and resources currently available are failing the transportation consumer. This study seeks to understand physical barriers to bicycle use, identify the specific instances of these barriers in Tucson, Arizona, and then develop design solutions that specifically target these barriers. The ultimate goal of the project is to develop design interventions that work within the current city framework to make alternative forms of transportation more viable options to driving for people traveling within the Tucson urban core.

The project involves three fundamental steps: understanding barriers and other already attempted design-based solutions through literature review and case reviews, site analysis and localized barrier identification through a GIS-based model, and site-specific problem resolution through focused design-based strategies. This final design product evolved in collaboration

Walking and cycling for daily transportation as the cheapest, safest, and most realistic way to increase the physical activity of Americans.

with the City of Tucson Department of Transportation (TDOT) and the local community, and includes a general bicycle boulevard master plan, as well as specific design solutions for two pilot routes.

The document is organized into three main sections: foundation, analysis and design. The first section includes the literature review and case reviews. The second section includes an explanation of the method employed, and the results of the GIS-based site analysis. The final section includes the final design solutions engendered by the process.

Definitions

Barrier:
Physical barriers to travel such as rivers, railroads, path ends or other impediments to continuity, as well as psychological limits such as comfort and fear for safety or security.

Bicycle Activated Signals:
Bike buttons, infrared motion detectors, pressure mats or other technologies that assist bicyclists in crossing signalized intersections by allowing a cyclist to activate the signal cycle either actively or passively.

Bicycle Boulevard:
A Shared Roadway that has been modified with traffic calming devices, safer street crossings, and bicycle amenities to prioritize the safety, comfort and convenience of bicyclists and to appeal to a broad spectrum of bikers. Bicycle Boulevards are meant to discourage cut-through motor vehicle traffic, while at the same time giving priority to bicyclists as through-going traffic.

Bicycle Facilities:
"A general term denoting improvements and provisions made by public agencies to accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically designated for bicycle use." (AASHTO, 1999)

Bicycle Lane or Bike Lane:
A portion of a roadway which has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists. (AASHTO, 1999)

Bikeway:
"A generic term for any road, street, path or way which in some manner is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes." (AASHTO, 1999)

Bioclimatic Design:
"Designing for human comfort by relating temperature and humidity conditions, while minimizing energy needs " (Harris and Dines 1998)

Chicane:
Curb extensions that alternate from one side of the street to the other, forming S-shaped curves in the roadway. Chicanes can also be created by alternating on-street parking, either diagonal or parallel, between one side of the street and the other.

Choker:
Similar to a Chicane, but achieved by placing edge islands opposite each other without staggering them.

Closure:
Closures stop vehicular thru-traffic. Full closures restrict motor vehicle movement entirely, while a partial closure may restrict only some movements.

Designated or Signed Shared Roadway:
An existing street system deemed suitable for bicyclists and signed or identified on bike maps to help provide continuity and way-finding, but otherwise unimproved for bicycle travel.

Diverter:
Direct cars to alternative routes, often main thoroughfares better suited for vehicular traffic, while allowing bicycles and pedestrians to safely continue along the route.

HAWK:
High Intensity Activated Crosswalk
Button activated, on/off light-controlled crossing that remains dark unless activated.

Horizontal Separation:
Segregates modes from each other on the same plane. This involves sidewalks, pedestrian paths and trails, and indoor walking areas that preclude vehicular traffic sharing the same space. (Ribbens 1996).

Paved Shoulder
An existing street with a section of pavement outside of the striped vehicular lane deemed suitable for bicyclist travel, but not meeting the standards of a Bicycle Lane.

Right-of-Way:
Land, property or interest therein, usually in a strip, acquired for or devoted to transportation purposes. Alternatively, the right of one vehicle or pedestrian to proceed in a lawful manner in preference to another vehicle or pedestrian.

Shared Roadway:
A roadway which is open to both bicycle and motor vehicle travel.

Shared-Use Path:
A bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers and other non-motorized users. (AASHTO, 1999)

Soft Separation:
Does not segregate modes but instead focuses on a safer, more cautious sharing of the same space and time. Soft separation devices are commonly referred to as 'traffic calming devices' and include Traffic Circles, Speed Humps and Speed Tables, narrowed sight lines and blurred boundaries between different paths. (Ribbens 1996)

Speed Control:
Speed control measures address speeding problems by changing vertical or horizontal alignment, or by narrowing the roadway. Speed control measures include Speed Humps and Speed Tables, Raised Crosswalks, Neckdowns, and Center Island Narrowings, Chicanes, Chokers and Traffic Circles.

Speed Humps and Tables:
Speed humps are raised, rounded segments of pavement 3-4 inch high and 12-22 feet long. Speed tables are raised 18 to 22 feet long, flat-topped pavement or pavers. Speed Humps and Tables are some of the most effective speed control devices used today.

Time Separation:
Segregates modes form each other in the same space by utilizing it at different times. These times can be strictly coordinated using lights or crossing monitors such as in school zones, or be indicated through pavement markings for pedestrian crosswalks or bike boxes that allow bicycles to stop at lights in front of vehicular traffic (Ribbens 1996).

Toucan:
A full light-controlled crossing for both pedestrians and bicyclists.

Traffic Calming:
A series of physical treatments meant to lower vehicle speeds and volumes by limiting the maximum speed that can be comfortably maintained along a given stretch, and/or creating the visual impression that certain streets are not intended for high-speed or cut-through traffic. Examples of these include Speed Humps, Chicanes, and Traffic Circles. (Federal Highway Administration)

Traffic Circle:
Raised island, placed in an intersection, around which traffic circulates.

Traveled Way:
The portion of the roadway for the movement of vehicles, exclusive of shoulders. (AASHTO, 1999)

Vertical Separation:
Segregates modes from each other by grade differentiation. This can be through over- and under-passes, as well as raised and sunken walkways and paths, curbs, medians and other physical barriers. (Ribbens 1996).

Walkability:
The quality of walking conditions including safety, comfort and convenience (Litman 2003)

Zebra Crossing:
Striped white or yellow lines painted on a street indicating a pedestrian crossing or a pedestrian right-of-way. (http://www.duhaime.org/LegalDictionary/Z/ZebraCrossing.aspx)

Literature Review

This literature review seeks to identify the commonly agreed-upon barriers to alternative transportation use through an exploration of the vast mode-choice literature produced in Transportation and Public Health research. By developing an understanding of what prevents individuals from choosing alternative modes, these barriers can be identified and resolved in the subsequent steps of the project. The literature review also includes a review of design strategies that address the barriers identified in the literature, as well as a vital inventory of current transportation trends and patterns within the City of Tucson.

1. Mode Choice

Every day people all over the world leave their homes and travel some distance for work, school, shopping, social activities and recreation. How they choose to get there and back varies, however. In comparison to other countries, for example, the United States has very low shares of walking and transit use (Hanson and Guiliani 2004). Understanding the motivations behind transportation choices, specifically the barriers that prevent choosing available alternative transportation options, can be of great importance for directing any targeted shift in mode use.

The transportation modes addressed here reflect the scope of the final design application of this document by focusing on walking and biking, as well as bus connections to these modes. Together these three modes of transportation are defined, for the purposes of this work as well as many scholarly studies, as alternative transportation. Some of the barriers to alternative transportation modes are identified and discussed below and may influence one mode differently from another. These differences must be acknowledged and understood, but when seen as a complete system, barriers to utilizing one mode may create barriers to using another. For example, walkability, or the extent to which the built environment is friendly to people moving through and spending time in an area, may also influence the viability of using a bus that stops several blocks from an intended destination.

There are various approaches to trying to understand why people choose the mode they do, and the literature has come to different explanatory conclusions. In a

classic work, McFadden (1976) reviewed all the variables used in mode choice models up to that time, and concluded that the variables with critical explanatory significance were travel cost, travel time, access to public transport, number of people in a household who can drive, and income level. Such models imply that the choice of mode is a function almost exclusively of socio-economic factors.

On the other hand, a large body of work on spatial variation in mode choice has identified links between the built environment and travel behavior. For example, Cervero and Radisch (1996) show that those living in compact, mixed-use and pedestrian-oriented areas tend to make more non-work trips by walking, cycling and public transport than those in more typical American suburbs.

Stated preference and other surveys tend to identify a mix of socio-economic and environmental factors as significant in determining mode choice. A 2005 study of bicyclists in Portland, Oregon for example, found that cycling in traffic, incomplete routes, motorist behavior and the quality of facilities (such as surface condition and signage) were the four most influential factors

Table 1. Main Barriers to Alternative Transportation Use and Potential Facilitators

Theme	Barrier	Potential Barrier Facilitator
Trip Complexity	Need to complete a variety of errands quickly and efficiently.	Central hub areas that accommodate a variety of one-stop errand completions in connection with multi-modal transportation. Secure bike facilities in all commercial areas and in conjunction with other modes of transportation.
Travel Time and Distance	Long distances between destinations and the segregation of land uses.	Zoning and land use changes to accommodate residential, commercial and industrial areas within easy travel distances of each other. Dedicated paths and routes for more rapid, longer distance travel.
Purpose of Trip	Carrying loads, large groups.	Cargo carriers, more options in transportation, shorter distances between potential destinations.
Flexibility	Dynamic conditions in trip purpose, route need, weather.	Shelter and thermal regulation, timely, frequent and reliable transportation. Connected multi-modal transportation options.
Perceptions of Safety/Security	Exposure, traffic, isolation, and lack of secure facilities for personal belongings.	Pedestrian and bike prioritization in street design, dedicated infrastructure for cycling, facilities for secure storage. Visible security presence, clear sight lines, hubs and stops in well monitored, peopled areas.
Social Perceptions of Transport	Social stigma of public transportation, norms, habits.	Promotion of alternatives, comfort, convenience and safety improvements.
The Built Environment	Priority placed on vehicular travel. Inadequate connectivity and continuity of paths and routes. Distances between destinations.	Mixed land use to provide variety of services. Improved pedestrian and bike facilities. Improved connectivity between modes and routes. Continuity and variety of paths and routes. Paths and routes between residential areas and common destinations. Storage, showering and changing facilities. Connected, multi-modal system that allows for mode changes and flexibility.
Weather and Seasons	Extremes in temperature, precipitation, exposure and lack of predictability in weather.	Adequate shelter at stops and hubs. Shelter, water, and thermal regulation along bike and pedestrian paths. Facilities for storage, showering and changing. Connected, multi-modal system that allows for mode changes and flexibility.

on choosing weather or not to bicycle (Bicycle Transportation Alliance 2005).

A review of the major findings in the mode choice literature of Urban and Transportation Planning, as well as Public Health and Psychology, indicates that modal transport choices in cases around the developed world are mainly influenced by seven general factors: trip complexity (Hencher and Reyes 2000), travel time and distance (Hess et.al. 2007; Stone et. al. 2003; Krizek et. al. 2007), purpose of trip (Stone et. al. 2003), perceptions of safety/security (Cleland et. al., 2008; Stone et. al. 2003), relative cost (Hensher 1998), perceptions of transport including familiarity and habit (Cleland et. al. 2008; Stone et. al. 2003; Stern 2000), and a variety of features within the natural and built environment. Although separated here, a great deal of overlap exists between these factors. Specifically, various environmental components are included in almost all of the other six factors. In some cases, barriers to choosing alternative transportation can be resolved simply through physical changes in the environment.

I: Non-Environmental Barriers

While it is necessary to examine the potential influence of environment on mode choice, it is also key to understand other factors besides environmental influence such as cost and trip purpose. It is also important to distinguish between the various forms of transportation alternatives, and to understand how the identified barriers variably affect walking, bicycling, and buses. Understanding exactly what kind of barriers can be targeted is essential to determining how to make realistic and sound changes in physical infrastructure to realize shifts in mode choice. Table 1 summarizes the main barriers identified in the literature, and some of the potential facilitators for overcoming these barriers. A more thorough discussion of these themes follows.

Trip Complexity

The research in Transportation Planning has found that trip chaining, or including multiple destinations on one trip, is a growing phenomenon in travel behavior. Rising demands on people's time budgets has increased the need to perform a series of different tasks during a single trip. This search for ways of completing a greater number of tasks and activities with less travel time has produced a number of responses, one of which is trip chaining. A particularly important policy implication of trip chaining is the potential barrier it creates in attracting car users to switch to public transport. Hencher and Reyes (2000) find that as the trip chains move from being simple to complex in nature, the relative utility gained from using public transport decreases. In other words, the benefit associated with the use of the car increases as the complexity of a trip chain increases.

Travel Time and Distance

A trip is often defined by how much time it will take and, as a connected function of time, the distance that must be covered. In 1994 the National Highway Administration estimated that while 90% of all trips are taken by car, 27% of these trips were less than one mile long, and a full 40% were less than two miles long (Moudon and Lee, 2003). Although many trips by car are not so long as to necessitate it, it is clear that alternative modes of transportation can become less viable to consumers if a trip on an alternative mode takes significantly longer than driving a car would. What may be slightly less obvious is that alternatives will also be less attractive as journeys become longer even if the time use is equivalent or even lower, if the alternative is perceived as less comfortable than the car. The reverse may also be true if the alternative is perceived as more enjoyable than driving. Research indicates, for example, that time spent cycling in mixed traffic is perceived of as longer than time spent cycling in bike lanes (Hunt and Abraham 2006) and that the ability to combine transportation and recreation increases the attractiveness of

> Predictability in travel time is particularly important to those who enjoy less flexibility in work times, work for hourly wages, or have low levels of job security

biking and walking.

Differences between modes are also crystallized when considering travel distances. For most travelers, walking and bicycling become increasingly less viable as distances grow longer (Hunt and Abraham 2006), whereas rail service and buses that free the commuter to work, read or sleep while traveling could become more viable. Transportation planning has identified short journeys as the target for increasing walking and cycling, and due to cost, higher usage journeys for public transport such as buses and rail services (Stone et. al. 2003). Alternative transportation is therefore generally seen along inner city routes between denser areas where alternatives can compete with automobiles for time efficiency due to congestion and parking dearth (Stone et. al. 2003).

An additional significant factor of travel time is predictability. The ability to anticipate the time needed to perform a commute is important particularly for work related transportation. Research has indicated that travel time predictability is valued, on average, as more than twice as important as travel time savings (Asensio and Matas 2007). The literature also provides some evidence that predictability in travel time is particularly important to those who enjoy less flexibility in work times, work for hourly wages, or have low levels of job security (Kingham et. al. 2001; Hess et al. 2006; Asensio and Matas 2007).

Purpose of Trip

The purpose of a trip can discourage the use of most transportation alternatives relative to the personal automobile (Stone et. al. 2003). This is primarily true when the trip requires transporting loads, and when the group size is larger, particularly when it includes elderly or ill people, and families with young children. In a large survey, researchers found that carrying goods was the most common reason for driving a car on a short trip (Mackett 2003). Hencher and Reyes (2000) found that the utility of a car increased when children were present, and that this was due mainly to the children's needs contributing to the complex nature of the trip, and to the increased size and frequency of carrying loads such as groceries.

Flexibility

A lack of flexibility has been identified as a major barrier to choosing transportation alternatives when the transportation system makes dynamic travel plans, times or routes difficult. The ability to respond to changing weather, schedules and travel demands, and to connect multiple modes and routes in a convenient and accessible way, is a major priority for a successful alternative transportation system. Stone et. al. (2003) find that in their survey work some of the very highest priority was placed on modes of transport that were "accessible, convenient and easily accommodated within a daily routine."

Perceptions of Safety/Security

Across modes, perceptions of personal safety and the security of property are key inputs for transportation choice (Stone et. al. 2003, Pucher and Dijkstra 2000.) Perceived road safety, for example, has been positively associated with higher levels of walking and bicycling for leisure, as well as transportation (Cleland et. al. 2008; Hunt and Abraham 2006). Hunt and Abraham (2006) further find that secure bike locking facilities were more important than showers at the destination for encouraging bicycle use.

Perceived road safety has been positively associated with higher levels of walking and bicycling for leisure as well as transportation.

Survey work has found that fears for personal safety were reported by both genders for all alternate transport modes, particularly within central city areas, and at night (Stone et. al. 2003). Identified as particularly vulnerable were children walking to and from school, older patrons waiting alone at transit stops, and cyclists on motor vehicle dominated roads (Stone et. al. 2003). These same participants identified moving in groups at night, safety infrastructure on roads, end-of-trip facilities for cycling and a visible security presence on public transport as strategies that

increased their sense of safety and security, and thus their likelihood to utilize alternative modes of transportation.

While environmental factors alone do not determine perceptions of safety, the safety of the built transportation environment is essential to successfully encouraging people to use it. Dangers from interactions with motor vehicles tend to dominate the safety concerns of most walkers and bikers, while the danger of isolated and un-monitored spaces concerned public transit users (Stone et. al. 2003).

Providing infrastructure for cycling and walking in the form of off-street paths dedicated trails, or prioritized routes is critically important for increasing perceptions of safety. Indeed, when provided with a dedicated bike trail, bicyclists travel on average 67% longer in order to include this trail facility on their route (Krizek et.al., 2007).

Relative Cost

While it is clear that the price of transport is important to mode choice, it is also clear that cost alone is not the determining factor for most consumers. Households that rely exclusively on non-motorized modes of transport and public transportation spend only about 3 to 5 percent of their income on travel, while that percentage rises to an average of 10 to 15 percent for people who own at least one motor vehicle (Schäfer and Victor 2000). Although alternative modes of transportation may be less expensive to the consumer, the actual cost difference of a given trip can be negligible for car owners who are already paying for insurance, depreciation and fixed costs regardless of frequency of use. Mackett (2003) found through survey work that cost was not a big factor in encouraging people to use, or not use, their existing car. It is primarily in the ability to provide a car-free life style that transportation alternatives can provide truly significant relative cost saving to the average consumer.

Perceptions of Transport

In psychology, transportation mode choice has been analyzed with such variables as social value orientation, trust in others, and environmental concern and awareness of the environmental problems caused by car use (Heath and Gifford 2002). Transportation research has also focused on personal capabilities like skills, and knowledge of how to use public transport, as well as contextual factors, such as rules and regulations in society and norms, beliefs, and values (Garvill et. al. 2003). Previous research has shown that attitudes to travel modes are significant for the choice of whether to travel by car, bicycle, or bus (Hoey and Levinson 1977; Nordlund and Garvill 2001). The most significant perception barriers have been identified as vehicle dependence as a social norm, habit, and considering public transportation as "second class" (Cleland et. al. 2008; Stone et. al. 2003).

II: Environmental Factors

Examining the role of landscape architecture in influencing mode choice necessitates a specific emphasis on understanding the link between the built environment and mode choice. Since the 1970's transportation planning research has produced a large volume of investigations into the relationship between the built environment and travel behavior (Crane 2000; Scheiner and Holz-Rau 2007). At the same time, a great deal of attention has been turned to understanding the sociological, demographic and life-style reasons that underlie neighborhood choice, as well as how "self-selection" might explain some of the observed differences in mode choice between different kinds of neighborhoods (Scheiner and Holz-Rau 2007, Vance and Hedel, 2008, Mokhtarian and Cau 2008). Studies have recently tended to stress that there are complex interdependencies between the socio-cultural and environmental reasons that underlie of travel behavior, but that there is a fundamental and direct connection between the built environment and travel behavior. Policy makers and planners are now looking to this literature for direction in modifying the built environment, and shifting individual

> In some cases, barriers to choosing alternative transportation can be resolved simply through physical changes in the environment.

travel behavior away from car dependency (Guo and Chen 2007).

The research looking at environmental factors occasionally focuses on a singular characteristic such as density (Newman, 2001) but most commonly examines the influence of a variety of characteristics labeled variably as "neighborhood character," (Cao et. al. 2007) "design" (Crane and Crepeau 1998, Moudon et. al. 2003, Cleland et. al., 2008 Cao et. al., 2007), the "built environment" (Guo and Chen 2007, Susilo and Maat 2007, Saelens et. al. 2002) and "urban form" (Handy 1996). The actual components of each of these labels are very similar, however. Other than safety, which has been discussed above, the general environmental elements that have been identified as the most influential on travel behavior are: land use, connectivity, safety, and aesthetics. These four elements will be discussed in more detail below.

Land Use

Low-density suburban sprawl is one of the key factors cited by all studies for the long-term rise in automobile use and the decline in public transportation. Urban planning and design has in the last decade become increasingly focused on the potential of developing and renewing neighborhoods with a mix of land uses through movements of smart growth, transit-friendly design, transit joint development, and transit oriented development. All of these movements aim to re-create the compact, transit-friendly land use patterns found in Europe, and that were traditionally present in most American cities (Hanson and Guiliano 2004).

The idea that the built environment is linked to individual travel behavior is not a novel one. In 1958, the Chicago Area Transportation Study revealed an inverse relationship between auto ownership and population density, and the following year, the Highway Research Board Bulletin 230 also showed population density as a major factor influencing transit and automobile use in urban areas (Guo and Chen 2007). These Studies in transportation planning have found that residents living in neighborhoods characterized by high density, high accessibility, mixed land uses and rectangular street networks, drive less and walk more than those living in neighborhoods without these characteristics (Cervero and Duncan 2003; Crane and Crepeau 1998). Indeed, the results of many studies indicate a direct relationship between proximity to destinations, along with providing alternative transportation options, and less driving (Cao et.al. 2007). All over the world, residents in communities with higher density, greater connectivity, and more land use mix report higher rates of walking and cycling for utilitarian purposes than those in low-density, poorly connected, and single land use neighborhoods (Saelens et. al. 2002).

A key component of changing transportation choices in the long term is therefore encouraging the development and redevelopment of residential areas proximal to a variety of services, commercial and retail centers (Krizek et. al., 2007). These kinds of fundamental changes are, however, by nature slow and costly, and smaller incremental changes to the existing physical environment, such as improving connectivity, can provide significant benefits to walking, biking and utilizing public transportation in the short to medium term.

Studies in transportation planning have consistently found that residents living in high density, high accessibility, mixed land use neighborhoods with rectangular street networks, drive less and walk more.

Connectivity

Connectivity alone can encourage alternative modes of transportation (Levine and Frank, 2007). Connectivity, the ability to move directly between two desired destinations utilizing a single path, or with an easy transition between paths, demonstrated strong positive associations with walking for transport (Krizek et. al. 2007). Continuity of the walking or cycling surface is particularly important for transport journeys versus recreation (Pikora et. al. 2003). On the other hand, the presence of cul-de-sacs, courts and no-through roads that limit not only cars but bicyclists and pedestrians were inversely associated with transport walking (Cleland et. al. 2008). Topography, as a subset of connectivity, is important for understanding willingness and ability to walk, bike and even utilize public transportation, as the connection between walking and public transportation use is virtually inherent (Hanson and Giuliano 2004). The ease of the connection is also significant. The presence, frequency and steepness of hills have, for example, been linked to lower walking and biking rates, as well as reduced public transportation use (Cleland et. al. 2008).

Continuity of the walking or cycling surface is particularly important for transport journeys versus recreation (Pikora et. al. 2003).

Aesthetics

Aesthetics are difficult to define, but in survey work, "attractiveness" as defined by the respondents themselves, was identified as contributing to their willingness to choose an alternative mode of transport, with the strongest correlations between "attractiveness" and walking (Stone et. al. 2003, Cleland et. al. 2008).

This self-defined aesthetic appeal may not be easily defined, and almost certainly is influenced by separate environmental factors such as exposure and safety, yet it cannot be ignored. The issue can be most successfully addressed on a project basis through public input and involvement in the design process. As aesthetics will inherently be locally defined, addressing aesthetic issues locally is the best method to determining locally appropriate design strategies that have the best chance of achieving the desired effect and encouraging walking and alternative transportation use.

Aesthetic appeal may not be easily defined, and almost certainly is influenced by separate factors such as exposure and safety, yet it cannot be ignored.

2. Facility Design

As shown above, a design-based strategy for targeting barriers to alternative transportation should focus on eight main factors: aesthetics, land use, accessibility, safety, security, comfort, connectivity and continuity. Below is a review of design strategies that address the six latter issues. In order to focus on more immediate changes in the physical transportation environment, aesthetics and land use will not be covered here.

Aesthetics, as a topic unto itself is best defined though a local community design process, and land use and large scale shifts in development patterns involve by their very nature long-term changes in the built environment. This work seeks to focus specifically on smaller barriers that can be

addressed more immediately to enhance and facilitate the existing transportation options in Tucson, Arizona. Future changes in land use to increase the viability of alternative transportation would arguably be facilitated by increased use of transportation alternatives currently provided.

In addition to meeting the basic needs of safety and accessibility, public spaces, including streets for biking and walking, should meet the requirements of all good public spaces. These are places that are not only accessible, but feel available, inclusive and engaging, are furnished to support appropriate activities, offer a sense of relief and physiological comfort, and balance art and function (Marcus and Francis 1998). A vital part of providing comfortable public spaces in a hot arid desert environment is thermal comfort.

Comfort

Pedestrians and bicyclists are subject to the effects of terrain, sun, wind, rain, snow, and sleet. Topography, thermal comfort and weather are therefore common barriers to using alternative transportation.

Grades for biking and walking should ideally be kept below 5 percent where possible, as cyclists may avoid steeper grades or may even be unable to negotiate them. Sustained grades over 100 feet long should not exceed two percent to accommodate the widest range of riders. The acceptability of a relatively steep grade is highly dependent on the length of the grade. Steep grades are tolerable for distances below 200 feet, and are preferable as an alternative to lesser grades above 3 percent that last for long distances (Harris and Dines, 1998).

Weather is a common barriers to using alternative transportation. The urban heat island, and wind 'canyons' between high-rise buildings can aggravate these effects. The built environment can also provide opportunities for mitigating weather, however. Buildings can provide shade and buffet high winds, for example. Providing outdoor thermal comfort and refuge from the elements is arguably a particularly important challenge in hot, arid climates.

Tree canopies can reduce the ground surface temperature by many degrees Fahrenheit.

Bioclimate Design

Bioclimate design is the concept of designing for human comfort by relating temperature and humidity conditions, while minimizing energy needs (Harris and Dines 1998). Human thermal comfort is a direct factor of ambient air temperatures, humidity and the velocity of winds or breezes. In hot and arid climates such as in the

A mature desert tree can shade an entire street, reducing surface temperatures by many degrees.

Harvesting street run-off can help support street plantings while reducing street flooding and storm water loads on the system.

desert southwest, the three key strategies for increasing thermal comfort are: balancing wide variations in diurnal temperatures, increasing humidity, and diverting desiccating winds (Harris and Dines 1998).

The main ways in which to achieve these three goals in outdoor spaces is the strategic employment of shade structures, wind barriers in the form of either walls or vegetation, using moisture-conserving plants, avoiding heat absorbing materials, and limiting impervious surfaces.

Shade is the single most important component of outdoor thermal comfort, while solar orientation is essential to understanding where shade patterns will fall along a given path (Toudert and Mayer 2001).To maximize the effect of shade structures and canopies, as well as other thermal comfort strategies it is essential to understand sun, wind and temperature fluctuations on site.

The ideal human thermal comfort zone is considered to be between 68F and 80F, with humidity between 20 and 80 percent, and wind velocity of at least .6 miles per hour. These factors are strongly influenced by the clothing worn by individuals, their level of physical activity and the ability to move between sun and shade, shelter and exposure, at will. Various studies have found, however, that conditions that most people adapted to temperate climates find unbearable are considered comfortable to local inhabitants in hot arid climates (Ochoa and Marincic 2005).

Tucson winds are generally mild (7 miles per hour on average) and southeasterly. Most of the spring and fall seasons, as well as winter days find highs and lows that fall within the human comfort zone. It is nonetheless obvious that achieving outdoor conditions that meet even desert dwellers expanded comfort zones can be a challenge in Tucson, where average daytime highs are over 90 degrees five months out of the year, and extreme fluctuations between daytime and nighttime temperatures prevail.

While designing stops, hubs and shelters along these principles is challenging, it is comparatively easy when contrasted with designing for movement along bicycle and pedestrian paths. Shade, vegetation and water stations along the route can, however, mitigate the effects of heat and aridity. Plant canopies can, for example, reduce the ground surface temperature by up to 8 degrees Fahrenheit (Spagnolo and De Dear 2003).

Shade trees are in fact the single most important outdoor aid in thermal comfort in hot arid climates during the summer. These trees can help block winds, while reducing surface temperatures though shade and evapo-transpiration (Toudert and Mayer, 2001). A row of trees in a median location, or

Providing regular access to drinking water along a route is critical for encouraging bicycling and walking in a hot, arid climate such as Tucson's.

along sidewalks is most relevant for east-west streets due to the much longer period of solar exposure, and resulting discomfort (Toudert and Mayer, 2001). For north-south oriented streets the time of discomfort is limited to a short period around noon, and thus may not benefit as much from street tree planting. For an east-west oriented street, the period of highest discomfort occurs on the north side during the latter part of the day and evening, indicating the particular importance of the use of trees at this location for afternoon and evening walking and bicycling. Trees should be placed in medians to shade bicyclist, and between the sidewalk and street for maximum shading of both user groups.

To provide for energy and water needs along the route the desert sun and seasonal rain cycles found in Tucson invite to bioclimatic design solutions that integrate both passive and active solar energy and water harvesting. Harvesting street run-off can help support street plantings while reducing street flooding and storm water loads on the system.

Drinking fountains are not traditionally part of bioclimatic design, but in an arid climate such as Tucson's, providing regular access to drinking water along a route is critical for encouraging bicycling and walking. Not only can a cooling drink and a rest in the shade help improve comfort for a rider or walker, it can in fact help the safety of the route and help prevent over-heating and dangerous dehydration.

It is essential that the facilities provided with public transportation systems meet, and even go beyond, simple accessibility.

Accessibility

The Americans with Disabilities Act (ADA) ensures that accessibility is a base-line attribute of any public design, the emerging new standard of accessibility goes beyond the regulations of ADA to try to more fully embrace all members of the population. Well-designed accessible facilities are usually more functional for all users, with and without disabilities.

Understanding how people with various disabilities function in the outdoor transportation environment is the first step in trying to accommodate their design needs. Wheelchair user require low running grades, preferably below 5 percent. Cross slopes should be no more than 2-3 percent. Amenities, such as phones, water fountains and pedestrian-actuated signal controls, need to be placed no higher than 4 feet from the

Table 2: Safety Impacts of Traffic Calming Measures (U.S. Experience)

	Number of Observations	Average Number of Collisions		% Change in Collisions
		Before	After	
12' Speed Hump	49	2.7	2.4	-11%
14' Speed hump	5	4.4	2.6	-41%
22' Speed table	8	6.7	3.7	-45%
Traffic circle (excluding Seattle)	17	5 9	4.2	-29%
Traffic circle (including Seattle)	130	2.2	0.6	-73%

Source: http://www.trafficcalming.org

Horizontal separation focuses on physically separating modes from each other on the same plane, such as with a road and sidewalk.

ground level. The buttons on signals need to be large, protruding and easy to push for those who have limited mobility in their hands. The buttons also need to be placed in an accessible path of travel for a wheelchair user.

Most sighted people get their directional and spatial cues visually. People who are totally blind get their cues from sound and touch. People with low vision may have an additional advantage of detecting contrasting colors. Older people often lose their hearing and vision at the same time, creating a compound difficulty. Curb ramps are typically thought of as an accommodation for bicyclists and wheelchair users, but they can be used by the visually impaired as a warning of the transition from the path to the street. If they fail to detect the ramp, they are at risk of walking into the street, which may result in serious consequences and injury.

Children under the age of twelve, and people with cognitive disabilities differ in their ability to take in and perceive the road environment, and then perform the multiple tasks needed to make fast decisions. Both groups may benefit from easy-to-interpret signs. This element is particularly important when a path intersects with another path or street.

Although all aspects of a public transportation system may not be used by all segments of society, it is essential that public systems meet and even go beyond, simple accessibility, to make them as easy and convenient as they can be for all user groups.

Safety

It is difficult to produce good data about the safety of bicycle facilities. The safety of such facilities depends on the accident risk of a path relative to the null hypothesis of not having that path, all else being equal. In addition, measuring accident risk requires knowing both the number of accidents and the number of bicyclists. Accidents are typically under-reported and are relatively rare events subject to random fluctuations, and accurately establishing the number of bicyclists requires a large number of special counts.

There are four general strategies for improving safety by separating different modes of transport from each other: horizontal, vertical, time and soft separation.

A good test of bicycle facility safety would compare the number of conflicts between bicyclists and motorists before and after installation, and also include a "control" location where no measures were taken, in order to monitor the background level of change over time.

Minimizing conflict with vehicular traffic is the main way to achieve safety for both pedestrians and bicyclists. There are four general strategies for separating different modes of transport from each other: horizontal, vertical, time and soft separation. Each has different applications and implications. Horizontal and vertical separation can achieve the most complete

Photo:http://bikeportland.org/wp-content/uploads/2008/03/bike-boxjaylawrence.jpg

A bicycle box, or advanced stop line, uses pavement striping and color to horizontally separate traffic, and helps increase the visibility and safety of bicyclists.

segregation of transportation modes, but many have argued that soft separation is the most effective way to achieve road safety because it keeps everyone more alert to the changing conditions of the road and traffic, making them more able to share the road as needed (Topp 1990).

Horizontal Separation

Horizontal separation looks at separating modes from each other on the same plane. This involves sidewalks, pedestrian paths and trails, and indoor walking areas that preclude vehicular traffic sharing the same space (Ribbens 1996). Vertical separation can be achieved through below-grade, above-grade and at-grade differentiation. This can be through over and underpasses, as well as raised and sunken walkways and paths, curbs, medians and other physical barriers.

Bike Box or Advanced Stop Line

Bike boxes typically consist of a dedicated, green approach lane and green waiting space for bicyclists in front of motor vehicles stopped at a red light. Boxes help make bicyclists more visible, give them a head-start into the intersection when the light turns, and reduce the potential for conflicts between bicyclists and motorists, particularly during right turns. Vehicular right turn on red must be prohibited with a bike box.

Time Separation

Time separation involves pedestrians, bicyclists and motorists using the same space, but at different times. These times can be strictly coordinated using lights or crossing monitors such as in school zones, or be indicated through pavement markings for pedestrian crosswalks or bike boxes that allow

Speed Impacts of Traffic Calming Measures

	Sample Size	85th Percentile Speed Afterward	Average Change in 85th Percentile Speed	Average Change
12' Speed Hump	179	27.4	-7.6	-22%
14' Speed Hump	15	25.6	-7.7	-23%
22' Speed Table	58	30.1	-6.6	-18%
Longer Table (>22')	10	31.6	-3.2	-9%
Raised Intersection	3	34.3	-0.3	-1%
Traffic Circle	45	30.3	-3.9	-11%
Narrowing	7	32.3	-2.6	-7%
Choker	5	28.6	-2.6	-14%
Half Closure	16	26.3	-6.0	-19%
Diagonal Diverter	7	27.9	-1.4	-0%

Note: speeds are measured at midpoints between measures

Volume Impacts of Traffic Calming Measures

	Sample Size	Average Change in Volume	Average Change
Choker	5	-392 vehicles/day	-20%
Full Closure	19	-671 vehicles/day	-44%
Half Closure	53	-1611 vehicles/day	-42%
Diagonal Diverter	27	-501 vehicles/day	-35%
Other Volume Control	10	-1167 vehicles/day	-31%

Source: http://www.trafficcalming.org

bicycles to stop at lights in front of vehicular traffic (Ribbens 1996).

Bicycle Activated Signals

Bicycle activated signals such as bike buttons, infrared motion detectors, pressure mats or other technologies assist bicyclists in crossing signalized intersections by allowing a cyclist to activate the signal cycle either actively or passively. Bike buttons require bicyclists to move to a specific area and push a button, while other technologies use surface loops or motion detectors to activate the signal cycle without the bicyclist needing to alter position or dismount.

Speed humps are effective at reducing traffic speeds, but can create noise pollution and lack visual appeal.

Soft Separation

Soft separation does not focus on a physical differentiation between modes, but on a safer, more cautious sharing of the same space. The idea behind soft separation is that when forced to share the road with other modes of transport, vehicular drivers will naturally tend to be more alert to bicyclists and pedestrians, and be more prepared to act safely and avoid conflict (Ribbens 1996). Soft separation devices are commonly referred to as 'traffic calming devices' and include Traffic Circles, Speed Humps and Speed Tables, narrowed sight lines and blurred boundaries between different paths.

Traffic Calming

Traffic calming measures can be separated into two groups based on the main impact intended: volume control and speed control. The distinction between the two types of measures is not always firm, as speed control measures frequently divert traffic to alternate routes, and volume control measures usually slow traffic as well.

Volume control

Volume control measures are primarily used to address cut-through traffic problems by blocking certain movements to discourage and divert traffic to streets that prioritize more efficient vehicular flow. Volume control measures include Full and Partial Closures, Diagonal Diverters and Medians.

Not all safety issues deal with traffic conflicts. Significant surface imperfections such as potholes can also pose a risk to bicyclists.

Closures and Diverters

Full and Partial closures as well as Diagonal Diverters direct cars to alternative routes, often main thoroughfares better suited for vehicular traffic, while allowing bicycles and pedestrians to safely continue along the route. Full closures restrict motor vehicle movement entirely, while a partial closure may restrict motorists to a "right turn only", while pedestrians and bicyclists are allowed to travel straight, but may allow left or right turns on to the same street from a perpendicular one.

Chicanes are curb extensions that alternate from one side of the street to the other, forming S-shaped curves in the roadway.

Medians

Medians sit in the middle of the road and prevent opposite travel directions from interacting with each other. Medians can also provide refuge for pedestrians and bicyclists, allowing crosser's attention to be safely focused in just one direction at a time.

Speed control

Speed control measures are primarily used to address speeding problems by changing vertical or horizontal alignment, or by narrowing the roadway. Speed control measures include Speed Humps and Speed Tables, Raised Crosswalks, Neckdowns, and Center Island Narrowings, Chicanes, Chokers and Traffic Circles.

Speed Humps and Tables

Speed humps are 3-4 inches high and 12-22 feet long, tables are 18 to 22 feet long and flat-topped. Speed Humps and Tables are the most effective speed control devices used today. Research has shown that speed humps, when designed and installed properly, reduce vehicle speeds to 15 to 20 mph when traversing the humps, and 25 to 30 mph between properly spaced speed humps. To be effective along a section of roadway speed humps should be placed in series at 200-600 feet intervals in consideration of the geometries of the roadway, and spaced no further than 275 feet apart. The first speed hump in a series should be placed 50 to 200 feet from a small radius curve or stop sign. If installed on a street with a significant grade, the first hump in a series should be placed at the top of the grade.

Although very effective at slowing traffic, humps also create some noise as cars move over and through the hump area. Many drivers find humps frustrating and uncomfortable to navigate. These devices also lack positive aesthetic value, providing no other benefits but pure speed reduction.

Narrowings and Refuges

If a roadway is narrowed out from the curbs at an intersection, you have a Neckdown. A Center Island Narrowing is a raised island located along the center line of a street that narrows the travel lanes at that location. These narrowing measures increase

A Center Island Narrowing is a raised island located along the center line of a street that narrows the travel lanes at that location and can increase pedestrian safety, have positive aesthetic value, and help reduce traffic volumes.

pedestrian safety, can have positive aesthetic value, and help reduce traffic volumes. Their speed-reduction effect is somewhat limited by the absence of any vertical or horizontal deflection, and in some cases they may require elimination of some on-street parking. Narrowings produce an average of a 7% decrease in the 85th percentile travel speeds, or from an average of 34.9 to 32.3 miles per hour.

Center Island Narrowings are often landscaped to provide a visual amenity. Placed at the entrance to a neighborhood, and combined with textured pavement, they are called "gateway islands." Center Island Narrowings are best for entrances to residential areas, and on wide streets where pedestrians need to cross.

When Center Island Narrowings are fitted with a gap to allow pedestrians to walks through at a crosswalk, they become pedestrian refuges as well. Refuge Islands should be considered for path-roadway intersections in which one or more of the following apply: (1) high volumes of roadway traffic and/or speeds create unacceptable conditions for path users, (2) roadway width is excessive given the available crossing time, or (3) the crossing will be used by a number of people who cross more slowly, such as the elderly, schoolchildren, or persons with disabilities.

The refuge area should be large enough to accommodate groups of pedestrians, groups of bicyclists, tandem bicycles, and wheelchairs The area may be designed with the storage aligned across the island or longitudinally. Adequate space should be provided so that those in the refuge area do not feel threatened by passing motor vehicles while waiting to finish the crossing.

Chicanes are curb extensions that alternate from one side of the street to the other, forming S-shaped curves in the roadway. Chicanes can also be created by alternating on-street parking, either diagonal or parallel, between one side of the street and the other. Each parking bay can be created either by re-striping the roadway, or by installing raised, landscaping islands at the ends of each parking bay. Chicanes are best utilized in locations where speeds are a problem, but noise associated with Speed Humps and related measures would be unacceptable.

Chicanes discourage high speeds by forcing horizontal deflection and are easily negotiated by large vehicles such as fire trucks, except under heavy traffic conditions. Chicanes must, however be designed carefully to discourage drivers from deviating out of the appropriate lane. Curb realignment and landscaping can be costly, especially if there are drainage issues, and Chicanes often require the elimination of some on-street parking

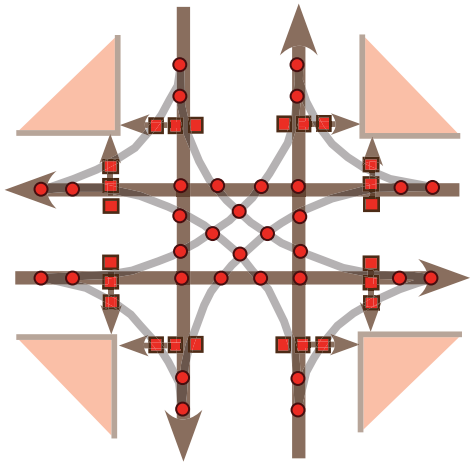
A Choker is similar to a Chicane, but achieved by placing the edge islands opposite each other without staggering them.

Traffic Circles

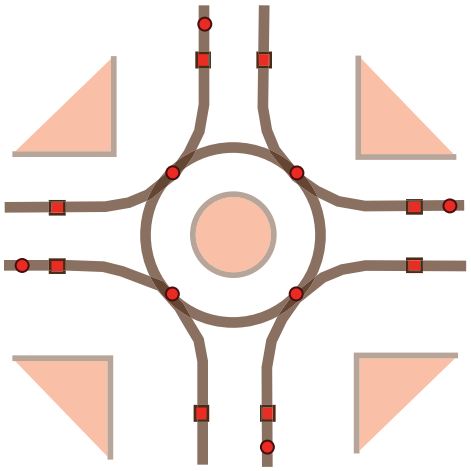
Traffic Circles are raised islands, placed in intersections, around which traffic circulates. Traffic Circles are very effective in moderating speeds and improving safety, and since placed in an intersection, do so on two streets at once. Placed in the middle of the street, they are also highly visible and can have great positive aesthetic value for a neighborhood.

Traffic Circles are, however, difficult for large vehicles such as fire trucks to circumnavigate, and must be designed so that the circulating lane does not encroach on the crosswalks. Occasionally Traffic Circles require the elimination of some on-street parking. Within the City of Tucson any

Traffic Circles are one of the best speed control applications, calming two streets at-once, and can add aesthetic value to a street.



- Vehicle to Vehicle Conflicts (32)
- Vehicle to Pedestrian Conflicts (24)



- Vehicle to Vehicle Conflicts (8)
- Vehicle to Pedestrian Conflicts (8)

Source: "Safety Benefits of Modern Roundabouts"

Traffic Circles help improve safety at intersections both by slowing traffic speeds, and by significantly reducing the number of conflict points, or places where vehicle, bicycle and pedestrian collisions may occur.

landscaping placed in the circle must be maintained by the local residents, and can become a liability if community interest in upkeep wains.

Traffic Circles are one of the best speed control measures with an average of 11% decrease in the 85th percentile travel speeds, from an average of 34.1 to 30.2 miles per hour. When including a large sample from Seattle, researchers found an astounding average of 73% decrease in accidents, from an average of 2.2 to 0.6 accidents per year. Excluding Seattle, the researchers still found a significant decrease in accidents of 29%, from an average of 5.9 to 4.2 accidents per year.

Collisions at Traffic Circles partially occur less frequently because of a reduction in conflict points compared to conventional intersections. A conflict point is a location where collisions could occur as vehicular, bicyclist, and pedestrian paths cross. With a circle, the number of vehicular conflict points are reduced from 32 points to 8 points- a 75 percent reduction. For vehicle to pedestrian collisions, the number of conflict points are reduced from 24 points to 8 points-- a 67 percent reduction.

Traffic Circles are best suited for calming intersections, especially within neighborhoods, where large vehicle traffic is not a major concern, but where traffic speeds, volumes, and safety are potentially problematic.

The smoothness of the riding surface also affects the comfort, safety and speed of bicyclists. Pavement surface irregularities can do more than cause an unpleasant ride. Wide cracks, joints or drop-offs at the edge of traveled way parallel to the direction of travel can trap a bicycle wheel and cause loss of control; a severe reduction in the operating speed of the bicyclist results in less stability of the bicycle, and holes and bumps can cause bicyclists to swerve into motor vehicle traffic.

Bikeways should generally be kept free of bumps, holes and other surface irregularities if they are to attract and satisfy the needs of bicyclists. Utility covers and drainage grates should be at grade and, if possible, outside the expected path of travel. Railroad crossings and trolley or streetcar tracks should also be improved as necessary to

Inverted U-shaped bicycle racks are a simple and inexpensive bicycle parking facility.

provide for safe bicycle crossings. Fixed-source lighting improves visibility along paths and at intersections. In addition, lighting allows the bicyclist to see the path direction, surface conditions and obstacles.

Renting a bicycle locker can be an affordable and attractive solution, particularly for bicycle commuters and those combining bicycling with another mode of transit.

Security

The security of personal belongings is a concern for everyone. As such providing bicycle parking facilities is an essential element in an overall effort to promote bicycling. Bicycle parking facilities should be provided at both the trip origin and trip destination and should offer protection from theft and damage.

The wide variety of bicycle parking devices are generally grouped into two classes, long-term and short-term. Long-term bicycle parking facilities provide a high degree of security and protection from the weather. These bicycle parking facilities are usually lockers, cages or rooms in buildings. Short-term facilities provide a means of locking the bicycle frame and both wheels, but do not necessarily provide accessory and component security or weather protection

Although a bike can be locked to a tree, post or other streetscape feature, the most simple and legal short term bike lock facilities for urban use are usually sidewalk bike racks. The bike rack allows the user to lock bicycles with either a standard U-shaped lock or a chain or cable and lock. City racks are installed in public spaces, usually on a sidewalk with six or more feet of clear sidewalk space remaining. Racks should be placed at convenient, usable locations in close proximity to building entrances without impeding pedestrians, and with adequate clearance from curb ramps and crosswalks, street furniture, driveways, and parked cars. Racks can be installed at bus stops or loading zones only if they do not interfere with boarding or loading patterns. Bike racks on private property are usually installed by a business or other private owner but following similar principles.

Bike racks typically take one of two forms: the rail-type rack or the inverted U. Such racks are made of a minimum 2" galvanized pipe, are 54 inches long, 32 inches high, and hold two bikes each. A myriad of more artistic bicycle racks can also be produced to add local flavor and flair to a given area. A multitude of shapes and styles work well for bicycle parking, but the rack should have no sharp edges or moving parts, and require little maintenance. Bike racks are most secure when either guarded by paid staff, located in active pedestrian areas, or within direct view of office or store windows.

Bicycle Corrals are also growing in popularity. These facilities utilize either sidewalk space or a automobile parking space to provide a large number of bicycle parking spaces. Twenty one bicycles will fit in a single traditional parking space. Corrals may be enclosed or covered. Covered bike parking areas are preferred, particularly in very hot and sunny, or very rainy, locations.

Photo: http://www.folsom.ca.us/images/bike%20lockers.JPG

Freestanding bicycle lockers can be placed almost anywhere to provide secure parking for bikes and gear, but are often seen as an eyesore.

Bicycle lockers provide excellent,

Photo: http://scooterparking.files.wordpress.com/2008/07/munich_bikes.jpg

Twenty one bicycles can fit in a single traditional automobile parking space.

secure bicycle parking and improve protection from theft, vandalism and weather, but are often seen as an eyesore and can benefit from some screening. Lockers are commonly designed to hold one bicycle each, along with bicycle gear. In the Bay Area Rapid Transit (BART) system over 200 lockers are available to store bicycles, gear, mopeds or wheelchairs.

Renting a bicycle locker is usually an affordable and convenient solution, particularly for bicycle commuters and those combining bicycling with another mode of transit. In the Washington DC Metro system, for example, bicycle lockers are available for $70 for one year, plus a $10 key deposit. To provide flexibility, keyed lockers require a rental agreement, while electronic lockers provide on-demand bike parking through a smart card system. These lockers are highly affordable at a cost of three cents per hour.

Valet bike parking facilities and bike stations can provide and efficient way to find a secure parking space quickly, and can also include facilities such as lockers, showers and changing rooms. Valet parking is often found as a novelty feature at bicycle gatherings and other special events across the country, but permanent parking stations have been popular for a long time in Europe, and bike stations have been opening in the states in recent years as well. These are run by advocacy groups, entrepreneurs and by local governments, funded through parking fines and permit fees, to help encourage cycling, reduce emissions and ease congestion (Steptoe 2007).

Connectivity and Continuity

The principles of Connectivity and Continuity promote a transportation system that accommodates choices. Connectivity denotes ease of travel to a final destination, but also the ability to transition between multiple paths or modes of travel. Continuity denotes the unbroken nature of a path type or route, as well as the number of stops, turns and other interruptions one finds along it. Alternating segments of Shared Use Paths, Bike Lanes, Signed Shared Roadways and Shared Roadways along a route is generally inappropriate and inconvenient, and can even be dangerous. Bicyclists may be forced to respond quickly to unexpected changes in route character resulting in wrong-way bicycle travel, sidewalk riding, and higher potential for conflicts.

Connectivity and Continuity thus focus on improving transit through path typology design, the strategic intersection of paths with other paths, and the provision of hubs that may also provide some of the amenities bicycle travelers need or want such as parking or rest rooms.

Path Typologies

When walking and biking, the path typology is fundamental to the transportation experience. The descriptions below provide an overview of the most common biking facility types and their general design.

Shared Roadway (not designated)

The continuity of a bicycle path is important for avoiding unpredictable responses from bicyclists reacting to sudden, unforeseen changes in facilities.

A community's existing street system, unimproved for bicycle travel.

Designated or Signed Shared Roadway

An existing street system deemed suitable for bicyclists and signed or identified on bike maps to help provide continuity and way-finding, but otherwise unimproved for bicycle travel. Signing on these roads serves to advise drivers that bicycles are present.

Paved Shoulder

An existing street with a section of pavement outside of the striped vehicular lane deemed suitable for bicyclist travel, but not meeting the standards of a Bicycle Lane.

Shared Roadway (not designated)

Signed Shared Roadway.

Paved Shoulder

Bicycle Lane

Bicycle lanes are striped lanes that dedicate a portion of the right-of-way exclusively for bicycles. Bike lanes segregate bikes from motor vehicles and help make movement by bicyclists and motorists more predictable. An operating space of 4 feet is the minimum width for any facility designed for exclusive or preferential use by bicyclists. A more comfortable operating space of 5 feet is preferred, particularly where motor vehicle traffic volumes or speeds are higher.

Within bike paths bicycle-safe drainage inlet grates should be used, pavement surfaces should be smooth, and traffic signals should be responsive to bicyclists. Regular maintenance of bicycle lanes should be a top priority, since a lane with potholes, debris or broken glass might force a bicyclist to swerve out of the lane.

Bicycle lanes can be dangerous to the extent that they encourage bicyclists to remain to the right at intersections, regardless of their intended destination or the conditions of the road. A bicycle lane with a solid stripe to the stop line of an intersection for example encourages bicyclists to stay right and motorists to stay left, even if the bicyclist intends to turn left, or motorist right, causing potential confusion and conflict. For this reason dashed lines at intersections are encouraged in the 1991 AASHTO Guide. Although dashing may reduce the problem, the existence of any dividing line at an intersection can discourage proper merging

maneuvers.

Bicycle lanes may also encourage riders to remain too close to rows of parked cars and risk collision with opening car doors or merging traffic.

Shared Use Path

A Shared-Use path is a bikeway physically separated from motorized vehicular traffic by an open space or barrier. Shared Use paths may also be used by pedestrians, skaters, wheelchair users, joggers and other non-motorized users (AASHTO, 1999). Generally, shared use paths are placed along corridors not served by streets and highways, or where wide utility or a former railroad right-of-way exists. The most common applications are along rivers, ocean fronts, canals, utility rights-of-way, former or active railroad rights-of-way, within college campuses, or within and between parks (AASHTO, 1999).

Shared Use paths most often provide a recreational opportunity, but sometimes they can serve as direct commute routes, particularly if cross flow by motor vehicles and pedestrians is minimized. Shared Use paths may also be used over short distances to close gaps in bicycle travel caused by railroads or freeways, or to circumvent natural barriers such as rivers.

The main potential hazards of these paths are conflicts between the different user groups, particularly if path widths are insufficient, and conflicts at road intersections. If the road crossing is a

Bicycle Lane

Wide Bicycle Lane Buffered by Textured Paving

Shared Use Path

marked crosswalk, drivers are legally obliged to give the right of way to pedestrians in the crosswalk, but bicyclists do not always have this legal protection unless they dismount and become pedestrians.

The ideal Shared -Use path is a minimum of 10 feet wide, but preferably 12 or 16 feet, or adjacent but separate paths for pedestrians, and has only grade-separated or fully signalized intersections. Few alignments are available that meet all these conditions, and constructing bridges or tunnels for full grade separation is quite expensive.

Bicycle Boulevard

A bicycle boulevard is a Shared Roadway that has been modified with traffic calming devices, safer crossings, and bicycle amenities to prioritize the safety, comfort and convenience of bicyclists, and to appeal to a broad spectrum of bikers. Distinctive pavement markings and signs, most often help set them apart from other bikeways. Bikers usually take the lane on bike boulevards, making it safe and legal to ride several abreast, pass other cyclists, and easily avoid the doors of parked cars. Bicycle boulevards are also meant to discourage cut-through motor vehicle traffic, while at the same time giving priority to bicyclists as through-going traffic.

Photo: Richard Masoner

Bicycle Boulevards, like the Ellen Fletcher Bicycle Boulevard in Palo Alto, California are designed to prioritize bicycle safety, comfort and convenience, and to appeal to a broad spectrum of bike riders.

Placement of bicycle boulevards depends on the available road network. A typical bike boulevard moves along an existing residential street that provides good access to a variety of destinations. Boulevards can thus be created in already developed and established areas, offering direct access to destinations in a way that few dedicated pathways can approach.

Removing or turning stops signs along the bicycle boulevard helps with continuity as cyclists can maintain momentum and speeds ideal for commuting. At the same time, taking the whole lane means faster bicyclists can easily share the path with lower speed users.

Controlling the growth of motor traffic is the most significant design challenge of a bike boulevard. A pleasant, direct route with turned stop signs and improved crossings may attract motorists. Bicycle boulevards thus should limit such traffic by diverting motor vehicles or by including a variety of traffic calming devices.

Although not officially labeled a bicycle boulevard, the 3rd Street Bike Path in Tucson functions very much like one with motor vehicle access restrictions and improved crossings for both bikes and pedestrians.

Sidewalks

Sidewalks generally are not acceptable for bicycling. However, in a few limited situations, such as on long and narrow bridges and where bicyclists are incidental or infrequent users, the sidewalk can serve as an alternate facility, provided any significant difference in height from the roadway is protected by a suitable barrier between the

Bikers take the lane on bike boulevards, making it safe and legal to ride several abreast, pass other cyclists, and easily avoid the doors of parked cars.

A paved sidewalk provides easy access to homes, public buildings, and businesses, and is at the same time largely segregated from other forms of traffic.

sidewalk and roadway.

Sidewalks are, however important to the pedestrian connectivity network. Paved sidewalks are the most common pedestrian path found in most cities. Non-paved sidewalk space can cause serious mobility and access problems for a number of different users, including people in wheelchairs, those using walkers, and those with reduced eyesight. Usually 4 feet wide in neighborhoods, and wider in commercial and downtown areas, the urban sidewalk provides utilitarian access to homes, public buildings, and businesses. Wider sidewalks, and more features such as benches, street trees and planters, tend to create a more inviting feel for pedestrians, while buffers from the roadway, slower traffic speeds, as well as fewer driveways and curb cuts tend to increase perceptions of safety and comfort (Petritsch et. al 2006).

Although all walking paths are to some degree separated from motor traffic, pedestrian pathways can range from Shared Use Paths that welcome bicyclists and other non-motorized forms of transportation, to Pedways, which are the most separated pedestrian paths. Pedways are typically networks of indoor urban walkways, often elevated or underground, connecting buildings and other destinations such as shopping centers, and transportation terminals. Generally climate controlled they provide a convenient and comfortable way for pedestrians to travel separated from traffic and weather. They can improve transit access and encourage walking, particularly in very cold, hot or wet climates. Pedway networks are expensive to implement and often develop incrementally over time as new buildings are constructed or retrofitted.

Hubs

One movement looking to increase transportation connectivity and its benefits, is the New Mobility Movement. New Mobility seeks to get away from large-scale, high-price transportation solutions such as large parking structures, new highways, or even rapid transit networks, to approach mobility provision through the flexible, community and technology-oriented provision of alternatives (Zielinski 2006). Part of the solution under the New Mobility agenda is to avoid traveling when tasks can be accomplished with technology at home, but also to bring travel alternatives together in hubs that create flexibility and connectivity when travel is

Even modest improvements of bus or train stops to include bicycle parking can be helpful in enabling or encouraging the combination of multiple modes of travel, lessening the need or desire to use a car.

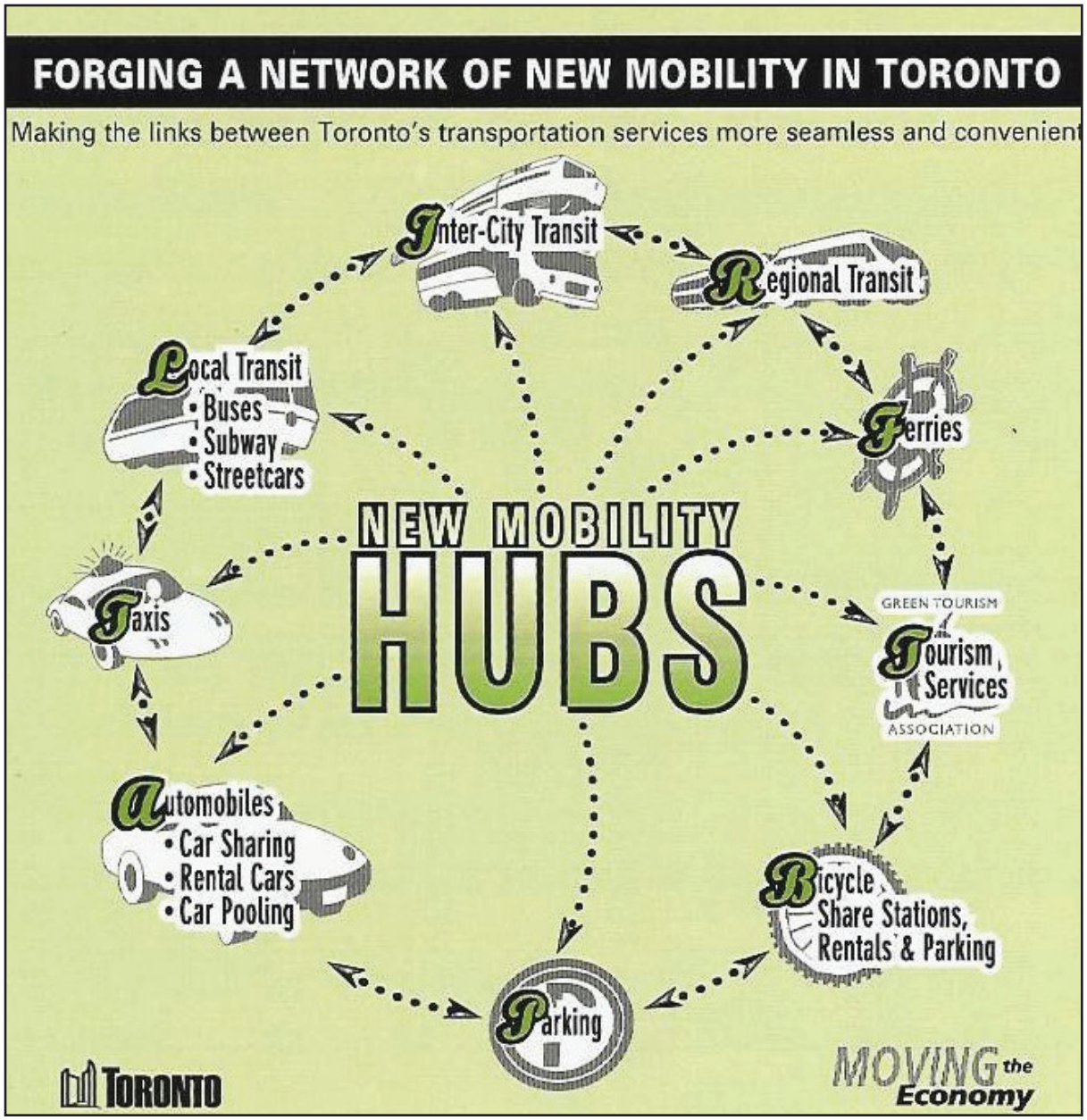


Image: http://www.crcresearch.org/files-crcresearch/Image/MobilityHub.jpg

Toronto, Canada is investing heavily in mobility hubs that bring together various forms of regional and city transit, car sharing, parking, bike sharing, bike rentals bike parking, tourism services, taxis and shops.

Photo: http://www.explace.on.ca/Sivia%20HUB%20Launch.jpg

Toronto's first New Mobility Hub was launched in the spring of 2006.

needed. New Mobility hub networks began in Bremen, Germany, and have been catching on in a number of other European cities, as well as in Toronto, Canada (Zielinski 2006).

New Mobility hubs connect a variety of sustainable modes of transportation and services through a network of physical nodes throughout a city or region. These kinds of hubs are particularly practical because they can be customized to fit local needs and existing resources. Mobility Hubs can link a variety of elements including multiple modes of transportation, cafes, shops, grocery stores, day care facilities, neighborhoods, bike and car sharing, public services and internet access hot spots.

Toronto's first New Mobility Hub was launched in the spring of 2006. The Hub provides multiple modes of transportation services such as local and regional trains, a Bikeshare Hub, bicycle parking, a WIFI

hotspot, taxi hotline, weather and tourist info, secure bicycle lockers, and a map of downtown Toronto.

There are three types of mobility hubs: primary, secondary and tertiary. Primary hubs are in significant regional city centers that have the potential for the highest levels of population and employment densities, or that generate the highest levels of travel demand, such as airports.

Secondary hubs are major activity centers or regional destinations that have inter-regional connections, such as railroad stations, universities and colleges, major parks and stadiums, and regional shopping centers.

Tertiary hubs are primarily transit stations. These might be located in denser residential areas, at a commercial center, a neighborhood park, by schools, or near other neighborhood or community scale destination.

Mobility hubs of all three categories improve access to multi-modal transportation, provide a strong sense of place, prioritize pedestrians, embed technology and encourage economic vitality.

The major challenges to building mobility hubs lie in the existing level of transit service and transit integration, parking needs, working within existing land uses and zoning, and the difficulty of aligning transportation facilities with development and infrastructure. Making the various modal connections between hubs safe, convenient and pleasant is also a major challenge, yet a critical component to their success.

Photo: http://img168.imageshack.us/img168/5971/smallbikeracks1zp6.jpg

The ability to combine bicycling with bus or train travel can be essential for long commutes.

Transit stations and stops, as well as larger bike parking facilities can make for natural multi-modal hubs. Long Beach, California pioneered the creation of commuter-biking hubs in the United States, (see Case Reviews.) The success of this station prompted numerous other cities to follow suit. For example, Chicago partnered with the McDonald's Corporation to build a "Cycle Center" hub in Millennium Park in 2004 (Steptoe 2007).

Hubs of all kinds help link travel modes and paths to make such travel more flexible, safer, more secure and pleasant, and overall easier to include in a busy lifestyle.

Case Reviews

The following case reviews were identified and studied in order to develop a more in-depth understanding of the specific design solutions and innovations that have been employed elsewhere to address the barriers identified in the literature review. Evaluating the relative success of tried measures provides a foundation for the strategies chosen in the final design. Case reviews focus on design-based solutions to connectivity, safety, continuity, comfort and accessibility problems that plague biking and walking in cities in Western North America.

In line with the goals of the project, the case reviews focus on interventions aimed at increasing bicycling, walking. A special focus is placed on projects that did this without the need for large-scale, long time frame, or very costly investments. The main cases examined here are the bicycle networks developed in Berkeley and Davis, California; and Portland, Oregon.

The main focus is on the bicycle boulevard networks of Berkeley and Portland. As leading bikeable cities with functioning Bicycle Boulevards, the systems found in these cities are particularly important to study for understanding how a similarly successful system might be designed and function in Tucson. A quick comparison of characteristics relevant to biking in Tucson and those of three prominent bike cities in the West can be seen in the table below.

Table 3: Prominent Bicycle Cities in Comparison to Tucson

	TUCSON	PORTLAND	BERKELEY	DAVIS
Population (2000)	518,956 (2006)	529,121 (2000)	102,744 (2000)	63,722 (2005)
Square Miles	156.3	124.7	10 5	10.5
Population per Square Mile (2000)	2500	3939	9823	6068
Percent of Population biking to work	1.7% (Census 2000)	4% (Census 2000)	6% (Census 2000)	17% (2000 Census)
Street System	Grid	Grid	Grid	Grid
Climate	Arid Desert	Temperate	Mediterranean	Mediterranean
City Topography	Flat	Some Hills	Flat	Flat

Emeryville, California

Context

Emeryville is a town of approximately 100,000 nestled on the east shore of the San Francisco Bay. The city is a neighbor of bike boulevard innovator Berkeley, and enjoys the same relatively wet winters and dry summers. Average annual precipitation is 23.6 inches. Temperatures are mild almost all year with an average of only 3 days a year with temperatures over 90 degrees Fahrenheit, and 1 day with temperatures below freezing.

Project History

Significant traffic growth accompanied Emeryville's rapid redevelopment from industrial to mixed-use urban forms in the late 1990s. As other city streets developed into high-speed arterials, only one, a new street, carried the potential to become a north-south bicycling route without an existing base of heavy traffic. The 1998-2010 Emeryville Bicycle and Pedestrian Plan anticipated that a series of disjointed streets would be connected as a condition of new development.

The identified roadway, just 1.3 miles long, served a variety of land uses, including light industry, artist studios, offices, street-level retail, a shopping mall, an Amtrak station, a biotechnology facility, a post office, the back wall of a new residential development, and the site of an abandoned paint factory.

Bike lanes were specified along much of the roadway, though the streets were too narrow for a consistent treatment. The city council supported cycling accommodations on this street, but the cycling community was divided over the best treatment.

Photo: http://www.bikeroute.com/NationalMayorsRide2008/

Distinctive way-finding signs help direct cyclists along the Mandela/Horton bicycle boulevard in Emeryville.

Emeryville's appointed Bicycle and Pedestrian Advisory Subcommittee includes representatives from the city council and the city's planning, public works, and police departments, as well as residents, commuters, and bike/pedestrian advocates. Some members of this group were concerned about the bike lane plan. They feared that traffic speeds and volumes could rise dramatically on a through road with bike lanes at the curb, rendering the street an automobile-dominated space unfriendly to less experienced cyclists. Bicycling goals for the City included making bicycling more attractive to inexperienced riders, and in the end the advisory committee recommended a bicycle boulevard with a shared street design rather than bike lanes along the entire length.

Although the Emeryville City Council agreed to create a bicycle boulevard on the new route, the design details were settled only after thorough debate among cycling advocates. The debate centered around the relative merits of bicycle lanes versus a bicycle boulevard and focused on two main questions: How will design affect traffic volume? and Who will use the route?

The city council would not promise to limit future traffic growth, which forced advocates to consider how the design would

contribute to traffic volume. If the average daily traffic load were to edge above 5,000 cars a day, or speeds were to increase to 30 mph, advocates preferred bike lanes. If speeds and volumes could be moderated and controlled, citizens favored a bicycle boulevard. Fire and police departments were however concerned about plans that could limit emergency vehicle access.

As far as user groups were concerned, skilled cyclists were deemed to be seeking the quickest and most direct route, and to be able to handle mixed traffic and speeds of 35 mph or more. Novice or young cyclists on the other hand, were deemed not to want to ride on any road with high traffic volumes or speeds. The community recognized these distinctions and discussed how to meet distinct cycling preferences and skill levels by identifying specific cyclist types and imagining how they would make complete trips within the city.

Route consistency was also identified as important. The community agreed that no one would be satisfied if the route was to switch character every few blocks.

In the end, the prevailing belief was that bike lanes and center stripes would facilitate a faster through street for motorists, whereas a shared street would reduce the route's arterial nature and lead motorists to choose the next street over.

The location and style of parking was also identified as important. Parking was deemed integral to economic vitality, but the community wanted parking styles that would moderate speeds, encourage pedestrian activity, and support street-level retail.

Design and Development

Pre-existing bike lanes along most of the route were removed and replaced with parallel parking. Car-sized bicycle stencils were placed in the middle of each travel lane along sections without lanes. Distinctive street and directional signage helped identify and brand the route.

The bike boulevard was installed for a mere 30, 000 dollars. Design development costs were minimized because pre-existing City of Berkeley design guidelines were adopted. A traffic signal, primarily to benefit motorists, was installed at a cost of about $250,000, and an additional 1 million dollars was used for an interlock with railroad signaling.

Emeryville's bicycle boulevard was designed as a shared street for adult cyclists who don't like heavy traffic or will trade some directness for a more pleasant route. Horton and Overland Streets are fully connected, marked, and operating as a bicycle boulevard. Parallel parking and the street's moderate congestion help to limit traffic speed and volume.

There are no diverters or barriers along the stretch, but the presence of cyclists, and the need to shift into the opposing lane to pass them slows traffic some. The posted speed limit is 25 mph. Cyclists and motorists looking for a faster route have an alternative one block over: a four-lane arterial with 35 to 40 mph traffic and bike lanes.

Project Evaluation

Actual vehicular speed varies between 20 mph on narrower, more congested stretches, to 30 mph on a wider section where original bike lanes remain and no parking is allowed due to homeland security concerns. Without diverters or barriers along the stretch, motor vehicle traffic volumes and speeds on the bike boulevard have actually increased somewhat. The city council has proposed a one-way choker which would create a barrier on either side of the street. This traffic calming device is intended to reduce traffic speed, noise and volume. Unfortunately the usefulness of the boulevard is limited in that it does not connect to a network of other bike boulevards.

Project: Bike Boulevard
Location: Emeryville, California
Size: 1.3 miles of bike boulevard
Cost: $30,000 ($11, 000 for pavement markings, $11,000 for signs, $8,000 for inspections)
Program Elements: Bicycle boulevard, bicycle lanes remain along a stretch, vehicular parallel parking, 25 MPH speed limit..

Berkeley, California

Context

Berkeley is a town of approximately 100,000 nestled on the east shore of the San Francisco Bay. The city houses the University of California, Berkeley, the Lawrence Berkeley National Laboratory and Graduate Theological Union. The city sits on 10.5 square miles of rolling plains, and enjoys relatively wet winters and dry summers. Average annual precipitation is 23.6 inches. Temperatures are mild almost all year with an average of only 3 days a year with temperatures over 90 degrees Fahrenheit, and 1 day with temperatures below freezing.

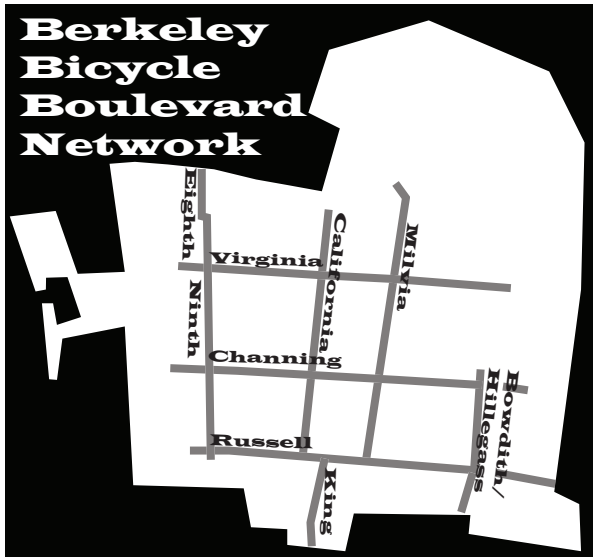


Image created from: http://www.ci.berkeley.ca.us/uploadedImages/Public_Works/Level_3_-_General/Bikegrp.jpg

Berkeley's bicycle boulevards were selected to span the city north-south or east-west, and as a result the network reaches most parts of the 10.5 square mile city.

Photo:http://www.ci.berkeley.ca.us/EllsworthParkerCircle.html

Berkeley's bicycle boulevard traffic calming elements include beautifying elements such as vegetated traffic circles.

Project History

The City of Berkeley has created a network of bicycle boulevards that is considered one of the best in the nation. The process began in the Spring of 1999 when the City of Berkely adopted their Bicycle Boulevard Plan, which identified a network of seven bicycle boulevards. The city then initiated a series of public design workshops to help develop the conceptual design of the network. Along with guidance from the cycle subcommittee of the City's Transportation Commission, the public process resulted in an inventory of the existing conditions on the streets that were to become bicycle boulevards, and the basic features of the new boulevards. A three step process for implementing the boulevards was also outlined. In Spring 2000 the City Council authorized staff to implement the project. About 90 percent of funding came from grant sources, including the Transportation Fund for Clean Air (TFCA), Transportation Development Act, Article 3, and Caltrans Safe Routes to School Funds.

Photo: http://www.ci.berkeley.ca.us/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=6734
Berkeley's bicycle boulevard traffic calming elements include semi-permanent installations such as this relatively low maintenance traffic circle.

Photo: http://www.streetfilms.org/wp-content/uploads/2007/02/bikeblvdsign.jpg
Distinctive bicycle boulevard distance and destination signs help riders with way-finding and trip planning, and help brand the boulevard.

Design and Development

The Berkeley bicycle boulevard streets are designed as places where bicycles and cars can equally share the road. The boulevards are primarily on residential streets, however some sections pass through commercial areas. Generally there are few cars on these streets, in large part because of the pre-existing traffic calming devices from a 1969 traffic plan to divert cars away from residential neighborhoods. Bicycle boulevard routes were also specifically selected to be near larger roads, so that car traffic could easily be diverted there rather than into other residential neighborhoods. Bicycles share the lane with vehicles on the majority of the boulevards, but preexisting bicycle lanes remain on those streets that had them before the project began.

Berkeley has a traditional urban street grid, and most roads stretch long distances, often from one end of the city to the other. These long, narrow side streets are ideal for the bike boulevard concept. All the boulevards were designed to be continuous routes, traveling the entire length of the city from north to south, or east to west, and to pass by, or very near, many popular destinations including schools, shopping districts, and BART stations.

A variety of traffic calming measures are employed to encourage use of bicycle boulevards to local vehicles only. Diverters direct cars to main thoroughfares, while allowing bicycles and pedestrians to safely continue along the route. At some intersections, motorists are restricted to a "right turn only", while pedestrians and bicyclists are allowed to travel straight. Traffic circles and speed humps help to reduce vehicle speed through intersections. At some intersections electronic detectors alert traffic signals when a bicycle approaches, allowing the cycle through while vehicles wait.

Photo: http://www.dbarchitect.com/images/dynamic/article_slide-show_images/image/bicycle_blvd_berkeley1.project_small.jpg

Large pavement markings make it clear to users that they are on a distinctive roadway, one that prioritizes bicycles.

Once the design and approval process was completed in early 2001, the first phase of construction involved placing signs and pavement legends along a demonstration stretch of the planned network. Signs were evaluated and modified based on feed-back. At this point contra-flow bicycle lanes were also added on a one-way street. In fall 2002 crossings were improved with new traffic signals, and existing traffic diverting bollards were replaced by landscaped diverters with cut-through for two-way bicycle travel. In early 2003 the remaining signs and pavement legends were installed to complete the network.

Photo: http://www.ci.berkeley.ca.us/uploadedImages/Public_Works/Level_3_-_General/Bikegrp.jpg

Vegetated Traffic Circles provide not only improved safety for the corridor, but add to the character of the neighborhood and the bicycle boulevard system.

Project Evaluation

Berkeley has achieved one of the highest rates of bicycle and pedestrian commuting in the nation. At the same time Berkeley is the safest city of its size in California for pedestrians and cyclists. The document *Berkeley Bicycle Boulevard Design Tools and Guidelines*, published in 2000, is extremely influential in spreading the concept to, and determining the standards for bicycle boulevards in, other cities.

Photo: http://www.bikeroute.com/NationalMayorsRide2008/Berkeley/BerkeleyBikeBlvd.jpg

Improved crossings are a key component to Berkeley's bicycle boulevards.

Project: Bike Boulevard Network
Location: Berkeley, California
Construction Completed: 2003
Cost: Approximately $330,000. (About 90 percent of funding came from grant sources.)
Size: Seven bicycle boulevards.
Program Elements: Sign changes, pavement markings, traffic circles, bulbouts, new traffic signals, high-visibility crosswalks, bicycle crossings, landscaping.

Davis, California

Context

The City of Davis is the largest urbanized area in a predominantly agricultural county in California's central valley. The city is home to the University of California Davis with a student population of 30 thousand, and due largely to its influence the city has grown steadily since the 1950's from a population under 5,000 to approximately 64,259 in 2005. Temperatures are generally mild in the winter and hot in the summer. October through April is the rainy season, and accounts for approximately 90 percent of the area's annual precipitation. South Davis is divided from the rest of the city by Interstate 80, the major freeway serving the area, and railroad tracks and other major roads also serve as barriers to bicycle travel.

Davis is known for bicycles, energy conservation, and a preference for slow, managed growth. Its notable physical characteristics are a traditional downtown, and an absence of large scale shopping centers. Davis is one of the premiere bicycling cities in America. Bicycling is so important to this community's identity that the city's logo features a bicycle.

Project History

Davis was one of the first cities in the U.S. to actively start planning for, and incorporating, the bicycle into its transportation infrastructure. As the university grew from about 2,200 students in 1958 to its current enrollment, the demands for adequate bicycle facilities and minimization of bicycle-motor vehicle conflicts increased. The bicycle improvement process began in the mid-1960's when a trial system of bike lanes was installed and soon proved immensely popular. After seeing the immediate success of the trial bikeway system, the University began taking steps to promote the bicycle network by banning all automobile use from its central roads, installing bike paths from the campus center to its perimeter to provide direct bike access, and building bicycle parking next to nearly ever building and activity center on campus.

The city bikeway system has steadily and consistently expanded and matured. Today Davis has approximately 50 miles of bike lanes and 52 miles of bike paths, with

Photo: http://farm4.static.flickr.com/3049/2886298882_72aa08e2f1.jpg

Davis is a relatively compact 10.5 square miles. South Davis is divided from the rest of the city by Interstate 80, the major freeway serving the area. Railroad tracks and other major roads also serve as barriers to bicycle travel but are being bridged through a series of bicycle grade separations.

bike lanes on approximately 95 percent of all its arterials and collectors, and 27 different grade separated crossings for bicycles and pedestrians. This path network crisscrosses the city to provide access to important destinations.

Goals set out in the 2006 Bikeplan include: Planning bikeways to provide attractive, shaded linkages between destinations; Providing adequate bike parking; Promoting inter-modal transportation; Ensuring that bicycle routing is an integral part of street design so that lanes and pathways form an integrated network; Maintaining roadways and bicycle related facilities so they provide safe and comfortable conditions for the bike driver.

Design and Development

Attempting to address the barriers posed by tracks and large vehicular roads, the City has spent millions of dollars completing a bicycle underpass of a county road, the six lanes of Interstate 80, and two sets of railroad tracks. Funds for the $4 million construction came from a variety of sources, including a local referendum, development impact fees, and redevelopment agency funds (Dorn 2001). The underpass provides Davis bicyclists and pedestrians with a safe and direct route between south Davis, the University, and downtown. In 2005, the City spent 3.2 million dollars on a bicycle overpass of I-80, and it has just initiated another bicycle underpass project of a major arterial. In the last ten years alone, the city has spent well over 14 million dollars just on bicycle projects.

Photo: www.activelivingbydesign.org

Located at mid-block path crossings, bicycle signal heads help protect bicyclist and control traffic.

The city of Davis has been using "bicycle signal head" traffic control devices since 1990. These are like standard traffic signals, except that they use red, yellow and green bike icons rather than circles. Bicycle signal heads are commonly used in the Netherlands, England, Germany, and China. Davis began using this type of traffic signal to help expedite the safe movement of bicycles through the city's most heavily used intersections. Located at mid-block path crossings, bicycle signal heads help protect bicyclist and control vehicular traffic.

At one particularly busy intersection that receives up to 1000 bicycle crossings per hour during peak times, the city has installed a bicycle signal head that provides bicyclists with their own separate crossing cycle during which only they are allowed to cross the street. Bicycle circulation was enhanced and safety has been improved at locations where these have been installed (Takemoto-Weerts 1998).

Within recent years, the City of Davis has also begun using roundabouts as traffic control and traffic calming devices.

Bicycle parking is readily available and fairly well appointed in Davis. Bicycle parking in Davis must be conducive for using "u-locks" and must be illuminated. Covered parking is encouraged. The 2006 Bikeplan also recommends the following amounts of bicycle parking:

Multi-family residential: two bicycle parking spaces per dwelling unit.
Commercial: 30 percent of motor vehicle spaces otherwise required and one bicycle space for every two employees.
Public facilities: 30 percent of the motor vehicle parking normally required or immediately available to the facility.
Schools K-12: 85 percent of peak enrollment.
Post-secondary schools: at least 50 percent of peak enrollment.

The City also has bike lockers available for rent at three locations in town. The lockers are located at City Hall, the train depot and at a large Park n' Ride lot to give bicycling commuters a safe and secure place to store their bikes while they are traveling or working. Lockers are available for rent on a first come, first serve basis and rates are $25 for 3 months, $45 for 6 months, $80 for an entire year.

Davis has found that more modest amounts of bicycle parking at many dispersed locations is however preferable to a few high capacity facilities, as cyclists tend to seek-out bike parking very close to their destination. The City helps determine the need for bicycle parking by actively looking for locations where parked bikes exceed the available parking, and where bikes are parked and no parking is provided.

Recognizing the importance of facility

Photo: www.activelivingbydesign.org

Davis is widely recognized as one of the most bikable communities in the United States.

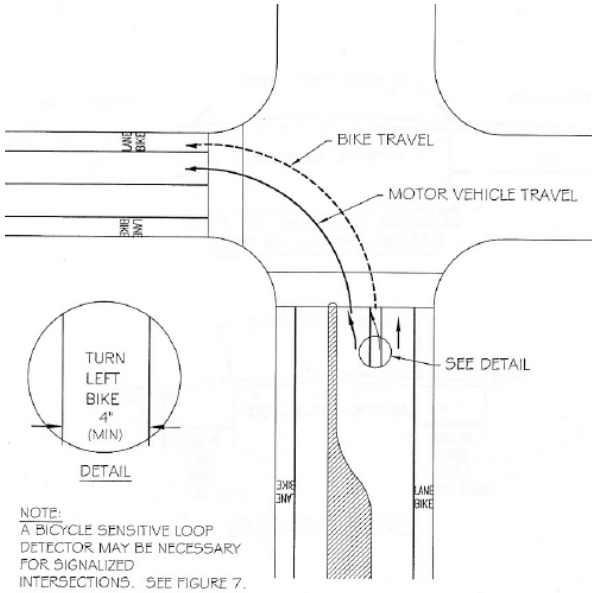


Figure: 2006 Davis Bikeplan

Innovative bicycle facilities such as left turn bike lanes have often been pioneered in Davis.

up-keep to bicyclists' comfort and safety, Davis budgets about $100,000 per year for bike path maintenance. The community is also looking to improve by constantly running pilot projects and tests of experimental facilities such as bike detectors, signal heads and bicycle-only roundabouts.

The Davis bus routes are directly served by bicycle facilities and the city provides for the installation of bicycle parking at bus stops to facilitate bus/bike trips The city's inter-modal rail facility also brings together rail, bus, bicycle, and motor vehicle modes at one location. Busses have bike racks, and the Amtrak "Capitol Corridor" train has installed bike racks on their passenger cars as well.

Project Evaluation

There are more bikes in Davis than there are cars. Out of a population of 64,000 residents, the City estimates there are over 60,000 bikes. At UC Davis approximately 15,000 students ride a bike or walk as their primary mode of getting to class. This is in addition to the 20 percent of faculty and staff members that also walk or bike to campus. The League of American Bicyclists awarded Davis Platinum status in October 2005.

The safety and popularity of the bike network in Davis was also an a important factor in a citywide vote to terminate Davis' school bus system, thus increasing the number of children getting daily physical activity by bicycling or walking to school (Dorn 2001).

The success of the bicycle network in Davis can be attributed to a number of factors supporting bicycling as a prevalent mode of transportation. Flat topography, a mild climate, and low yearly rainfall makes bicycling a comfortable choice. As the home of UC Davis, the city has a large population of young students with limited incomes for whom bicycles provide a cheap and convenient form of transportation. Furthermore, the compact nature of the city and its isolation within an agricultural context also helps improve bikability. For example, most students and many staff and faculty members of the University live within a very bikable one to three mile radius of the campus (Takemoto-Weerts 1998).

Currently an impressive 17 percent of

Photo: www.activelivingbydesign.org

Under and over-passes to help bicyclists safely traverse barriers are key to the success of Davis' bike system.

trips in Davis are by bike, but although a 17 percent mode share is very high, the share has decreased from where it was 20 years ago. The 1990 census indicated that 20 to 25 percent of all trips to work were made by bicycle. Perhaps instituting bicycle boulevards in Davis would help increase biking even more.

Project: Bike Network
Location: Davis, California
Size: 50 miles of bike lanes and 52 miles of bike paths.
Program Elements: Under- and overpasses, bicycle signal heads, dedicated bicycle paths, bicycle lanes, roundabouts, bicycle parking, improved bicycle crossings and intersection facilities.

Portland, Oregon

Context

Portland is a city of about 500,000 that has become well known for its progressive land planning and transportation efforts. Portland's land-use plan calls for the creation of a network of regional and town centers in which residential and commercial activity are concentrated. These town centers are in turn linked by public transit. A supporting regional vision includes a connected network of trails, parks, and greenspace and an urban growth boundary.

Project History

Between 1991 and 2007 Portland significantly expanded the length of its bikeway network, giving priority to bridging barriers, creating continuity, improving way-finding, and enhancing the safety and comfort of the bicycling experience.

The development of bicycle boulevards as part of this project sprang by accident from a city traffic calming effort. The popularity and success of these bicycle boulevards has however led to a great surge of interest in implementing the concept throughout the city.

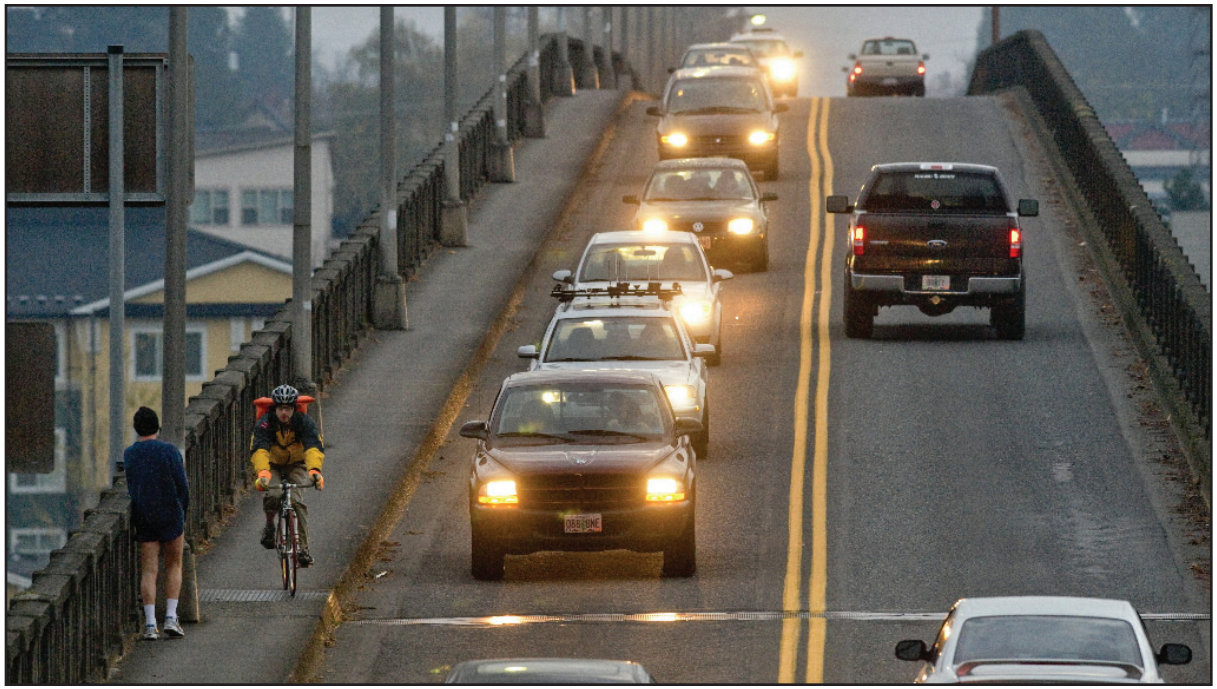


Photo: http://blog.oregonlive.com/environment_impact/2009/03/Sellwood-Run-Bike.JPG

Portland's bridges proved to be effective barriers to cycling and walking where pedestrian and bike facilities were insufficient to provide for safe, comfortable passage.

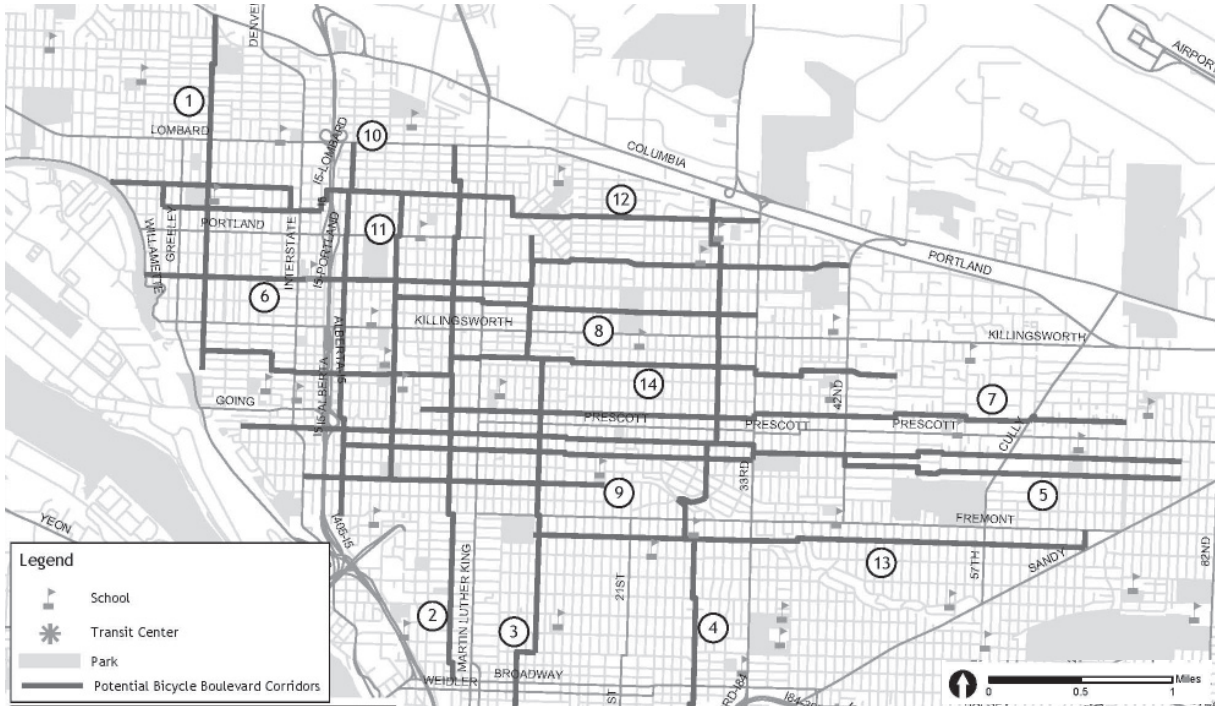
Photo: http://farm2.static.flickr.com/1026/879476720_adb5627324.jpg?v=0

Bridge improvements such as the pedestrian and bicycle path at Steel Bridge help encourage bicycling by providing safe and comfortable passage.

Design and Development

Portland expanded the length of its bikeway network by 240 percent between 1991 and 2007, focusing particularly on creating continuity by bridging path gaps and improving way-finding, as well as on enhancing the safety and comfort of the bicycling experience by improving intersections, crossings, and bicycle lanes, and creating bicycle boulevards. Special attention was paid to overcoming the barriers caused by the approaches and spans of four bridges crossing the Willamette River, which divides the city.

The development of bicycle boulevards as part of the larger City bicycle improvement effort came along almost by accident. In the mid nineties the City began responding to neighborhood requests for neighborhood



The proposed boulevards for North/Northeast Portland connect a number of destinations, and are spaced less than a mile apart to be convenient for almost all of the area residents.

Improved crossings for both pedestrians and bicyclists, as well as motor vehicle access restrictions, are common along Portland's bicycle boulevards.

Direction signs include time-to-destination estimates to help bicyclists with way-finding and trip planning.

traffic calming, predominantly in Southeast Portland, and in so doing began to create great streets for biking as well. As bicyclists discovered these routes, the routes were formalized with signs, including destination and distance signs, and labeled as 'bike boulevards' on the Portland Bike Map. The popularity and success of these accidental boulevards has led to great interest in implementing the concept throughout the city.

The Portland Bicycle Transportation Alliance (BTA), a non-profit advocacy group, began the more formal effort to incorporate bicycle boulevards into the Portland network in 2007. Working with a group of Portland State University (PSU) students, the group began by conducting neighborhood surveys asking questions such as "What streets do you like to ride on?" By mapping these responses,

Portland's bicycle boulevards move along both residential and mixed use streets.

the group got a good idea of potential routes. Routes were then evaluated first on the basis of existing traffic volumes, connectivity and land uses. The next step was to ride the routes, looking for existing conditions such as a lack of pavement, very unsafe intersections, or other necessary improvements that might render the stretch too expensive to convert into a suitable bike boulevard. By riding and evaluating the routes on the ground BTA and the PSU students were able to settle on 14 routes and create a a 'Potential Bike Boulevards' map for the Northwest quadrant.

Concurrently the City was looking to expand bicycle boulevards city-wide through its 'Safe, Sound and Green Streets' campaign. The proposal ended up including 110 miles of bicycle boulevards that would expand the network to reach within a half mile of 87% of the city's population. The method employed by the City for these selections involved primarily GIS-based assessment of connectivity. More detailed analysis and assessment, including ground-truthing of all the identified routes, is underway.

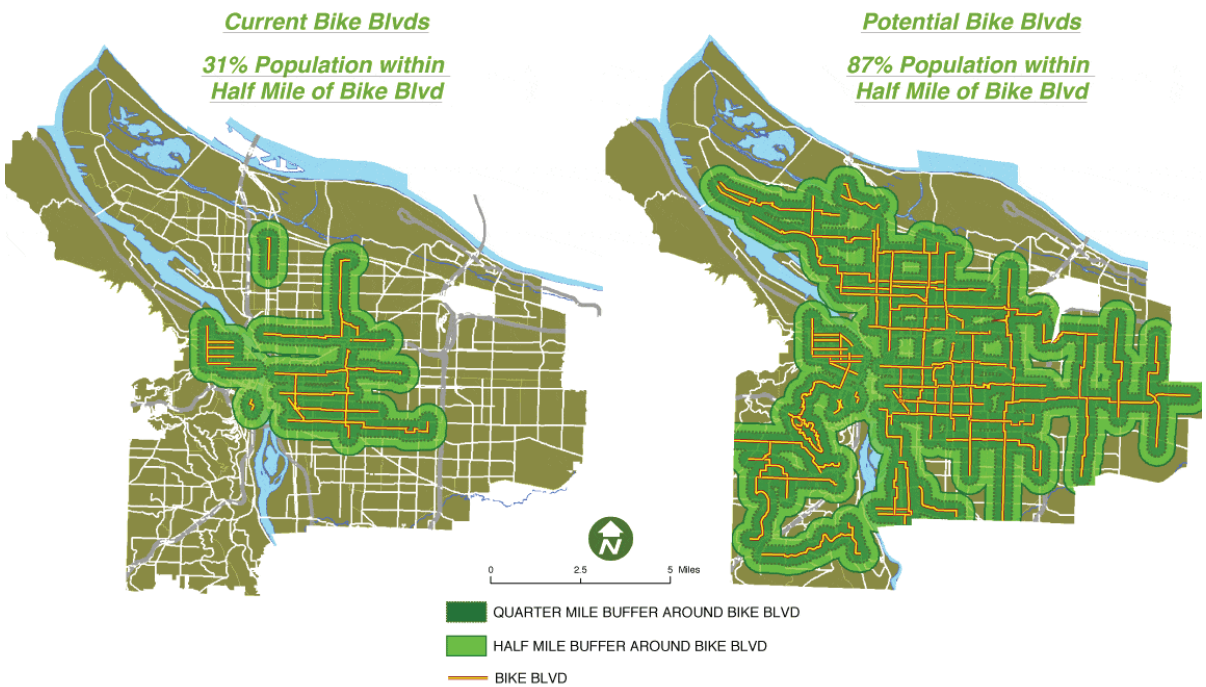
BTA is now also working with the City to determine the most suitable bicycle boulevard routes in Southwest Portland. BTA surveys indicate that 60% of Portland's population is interested in bicycle riding, but have concerns. The general emphasis of this project is thus on shifting bike facilities from major streets to low-traffic streets, and filling gaps in the existing system. The BTA and the City solicited community feedback and held two open houses to help in the selection and evaluation of potential routes. Ground-truthing rides were conducted during the summer of 2007.

Project Evaluation

Portland's bicycle network has grown from 60 to 260 miles since the early 1990s. Overall, census data show that trips by bicycle in Portland doubled between 1990 and 2000, without any increase in crashes (Birk and Geller 2007). Portland now has a good quality, varied bicycle network that connects almost all parts of the city. In fact, a 2005 study of the bikeway improvements found that the two key factors relating to the success of Portland's bicycle program were the completeness and clarity of the network, and the quality of the facilities, including bike lanes, bicycle boulevards, and intersection improvements.

Portland's 2007 bicycle count shows that trips by bicycle across the city's four main bicycle friendly bridges increased by 410 percent between 1991 and 1997 (Birk and Geller 2007). The trend toward increased rates of cycling continues in Portland, with the city seeing increases in trips made by bicycle each

Bicycle boulevards in east Portland feature attractive, traffic calming Traffic Circles, and often move along stretches graced by beautiful, mature trees.



Source: http://www.portlandonline.com/transportation/index.cfm?c=45231

Portland Mayor Sam Adams has been lobbying for a 24 million dollar 'Safe, Sound and Green Streets' proposal that would implement 110 additional miles of bicycle boulevards in Portland, and bring 87 percent of the population within a half mile of a bike boulevard.

year. The percentage of workers commuting to work by bike rose from 1.8 percent in 1996 to 4 percent in 2000. Some have measured current levels at 16 percent (Ross 2008). Bicycle boulevards are becoming an increasingly important and prominent parts of this improvement effort.

Emily Gardner of Portlands BTA has been a major player in the bicycle boulevard planning movement in the last several years. She places bicycle boulevards as central to Portland's ongoing success story, stating, "We started with bike lanes and trails, and are only now, 10-ish years later, realizing that bike boulevards are the facility that appeals to the most current and potential riders." She believes long-term that the key to real bikability is offering the same kinds of options to bicyclists as to motorists-- a choice between the bike equivalent of the highway, the collector or the residential street depending on preference, destination, distance and comfort. The danger of a movement towards bicycle boulevards is that other facilities, such as bike lanes, might fall by the wayside, making biking choices less diverse.

Gardner identifies improving intersections with major streets as the most critical design feature of a bicycle boulevard. While many of the routes selected as bike boulevards are chosen because they have preexisting crossing improvements, Gardner stresses that if all such intersections are not improved, the bicycle boulevard becomes merely a neighborhood loop, not a transportation stretch, and that new bikers and families in particular, will not cross major streets without significant safety improvements.

Feedback and comments on the Southwest Portland proposed bicycle boulevards indicate that, although a wide variety of rider types are interested in bicycle boulevards, there are occasional concerns about the suitability of routes selected, primarily due to steep grades. As no slope analysis underpins the selection of suitable routes, it seems perhaps a GIS-based suitability test that included slopes might have been able to eliminate some of the steeper routes as attractive bicycle boulevard candidates.

Project: Bike Network
Location: Portland, Oregon
Size: 200 miles of bike lanes and bicycle boulevards.
Program Elements: Bridge improvements, bicycle boulevards, dedicated bicycle paths, bicycle lanes, traffic calming, improved bicycle and pedestrian crossings.

Long Beach, California

Context

Long Beach is located about 20 miles south of downtown Los Angeles with a population of about 461,000 and an average density of about 1,300 people per square mile. The city streets are on a grid system. Bike paths are found on city streets, and dedicated pedestrian and bikeways are found along the Shoreline and the San Gabriel and L A. Rivers.

Project History

In the early 1990s a citizen of Long Beach, inspired by cities in Europe and Japan that achieve high levels of bicycle and transit ridership, convinced the City to embrace the idea of a public cycling or bike-transit center to help increase bicycle ridership in the Long Beach area. Long Beach thus built the first bike-transit center, named Bikestation, in North America in 1996. The concept was intended to promote alternative transportation choices by using a service hub to help people connect to transit employment centers in downtown. The concept soon proved successful, and ten years after the first Bikestation was built, construction began on an updated, state-of-the-art version on the same site.

The new Bikestation Long Beach adapted and reused existing structures, and costs for phase one were kept to about $450,000. Construction funds came from the state's bicycle transportation account and the Long Beach Redevelopment Agency provided matching funds. The facility's operating costs are $130,000 annually. The City of Long Beach contributes $48,000 per year; fees for Bikestation services (rentals, retail, repair, and parking) cover the balance.

http://www.toistudio.com/blog/uploaded_images/bikestation-766360.jpg

By not only encouraging cleaner transportation alternatives, but by featuring solar panels and recycled materials, the Bikestation Long Beach bike-transit station helps the city showcase its commitment to a green future.

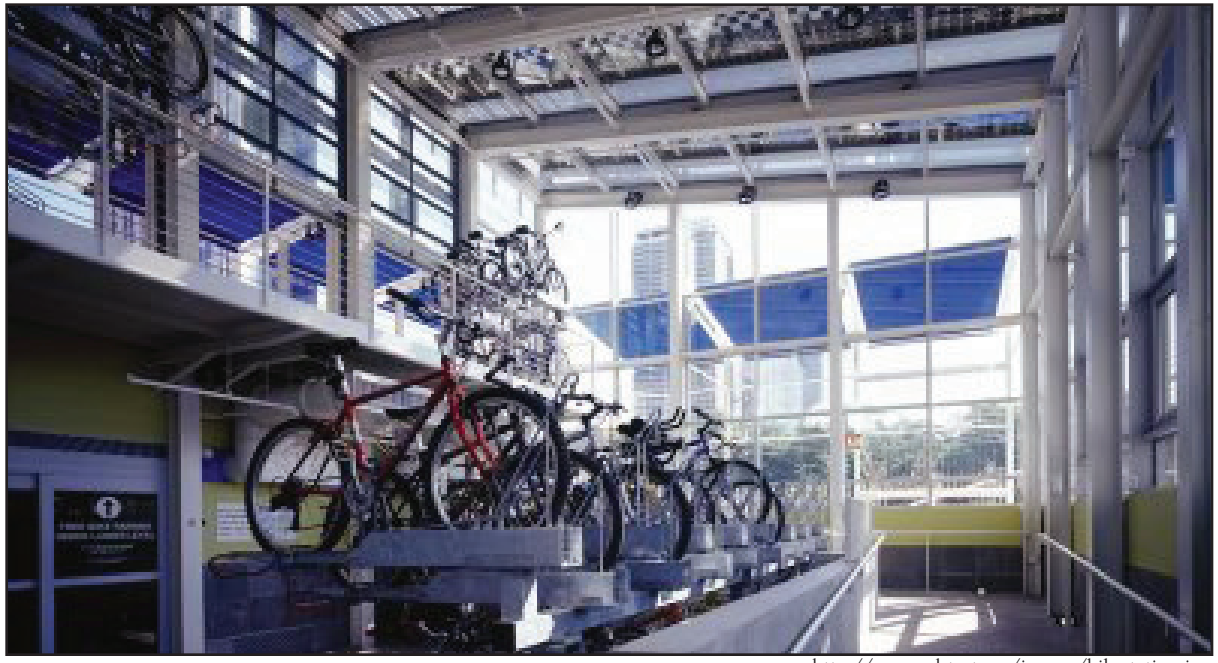
Design

The stated goal of the Bikestation bik-transit hub is to help overcome real and perceived barriers to bicycling including fear of bicycle theft, concern for personal safety, a lack of knowledge and information about bicycling in general, the need for changing and showering facilities for bike commuters, and the confusion of combining multiple modes of transport such as bus, train, biking and walking.

In order to help alleviate these barriers, Bikestation Long Beach provides secure, indoor bike parking 24 hours a day and seven days a week, on-site repairs, rental and retail tools, classes and information on bicycling and bike maintenance, bicycle registration, showers and bathrooms. In

addition the facility is sited so as to provide easy access train and bus stations for multi-modal trips, and close to popular dedicated bicycle routes and within walking distance of downtown destinations and employment centers. The station also includes access to bicycle and electric car sharing. In order to provide more of a lively, destination feel, the design also includes an on-site cafe, and bike tours of the city depart from here. General environmental consciousness is also demonstrated through prominent solar panels on the station roof.

Membership rates for round-the-clock indoor, bike parking cost users one dollar a day, twelve dollars a month, or ninety-six dollars a year.



http://www.calstart.org/images/bikestation.jpg
Incorporating striking architecture and design makes for an eye-catching addition to the city, a pleasant space for commuters and recreational cyclists alike, and is emblematic of a city's commitment to bicycling.

Project Evaluation

Bikestation's user surveys consistently show that 30 percent of users previously drove their cars alone to their destinations and would still be doing so if the Bikestation weren't available. More than 60 percent of Bikestation users who were already cycling ride their bikes more frequently. In 2006, Bikestation parked over 50,000 bikes, helping to keep over 300,000 pounds of carbon dioxide and other pollutants from the air.

The Bikestation organization now has six facilities located in Long Beach, Santa Barbara, Palo Alto, San Francisco, Berkeley, and Seattle. The centers are operated by public-private partnerships, or directly by the non-profit Bikestation. Each facility features services and amenities tailored to the local community's needs and resources.

A bike-transit center helps remove many barriers to bicycling. In addition to this, incorporating striking architecture and design makes for an eye-catching addition to the city, and is emblematic of a city's commitment to bicycling. By not only encouraging green transportation alternatives, but by featuring solar panels and recycled materials, the Bikestation Long Beach bike-transit station helps the city showcase its innovative nature and commitment to a cleaner, smarter future.

Project: Bikestation Long Beach
Location: Long Beach, California
Construction Completed: 2006 (Phase I) 2008 (Phase II)
Cost: Approximately $450,000. (Phase I) Operating costs $130,000/year.
Program Elements: 24-hour indoor bike parking, bike valet, bike repairs, tools, café, classes, transit information and access, bicycle and electric car sharing, shower and bathroom, bike tours.

Case Review Implications for Bicycle Boulevard Design:

Route Selection:

Bicycle boulevard routes should provide **convenient access to popular destinations** such as schools, parks, commercial areas, and transit stops.

Bicycle boulevards should be placed along **streets parallel to vehicular arterials** that provide an appropriate outlet for displaced motorists.

Residential streets and narrow commercial or mixed-use **streets capable of supporting lower traffic speeds are most suitable for conversion** into bicycle boulevards.

Utilizing routes with some existing good quality signalized crossings, traffic calming devices, and areas of smooth pavement **helps reduce costs** of implementation.

Areas with **flat topography and a continuous rectilinear street grid system** are most appropriate for bicycle boulevards.

Streets with existing **street trees or room for planting** of new ones adjacent to the road are well suited for a bicycle boulevard, particualrly in sunny or hot climates.

Routes should **interconnect with other bikeways**, and preferably be part of an interconnected network of bicycle boulevards.

Routes should be as **long and continuous as possible**, preferably traversing the entire city and terminating at the intersection of a perpendicular bicycle boulevard or other bikeway.

Route Design:

Distinctive signs and pavement legends help identify the bicycle boulevard and set it apart form other facilities.

Traffic calming devices that help **calm and discourage motor vehicles** are particularly critical when optimizing the roadway for bicyclists as thru-going traffic by removing or turning stop signs or otherwise improving the connectivity of the route.

Safe, signalized, convenient **crossings at all streets with heavier traffic volumes** or higher speeds are essential for encouraging use

particularly by commuters, novice riders and families.

Changes in route typology or design treatment, as well as jogs and turns **should be minimized**.

Parallel parking should be maintained or implemented as it visually narrows the roadway and makes vehicular traffic move more cautiously, while the hazards of merging traffic and opening car doors are minimized for bicyclists when they utilize the entire travel lane.

A **single travel lane in each direction should be maintained** to help moderate speeds as motorists must pass slower bicyclists by moving into the oncoming traffic lane.

Facility Design:

Bicycle parking should be provided at **dispersed locations** along bicycle boulevard routes, including bus stops.

Bicycle parking should be **illuminated and covered** when possible.

Investment in higher cost, **larger scale, longer term bicycle parking facilities should be reserved** for large transit stations, downtown cores and major destinations.

The Process:

Involving activists, bicyclists and the general public in the route selection and design process is key to selecting appropriate bicycle boulevards, appropriate traffic calming and other design elements, and to the ultimate success and acceptance of the boulevards.

Maintenance:

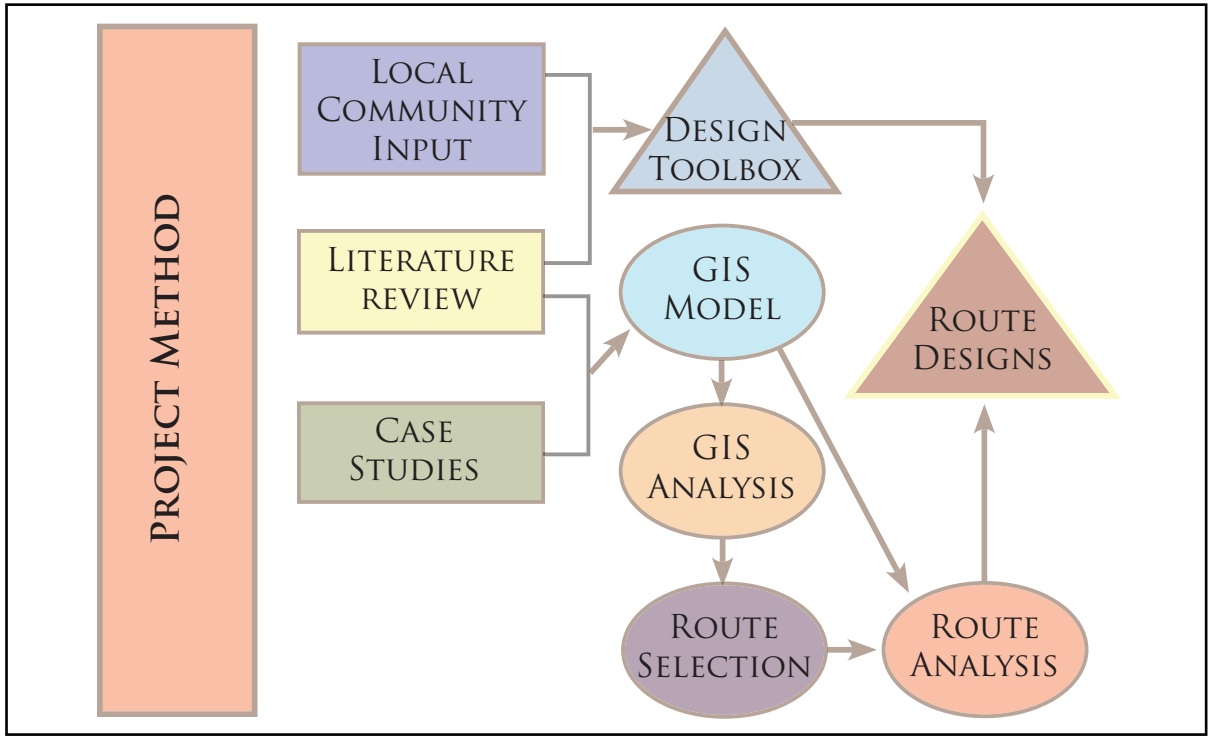
Maintenance of facilities and surfaces is **critical to the continued safety and comfort** of the bicycle boulevard.

Method

This project involved three fundamental steps:
1. Understanding barriers to biking and walking, and design-based barrier interventions, through literature review and case reviews.
2. Barrier identification and suitability assessment on the city scale through a GIS-based model.
3.Route-specific analysis and design for two pilot bicycle boulevard paths in Tucson.

The most significant aspect of the method employed here was the development of a GIS-based model for site analysis and barrier identification. The identification of barriers and bicycle boulevard suitability involved classifying indicators, and weighting them to reveal geographic areas suffering from lack of connectivity and safety, and those most suitable for bicycle boulevard improvements.

While a network of bicycle boulevards should ideally come to provide access to the entire city, identifying areas of high suitability helps with prioritization of implementation. By placing the first bicycle boulevards in Tucson in places where they are most likely to build connectivity, bridge barriers, and targeting populations that stand to benefit most from them, the success of these pilots, and thus the eventual completion of an entire network, may be more likely. This process and the GIS models shown on the following page are described more fully in the Analysis and Assessment chapter that follows.



Project Method- This project was built on the three fundamental components of literature review, case study and community feedback.

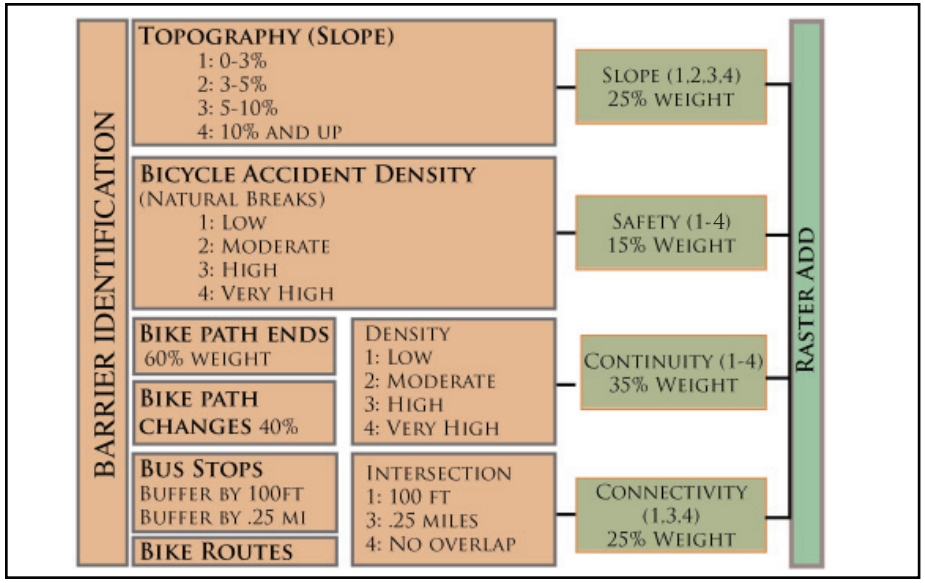
Once areas most suitable for bike boulevards were identified, existing city-proposed bicycle boulevard routes were overlaid to determine target corridors for design intervention. Holes in the city's planned bicycle boulevard network could also be easily evaluated concerning both suitability and existing barriers.

Two proposed north-south bicycle boulevard routes previously identified by both the city and local community members as ripe for bicycle improvements also showed high suitability based on the GIS analysis. These two paths were then selected for refinement and design as bicycle boulevard pilot projects.

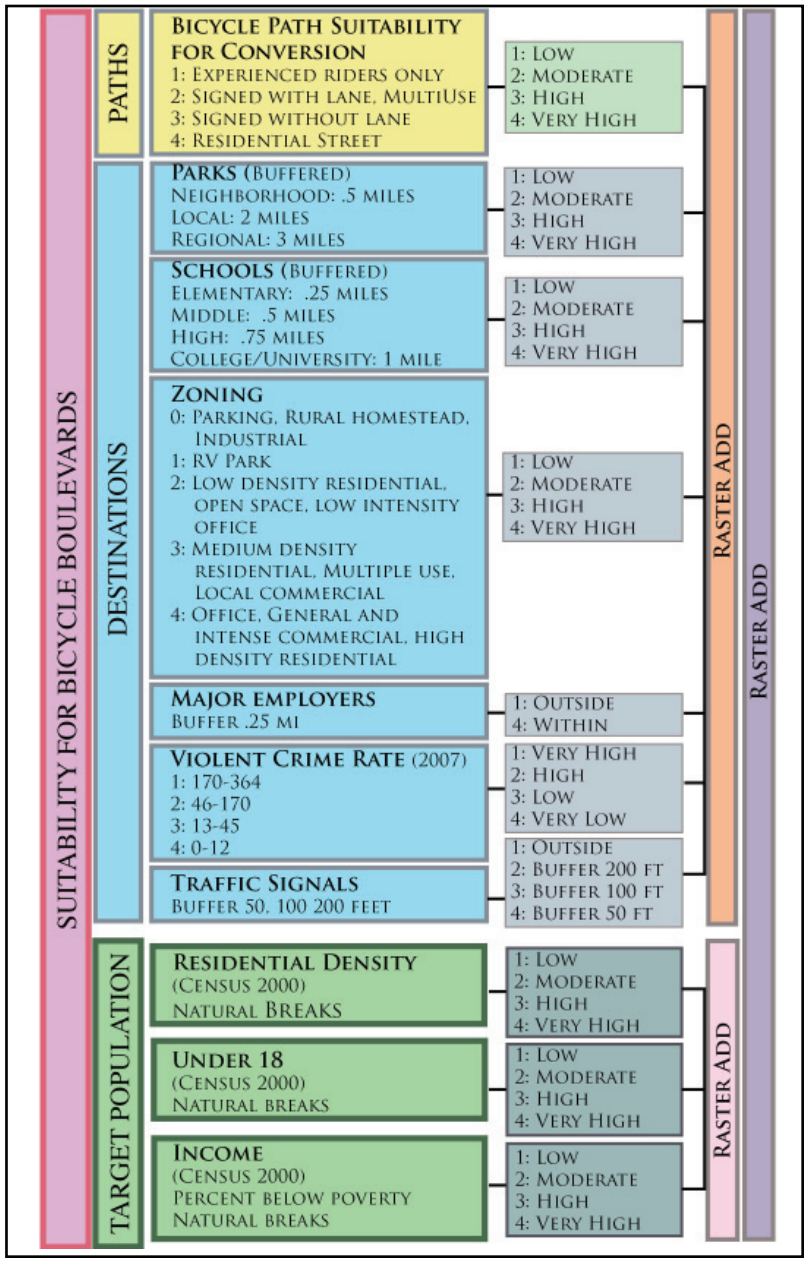
A focused site analysis of both routes, including on-site assessment of existing facilities and conditions, two conceptual master plans, and the development of specific design applications and renderings followed.

The Design Toolbox of general bicycle boulevard design guidelines for Tucson was developed based on research, case study precedent and community feedback. Particularly influential were the bicycle boulevard guidelines developed by Wilbur Smith Associates for the City of Berkeley, and the feedback of the Tucson-Pima County Bicycle Advisory Committee (TPCBAC). The Toolbox is intended to underlie and inform planned future bicycle boulevard implementation in Tucson. The two pilot routes were designed as applications of the guidelines developed in the Design Toolbox.

After preliminary master plans and design concepts were devised, the relevant neighborhood associations, and the larger biking community through the BAC, were invited to share in the process through a series of community meetings, feedback and discussion. After careful consideration of feedback, the designs were finalized as shown in the Design chapter.



Barrier Identification~ The first component in the GIS analysis involved identifying areas of discomfort, significant safety concerns, and broken continuity and connectivity in the existing system.

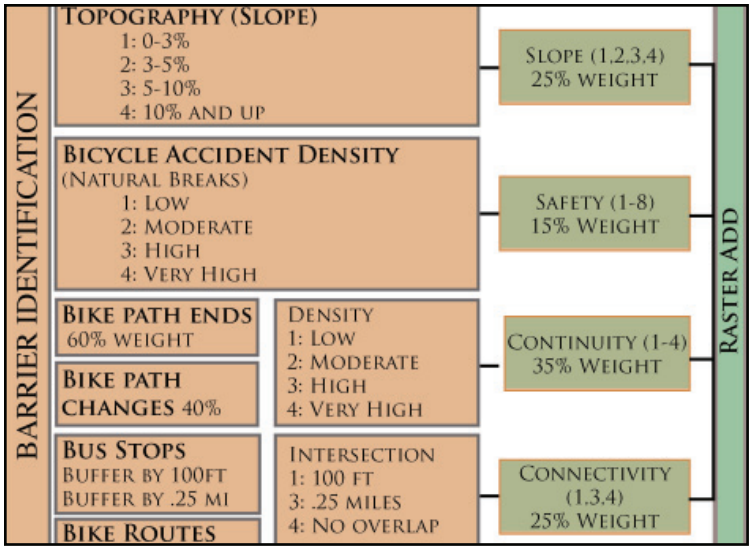


Bicycle Boulevard Suitability~ The second component of the GIS analysis involved identifying areas with suitable and popular destinations, and the locations of the populations most likely to benefit from bicycle boulevards.

Analysis and Assessment

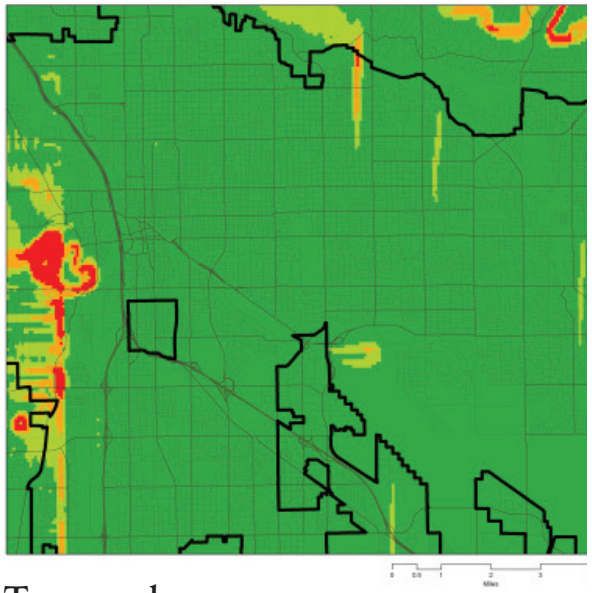
I. City Scale

The barrier identification and suitability assessment on the city scale through a GIS-based model involved classifying indicators, and weighting them to reveal areas and spots suffering from key barriers to bicycling and those zones most suitable for bicycle boulevards to aid in placement and prioritization of implementation.



Barrier Identification

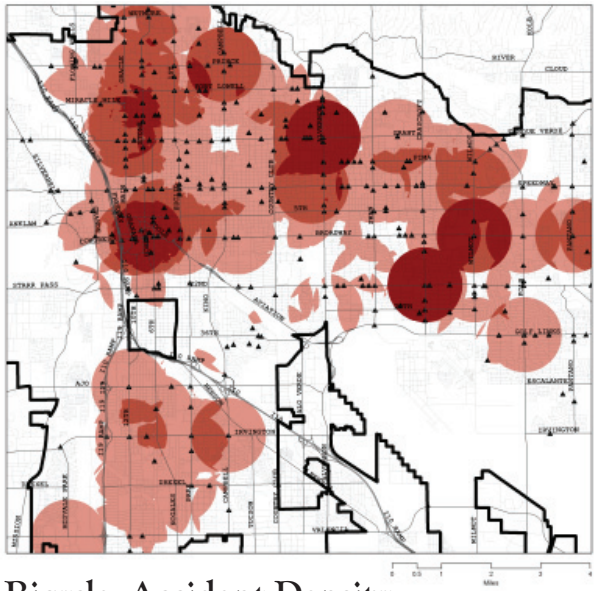
The first step in the GIS analysis involved identifying areas of discomfort, safety concerns, and broken continuity and connectivity in the existing system. These values were then added with a weight towards the most significant factors to determine city-scale barrier zones.
This analysis is intended to give an indication of the kinds and quantities of improvements necessary to overcome barriers along any stretch identified for a future boulevard.



Topography

0-3% | 5-10%
3-5% | 10% and above

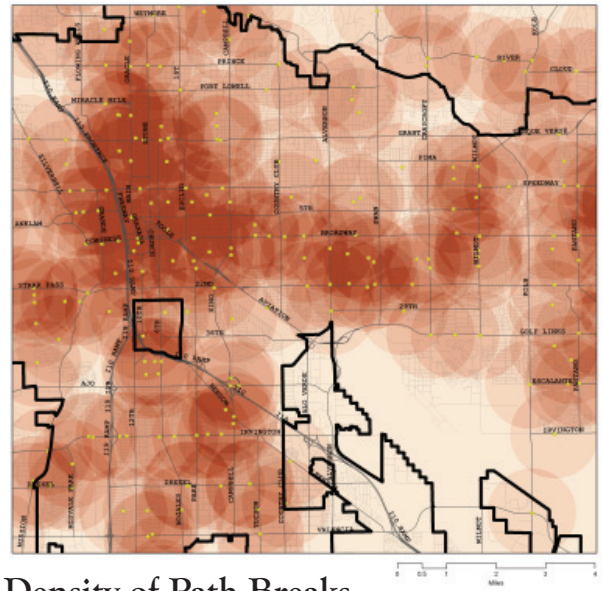
Grades above 5 percent can discourage bicycling if they exceed 100 feet in length. 2 to 3 percent grade can be negotiated indefinitely by all but the most unathletic however. As such the highest suitability score (4) was given to grades of 0 to 3 percent, next highest (3) was given to grades from 3 to 5 percent, a 2 was given to grades of 5 to10 percent, and a very unsuitable score of 1 was given to grades above 10 percent. Overall, the topography of the City of Tucson poses few problems for a bicyclist, and this factor was weighted less heavily in the final Barrier Identification analysis than the other factors.



Bicycle Accident Density

Low
Medium
High
Very High
Accidents

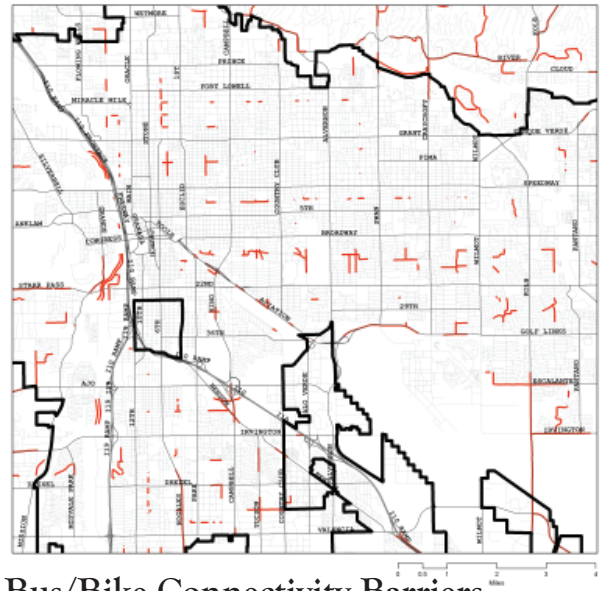
Geo-referenced bicycle accident statistics were used to identify the most dangerous areas for bicyclists in Tucson. The density of accident points was determined through the number of accidents within1 mile zones. Although accidents happen at one spot, the zones help give a more accurate picture of barriers at this scale, as neighbors and riders may feel less safe, or choose to avoid riding altogether when they see or hear of a lot of accidents. The split between low, moderate, high and very high accident levels was determined by Jenks Natural Breaks, and the measures are thus relative to the larger Tucson context.



Density of Path Breaks

High
Low
Path Break Points

In order to assess continuity path breaks and path changes were identified for the existing Tucson bicycle system. These are areas where a bicycle lane may end altogether, or where a facility changes from one level of service to another. The density of break points reveals the number of breaks within 1 mile zones. Although path breaks happen at specific points, a density zone of difficult connectivity is more revealing at this scale, helping to identify areas where residents may choose to avoid riding due to a lack of comfort riding on a variety of bicycle facility types, or switching between riding on and off facilities.

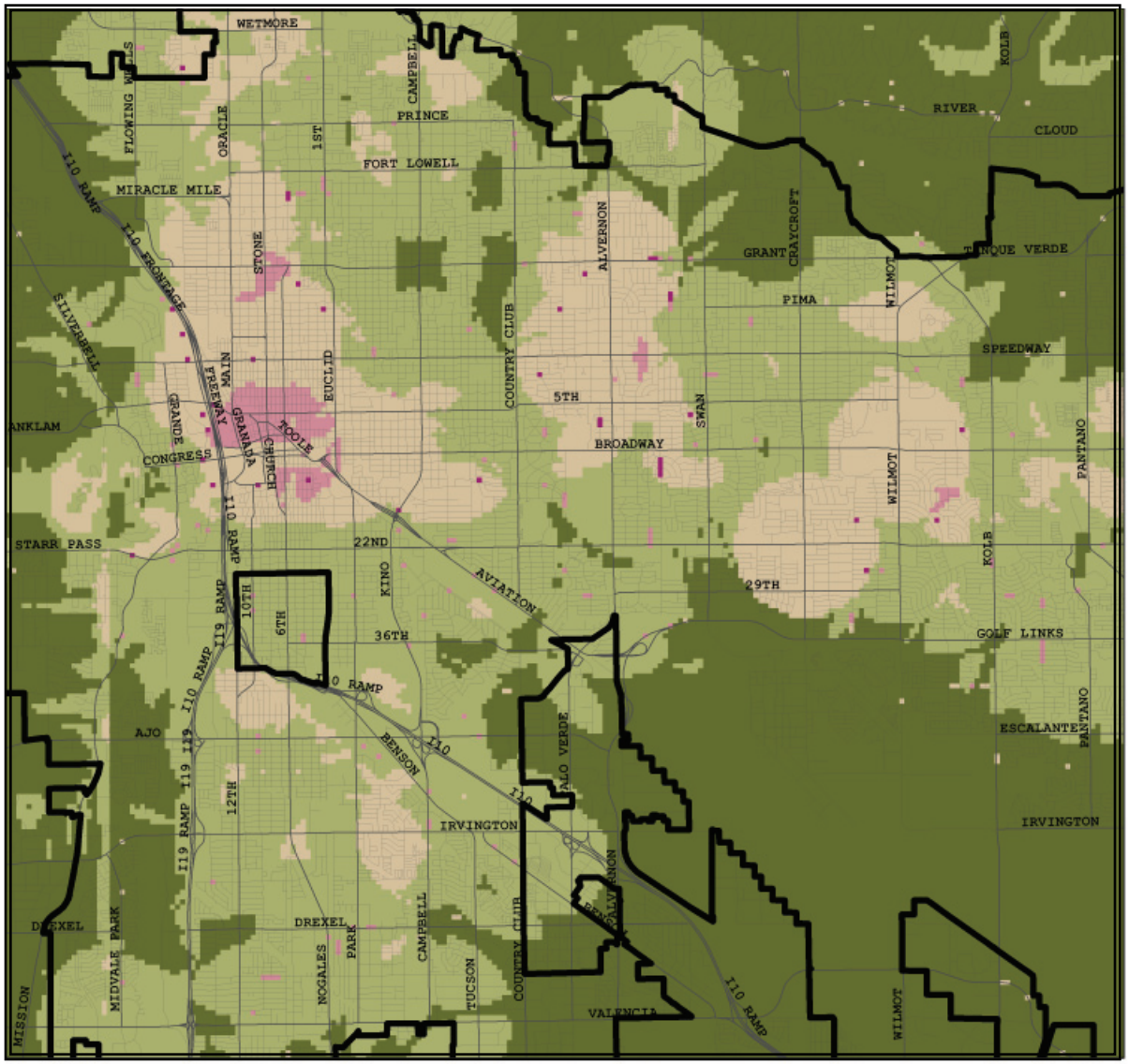


Bus/Bike Connectivity Barriers

Bus/Bike Connection Breaks (Buffered by .25 miles and 200 ft.)

This analysis assesses connectivity breaks with the existing transit. In Tucson transit is supplied almost exclusively by the Sun Tran bus system. Thus connectivity between the two on a city scale was determined by buffering existing bus stops by a walkability radius of .25 miles, and bicycle paths of all types by 200 feet. The two buffer zones were then joined to reveal areas of good connectivity between the two modes of transportation. This overlaid area was then rasterized and subtracted from the buffered bicycle routes to reveal the multiple areas of poor connectivity between the two modes seen above.

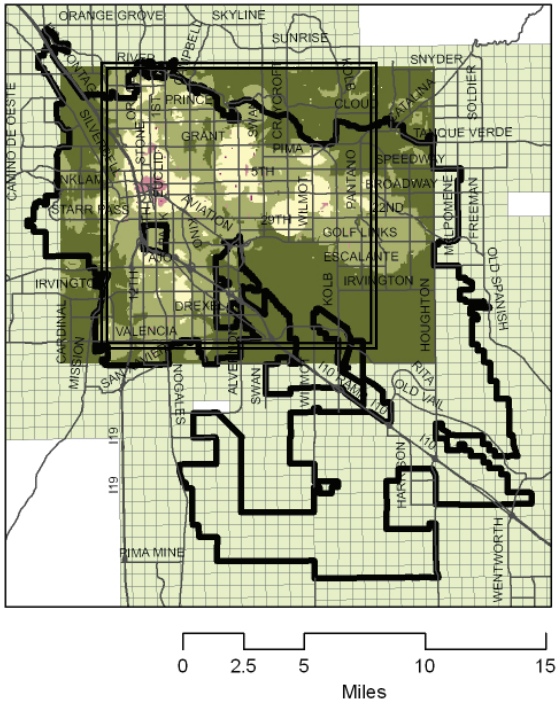
The composite barrier map below reveals bicycle barrier zones and spots. This analysis helps reveal areas most in need of improvements, guides in the selection of potential routes with few barriers, as well as gives an indication of the kinds of improvements needed in particular areas. A significant trouble spot is revealed in downtown. Referencing the individual analysis maps reveals that topography and connectivity to transit are good in this area, indicating that successful barrier reduction in this area must focus on path continuity and safety.

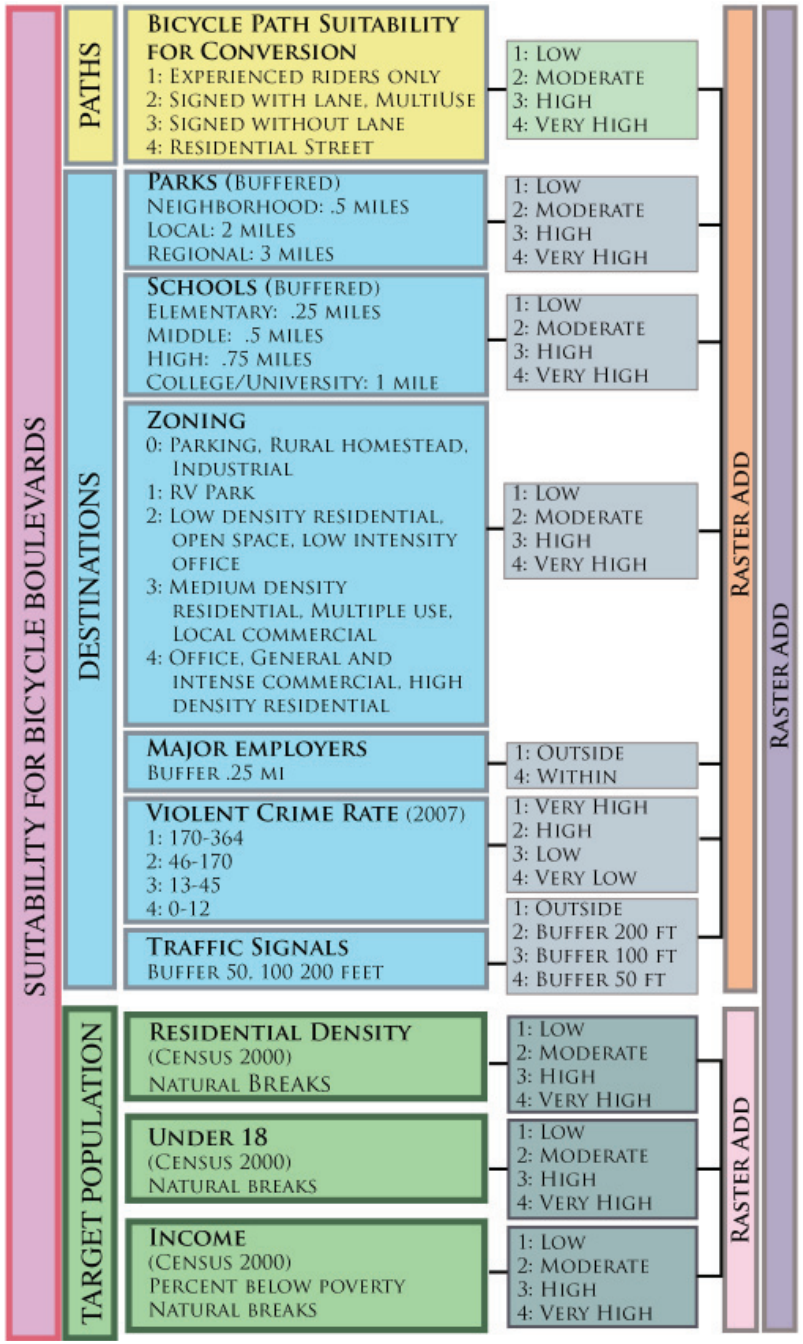


Barrier Identification Map

Barrier Level

- Very Low
- Low
- Moderate
- High
- Very High





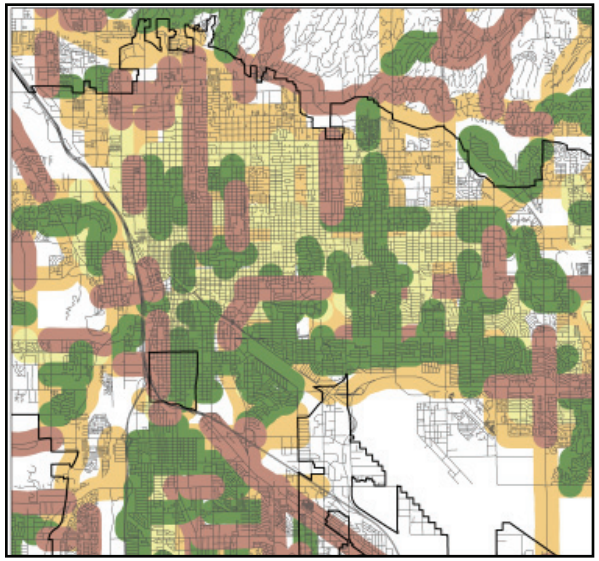
Bicycle Boulevard Suitability

Suitability for bicycle boulevards was determined by evaluating popular and important destinations and target populations.

Destinations included major employers, commercial areas, schools and parks.

Areas with target populations included those with high percentages of children under 18, larger percentage of households below the poverty level, and higher residential density.

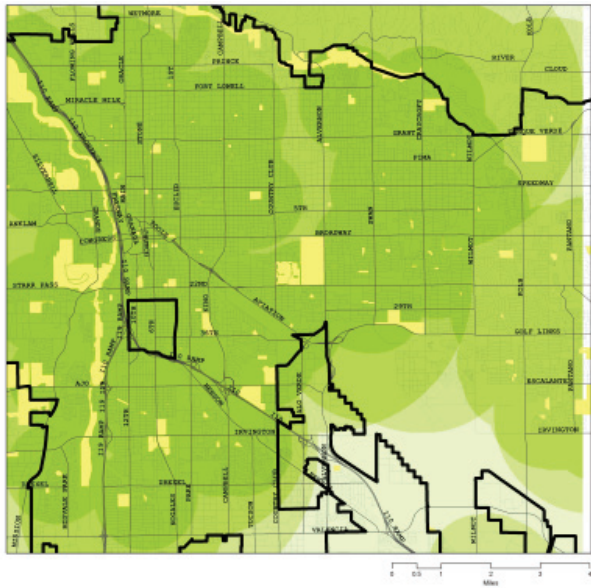
A network of bicycle boulevards should ideally provide access to the entire city, but identifying areas of high suitability can help with prioritization and targeting as that network develops.



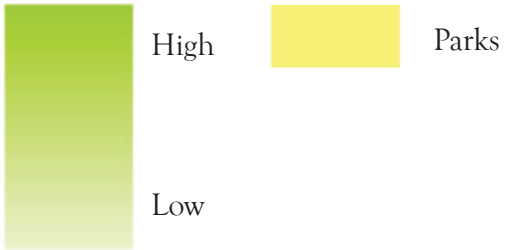
Path Suitability for Conversion

- No Facility
- Signed Without Lane
- Experienced Riders Only
- Residential Street
- Signed With Lane or Multi-Use

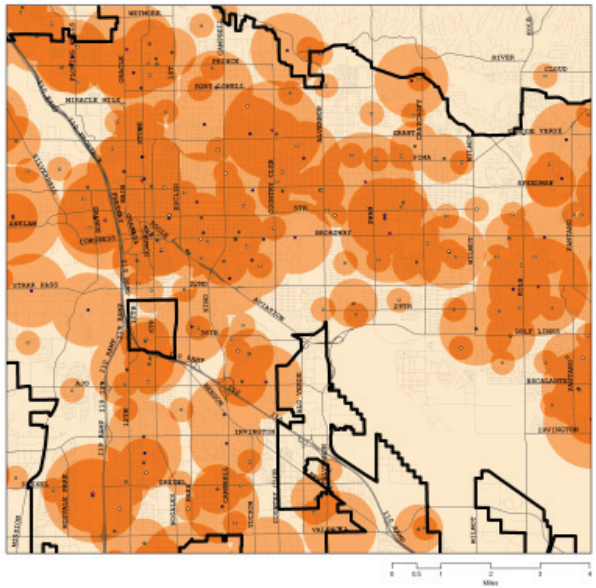
In order to identify the current service level of bicycle facilities inside the city, as well as to identify areas with paths suitable for conversion, bike routes were separated by type with facilities suitable only for experienced riders, or already developed into dedicated multi-use paths being given the lowest suitability rating, and signed routes without lanes and particularly residential streets the highest. All streets without any bike facilities were given a rating of 0. Bike routes were then buffered by .25 miles to give an indication of the areas within easy proximity to these routes.



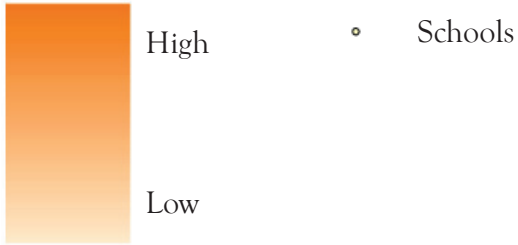
Park Access



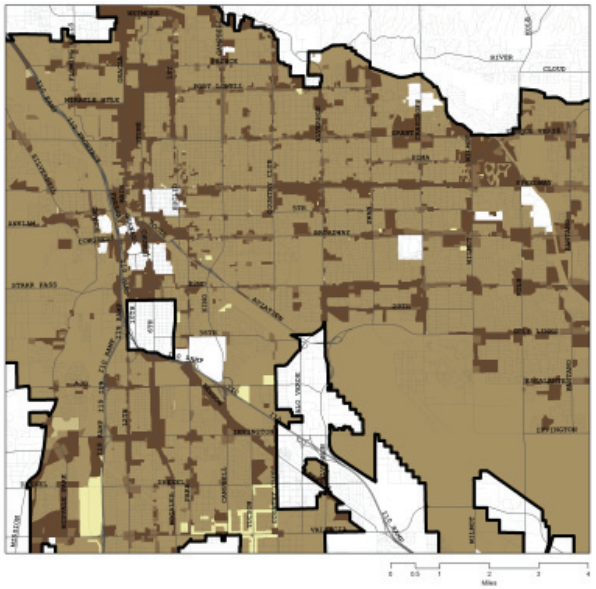
Areas of high and low access to park were determined by separating existing city parks into 3 categories, neighborhood, local and regional, based on size, significance and facilities provided. Neighborhood parks were buffered by .25 miles, local parks by 2 miles and regional parks by 3 miles. These buffers were then rasterized and added to indicate zones of highest and lowest access to parks.



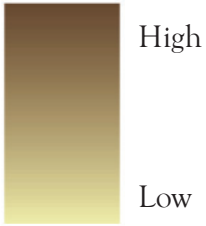
School Access



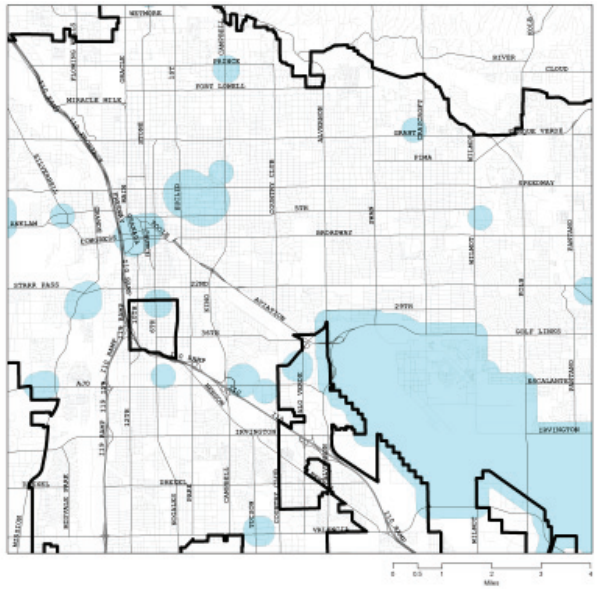
Areas of high and low access to schools were determined by separating existing schools based on the grade level of the students. Elementary schools were buffered by .25 miles, Middle Schools by .5 miles, High Schools by .75 miles and Colleges and Universities by 1 mile. These buffers were then rasterized and added to indicate zones of highest and lowest access to schools.



Land Use Access



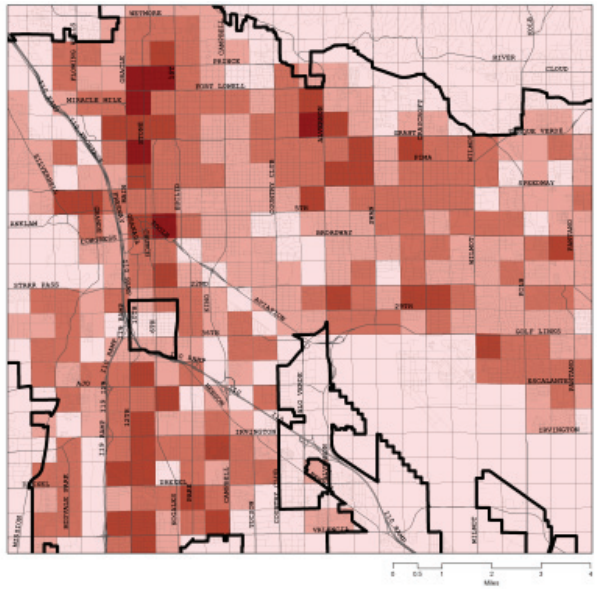
Areas of high and low access to commercial and office zones, as well as other areas of attractive land use were determined by separating existing city zoning classifications based on their potential draw. Parking, rural homesteads, and heavy industrial areas were given the lowest suitability, while areas zoned for multiple use, office, general and intense commercial and high density residential were given the highest rating.



Major Employers

Major Employers (.25 mile buffer)

In order to assure that the population draw of very large employment centers be reflected in the analysis, the top ten employers in Tucson were identified. These are Raytheon, the State of Arizona, The University of Arizona, TUSD, Davis Monthan Airforce Base, Pima County, the US Army Intelligence Center, the City of Tucson, and collectively the local hospitals. TUSD schools were eliminated due to their weight from the School access analysis. Using existing layers for County, City and Federal office, hospitals, and then locating the other employers by hand, each employer was buffered by a .25 mile walkability radius.

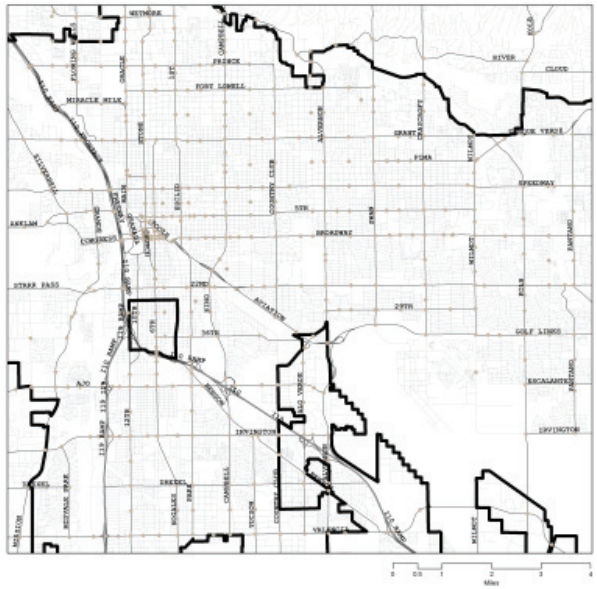


Violent Crime

Number of Incidents

- 0-12
- 13-45
- 46-92
- 93-170
- 171-364

Crime statistics for 2007 were used to identify areas cyclist might avoid despite developed bicycle facilities. Although violent crime rates may not be the main concern of a cyclist, of the limited categories in the data, violent crime was deemed to best indicate the general feeling of safety and security a cyclist might feel moving through a given geographic area, or leaving their property unattended there. Areas with high levels of violent crime are very likely to suffer from other crimes as well.

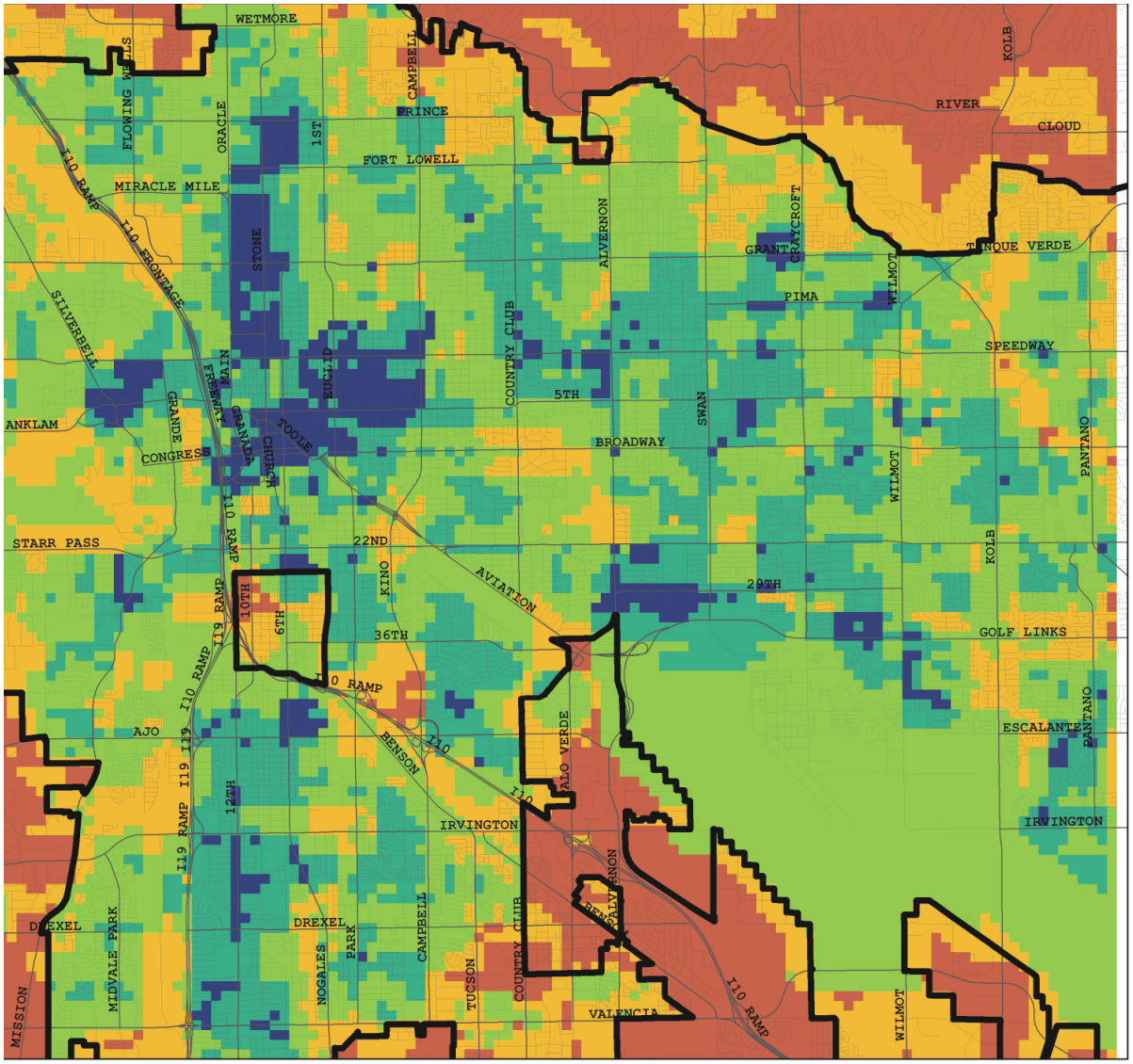


Traffic Signals

- 50 Foot Buffer
- 200 Foot Buffer
- 100 Foot Buffer
- Traffic Signals

Identifying traffic signals as part of this analysis helps place future bicycle boulevards on routes where safety, connectivity and continuity are already being aided by signalized intersections. By placing bicycle boulevards on highly suitable stretches that also have existing lights, the implementation of each boulevard can be much less expensive. This in turn allows more bicycle boulevards to be developed.

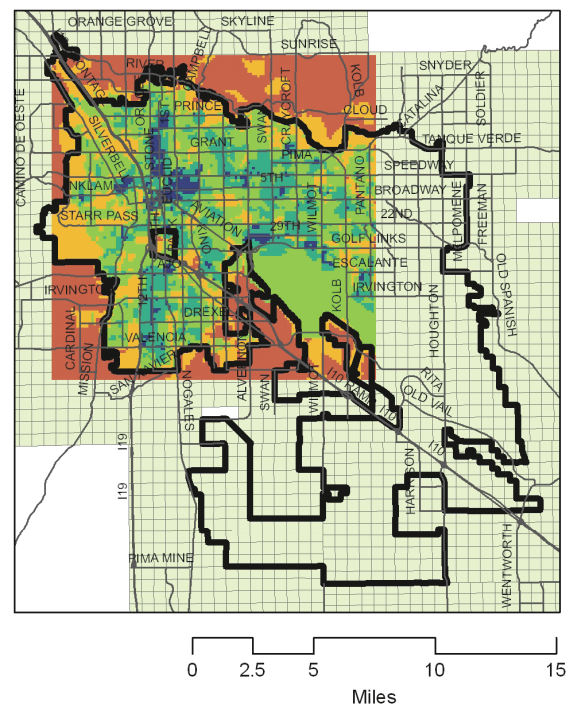
The popularity of destinations was determined by expected use. As such the buffer distances applied in each category of sub-analysis reflected the difference in travel distance one might expect to reach each type of destination. Elementary schools provide a smaller radius of attraction than a regional park, for example. As such, this analysis helps provide an indication of where people in Tucson want to go to inform appropriate placement of bicycle boulevards to ensure good connectivity.

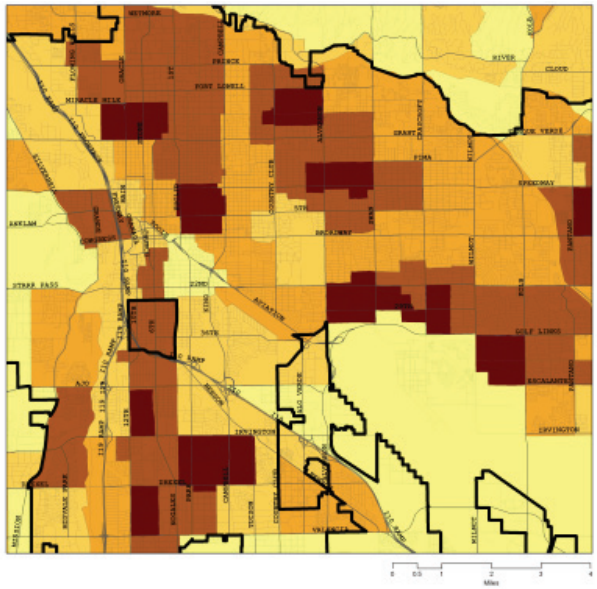


Destinations Map

Destinations

- Very Few
- Few
- Average
- Many
- Very Many

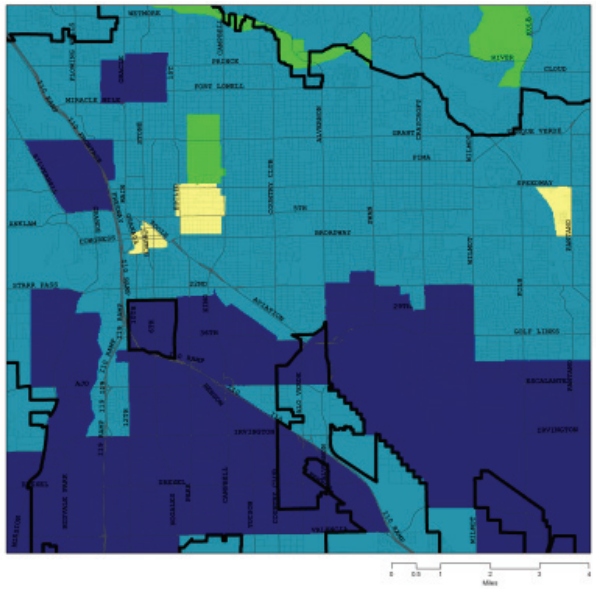




Residential Density

- Very Low
- Low
- Average
- High
- Very High

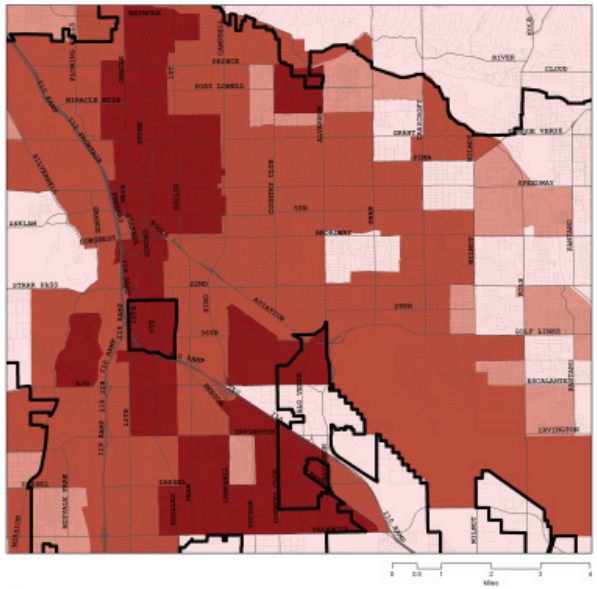
Areas of higher residential density are more suitable for the development of bicycle boulevards as they can more easily serve larger segments of the population. Areas with a 2000 Census density below the Tucson average of 965 people per square mile were given a value of 1 or 2, areas close to the average were given a value of 3, and values above, and well above, average were given a suitability value of 4.



Under 18

- 0-15%
- 15-24%
- 25-60%
- 60% and above

Areas with concentrations of a known largely non-driving population-- children under the age of 18-- were given increased suitability values as the relative percentage of this group increased. The Tucson average of children under 18 is 25 percent of the population. Low suitability of 1 and 2 was assigned to the two divisions below this average, while higher suitability ranks of 3 and 4 were given to areas of above average and significantly above average youth populations.



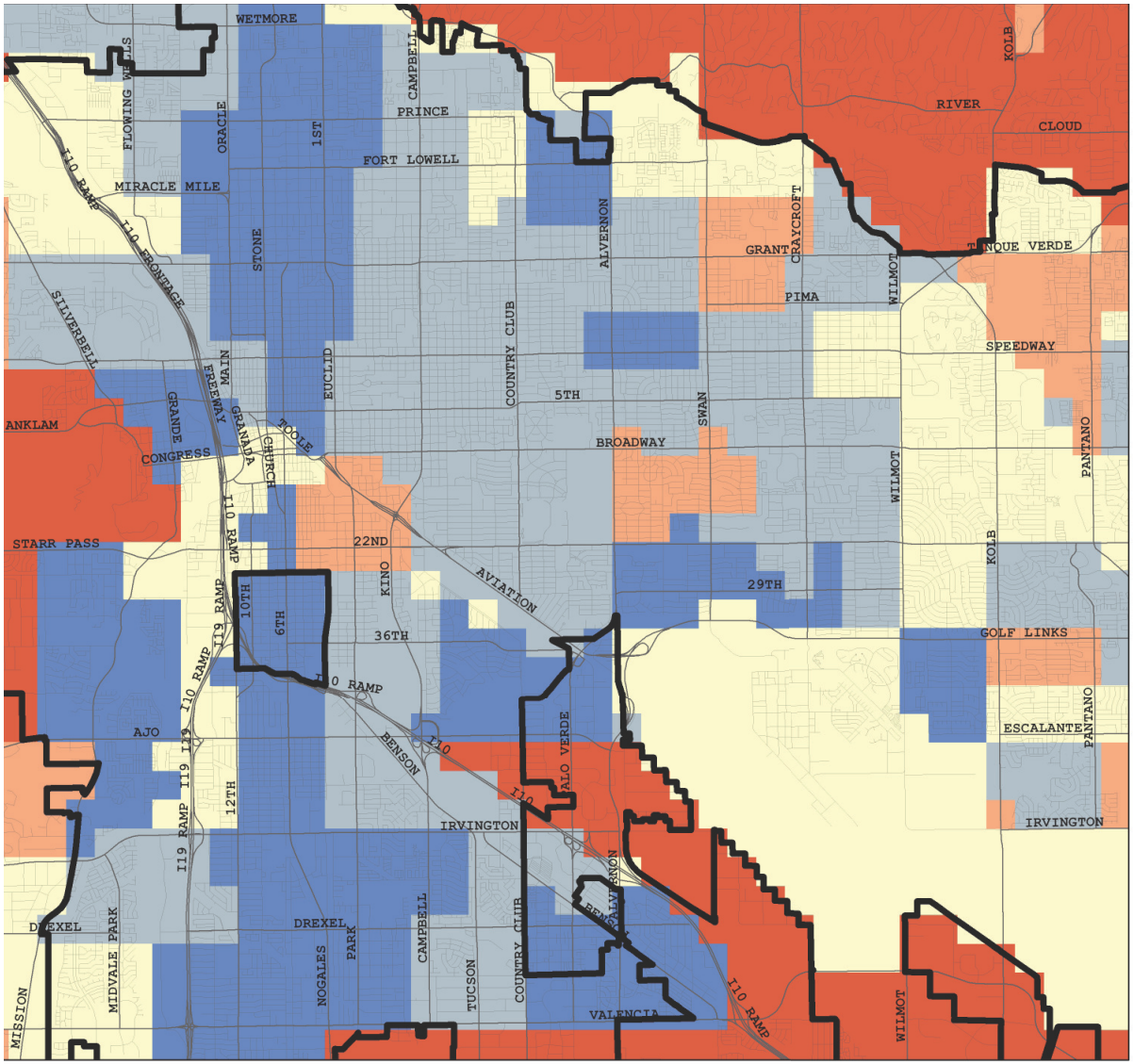
Income

- 0-15%
- 15-24%
- 25-50%
- 50% and above

Areas with higher concentrations people known to be without access to a car, or otherwise in greater need of inexpensive transportation- households under the poverty level-- were given increased suitability values as percentages of this group increased. The average percentage of people below the poverty level in Tucson is 15 percent. Low suitability of 1 and 2 was therefore assigned to the two divisions below and just above average, while higher suitability ranks of 3 and 4 were given to areas of above, and significantly above, the average.

The Target Population map gives an indication of the geographical areas where Tucson residents would benefit most from bicycle boulevards. By focusing on higher density areas and non-driving populations, the network has the opportunity to increase mobility and improve equity.

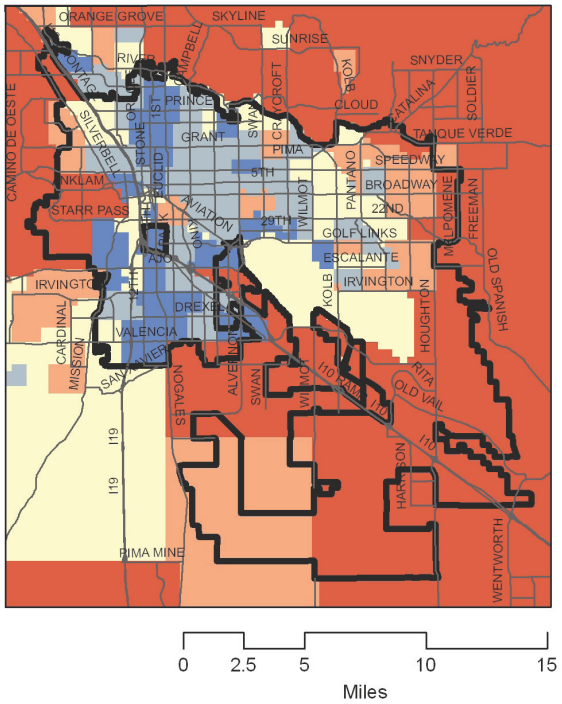
This part of the analysis was unfortunately limited by having to rely on now outdated 2000 Census demographic data.



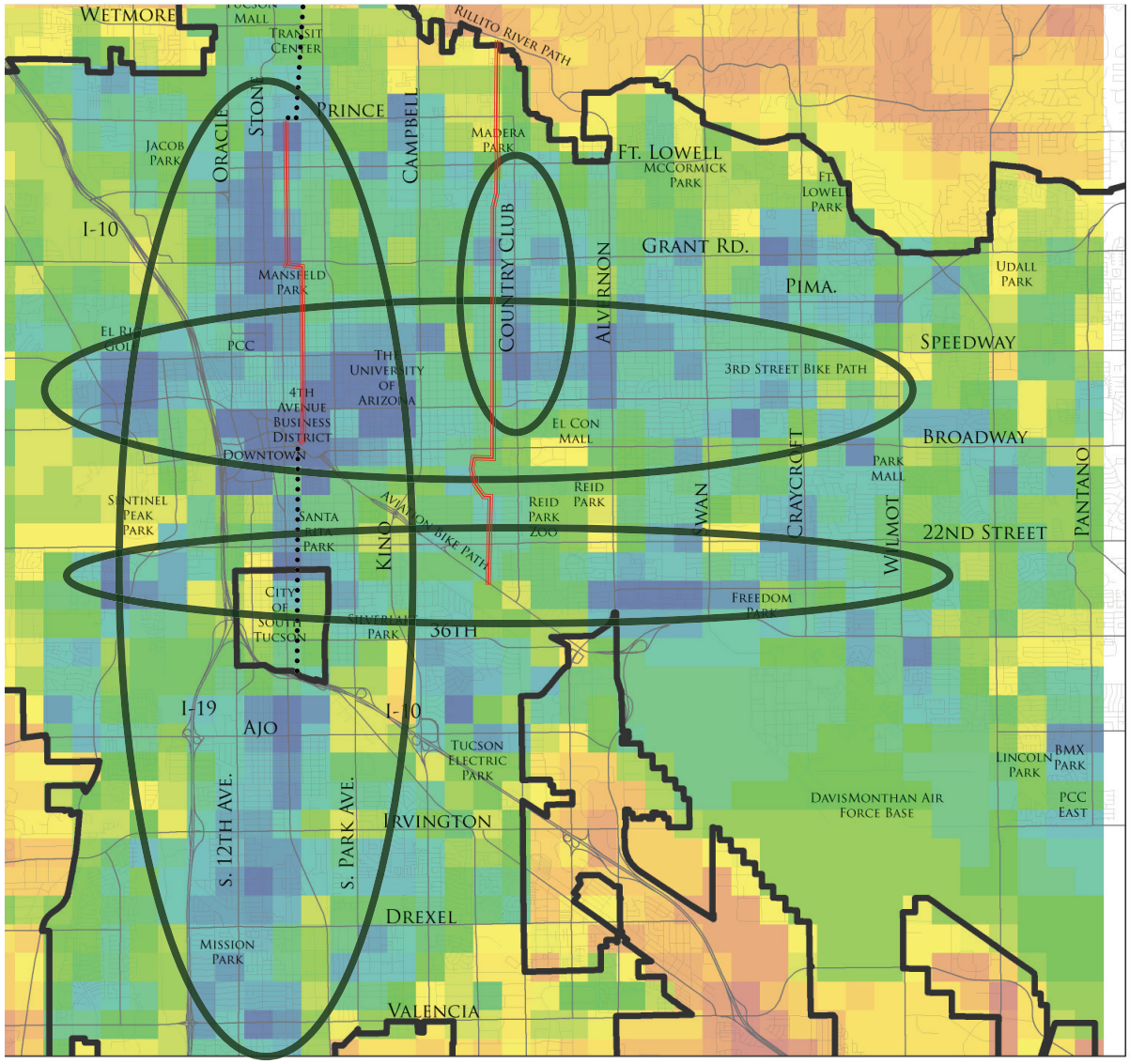
Target Population Map

Population Suitability

- Least Suitable
- Not Suitable
- Moderately Suitable
- Highly Suitable
- Most Suitable



The final composite map reveals zones and corridors most suitable for bicycle boulevards. These are the areas in Tucson most likely to serve the whole population, as the analysis put a strong emphasis on destinations and density, but also targets populations most in need of better access to alternative transportation.



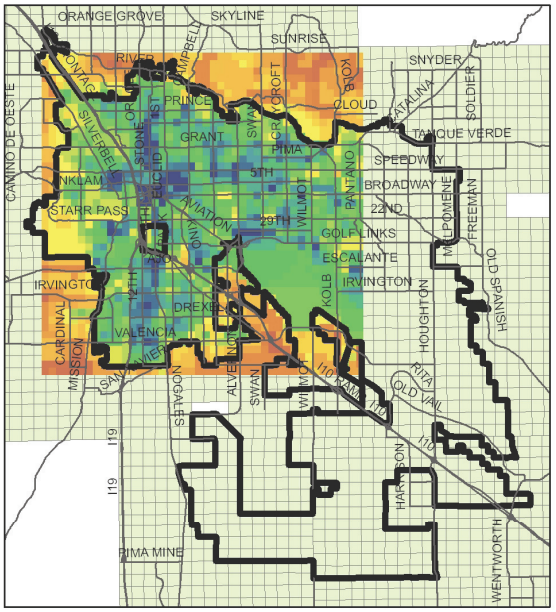
High Suitability

Low Suitability

Corridors of Highest Suitability

Proposed Pilot Bicycle Boulevards

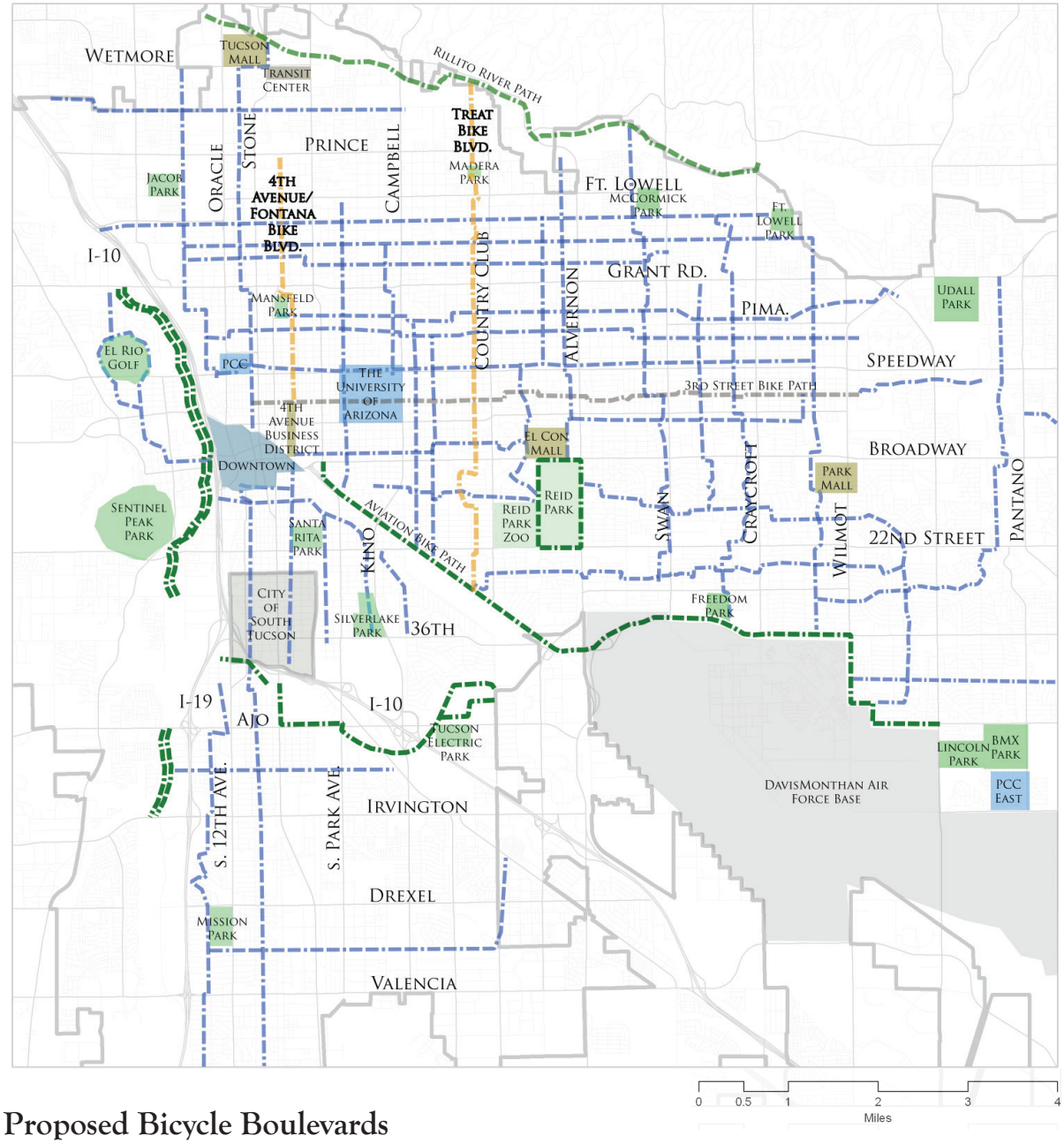
Future Extension of 4th Avenue/Fontana Bicycle Boulevard



0 0.5 1 2 3 4
Miles

0 2.5 5 10 15
Miles

Bicycle Boulevard Suitability Map



Proposed Bicycle Boulevards

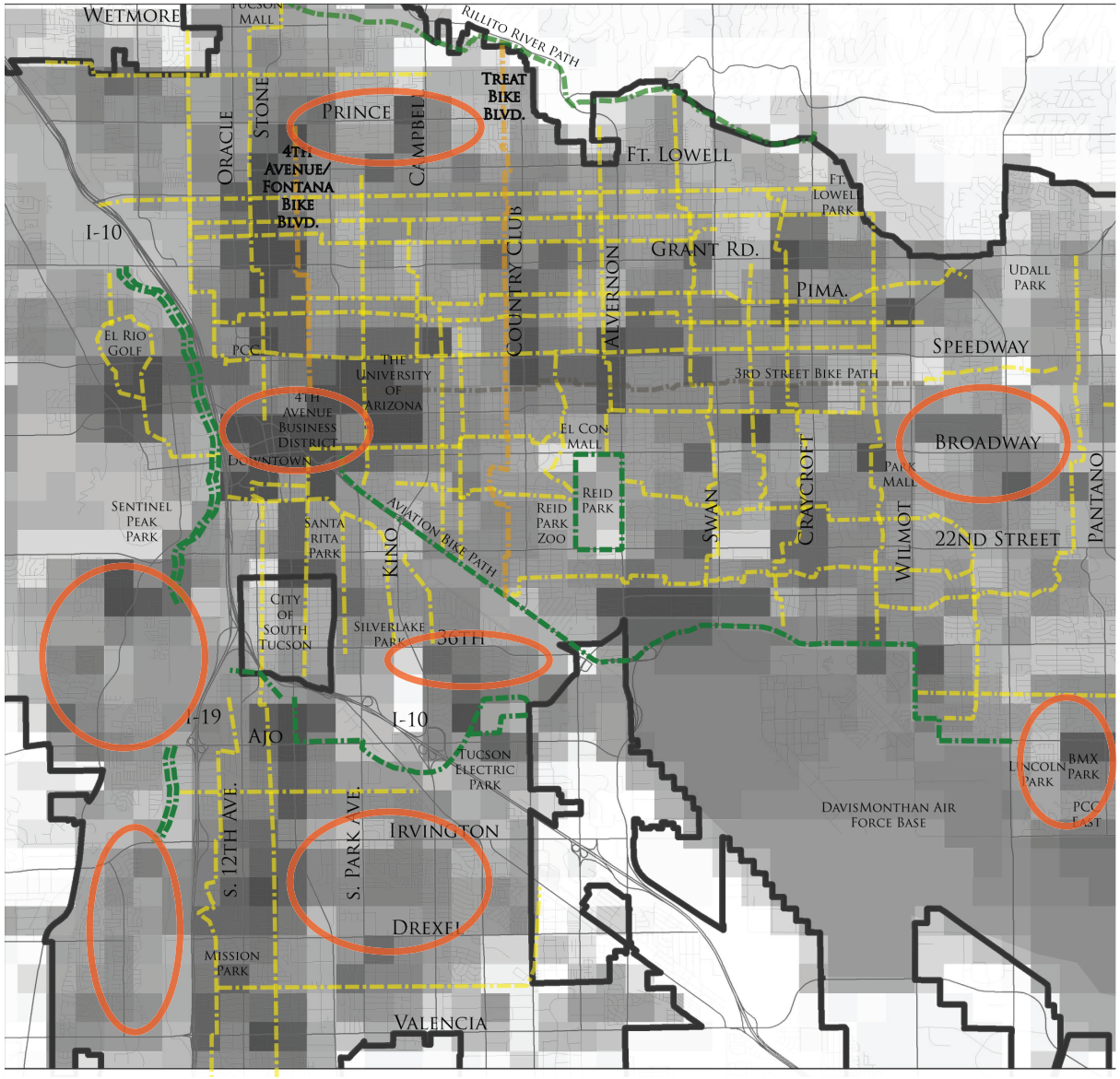
Proposed Bicycle Boulevards

- Tucson City Limits
- Existing City Multi-Use Paths
- City-Proposed Bicycle Boulevards
- Pilot Bicycle Boulevards

The City of Tucson Department of Transportation Bicycle and Pedestrian Manager Tom Thivener developed a list of planned future bicycle boulevards for the City in the fall of 2008. These proposed routes are shown on the map to the left.

In order to evaluate this proposed network under the suitability criteria outlined above, these routes were overlaid on the final Bicycle Boulevard Suitability map, in black and white to be more legible, shown to the right.

The overlay reveals a few proposed routes within the strongest suitability corridors. Prominent among these for their suitability and connectivity potential are the 4th Avenue/Fontana and Treat Avenue routes. These two are therefore selected to be the pilot bicycle boulevards developed in the Design chapter of this document.



Bicycle Boulevard Suitability Map

Suitability, with Proposed Bicycle Boulevards

- High Suitability
- Low Suitability
- Tucson City Limits
- Existing City Multi-Use Paths
- City-Proposed Bicycle Boulevards
- Pilot Bicycle Boulevards
- Remaining Suitable Development Areas with Proposed Bicycle Boulevards

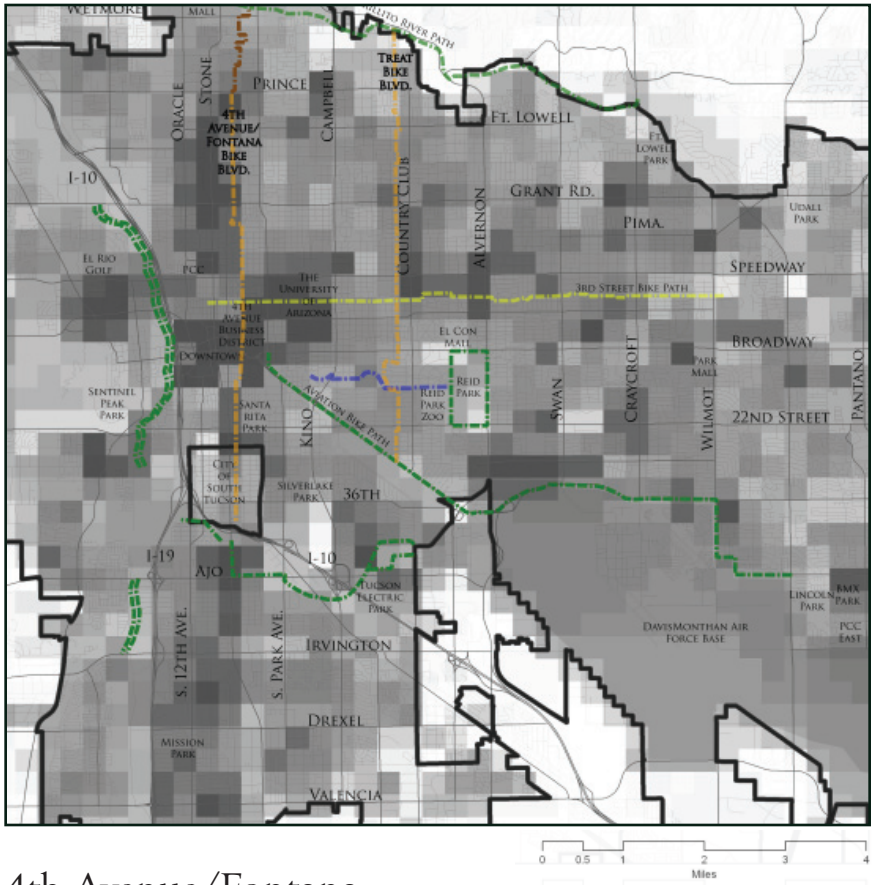
This overlay also shows that the proposed network would generally serve the Tucson area very well. A few zones suitable for bicycle boulevard development, but currently without proposed facility development, do emerge, however as indicated in the orange ovals to the left. The recommendation would be for the City to use these identified areas to help focus a revised or updated version of its bicycle boulevard master plan.

II. Route Scale

The two routes identified here as appropriate for development into Tucson's pilot bicycle boulevards both move through areas of high suitability as identified by the criteria of the city scale analysis outlined above, use primarily existing residential bike routes, and maintain a high level of continuity without many jogs or breaks.

In addition, both connectivity and continuity are improved by the identified route's connections to the 3rd Street Bike Path-- a path which itself functions very much as a bicycle boulevard already. The 3rd Street connection helps these two pilot bicycle boulevards create the beginnings of an interconnected network. In addition, Treat Avenue makes a city-wide connection between two significant multi-use dedicated facilities-- the Aviation and Rillito River Bikeways-- and will in the future connect riders to Cherry Field and Reid Park's multi-use path system through the proposed Arroyo Chico Greenway.

Although these two paths are well suited for conversion into bicycle boulevards, the specific design treatments warrant a more detailed site analysis. The route-scale analysis focused on barriers and opportunities along the routes, identifying areas of discomfort, safety concerns, high traffic speeds and volumes, as well as broken continuity and connectivity. Refer to the Appendix for more 4th Avenue/Fontana and Treat Avenue analysis maps.



Bike Boulevard Suitability and Significant Existing and Proposed Paths

Suitability
High
Low

Tucson City Limits

Pilot Bicycle Boulevards

3rd Street Bike Path

Existing Multi-Use Paths

Proposed Arroyo Chico Greenway

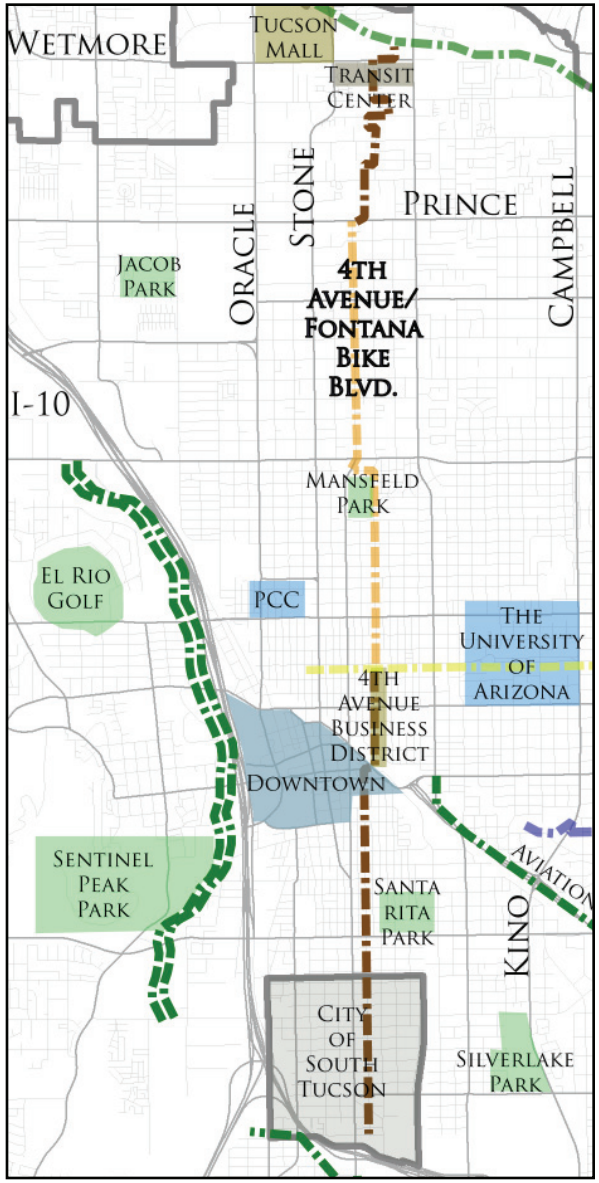
4th Avenue/Fontana

The 4th Avenue/Fontana Bike Boulevard would extend from Prince Road in the north, to University Avenue in the south, along 4th Avenue, Sahuaro Street, Sixth Avenue and Fontana Street.

This route fills a vital hole in centrally located, quality bicycle facilities, moves through a series of dense and underprivileged neighborhoods mostly within the Tucson Empowerment Zone, and connects a myriad of schools, parks commercial areas and major destinations.

Connectivity

The 4th Avenue/Fontana route is within a mere quarter mile of 6 Elementary, 1 Middle and 5 High Schools, Pima Community College's Downtown Campus, 4th and University Avenue's many shops, galleries, and restaurants, and The University of Arizona. There are also multiple linkage



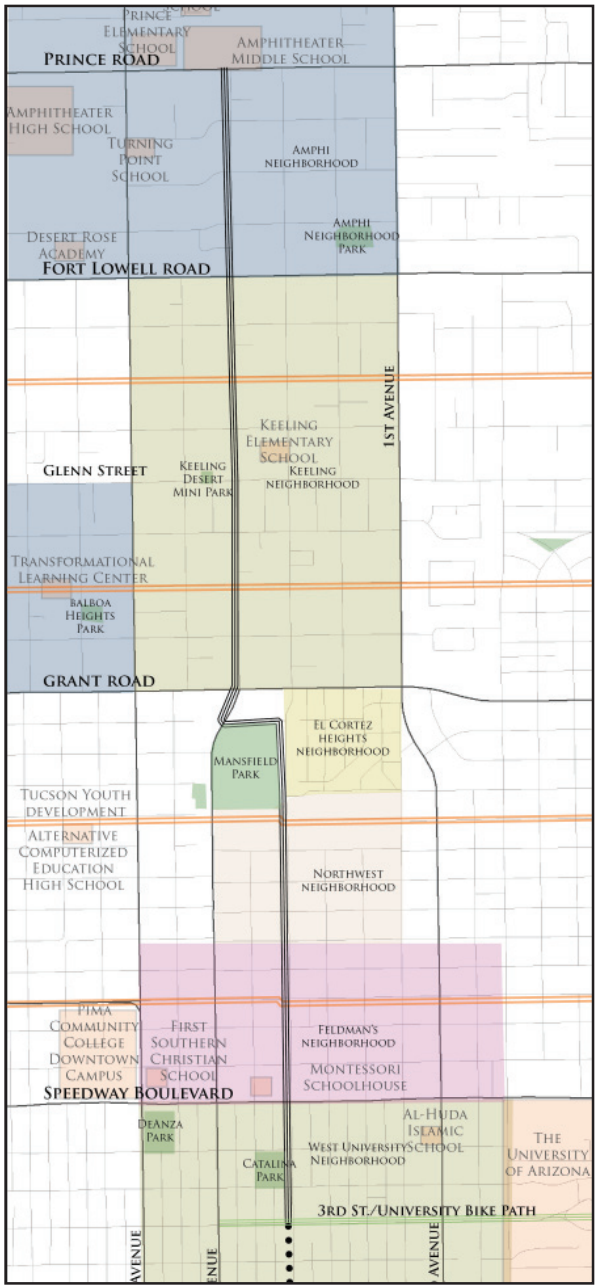
The 4th Avenue/Fontana Bike Boulevard would help connect major destinations such as the University of Arizona and the 4th Avenue Business District. If extended a short distance north and south it would also connect the Rillito River Path and downtown Tucson.

opportunities to public parks along the route. The most significant of these is Mansfield Park, where the Northwest Neighborhood Center, as well as ball fields, a pool, and youth activities serve as a major draw for the surrounding neighborhoods.

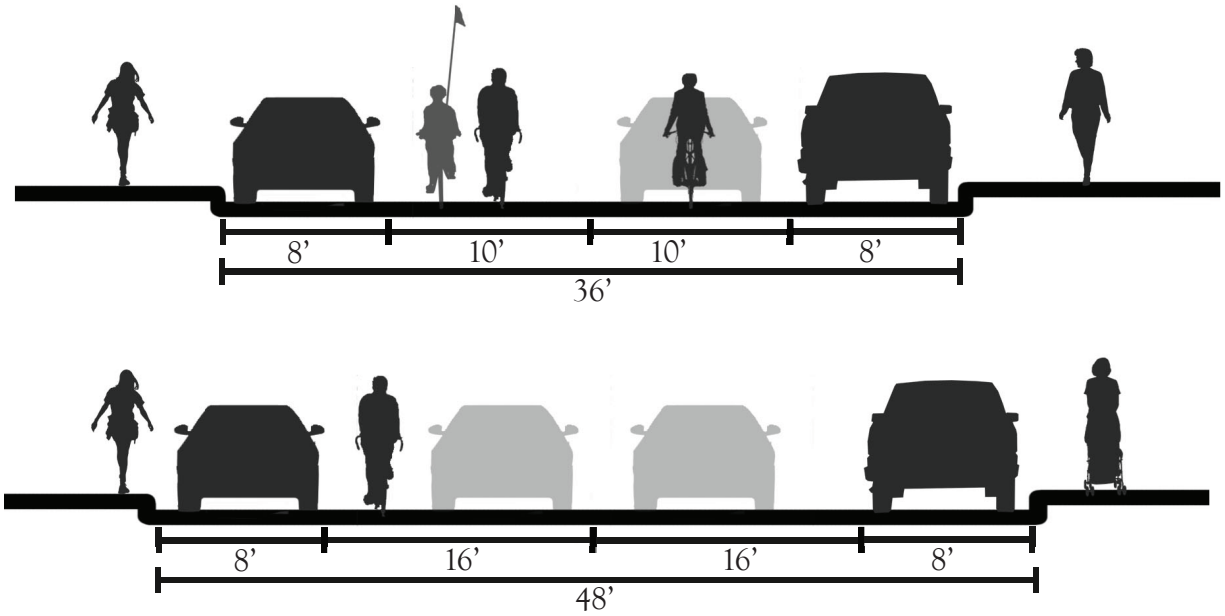
Possible future extensions north and south, as shown on the map to the left, could also connect this route to the Rillito River Path, and move it through the 4th Avenue Business District, into downtown, to the City of South Tucson, and to the future El Paso Greenway.

Once plans for the Tucson Modern Streetcar system, set to move along University Boulevard and 4th Avenue south of University have been finalized, the 4th Avenue/Fontana Bicycle Boulevard could be extended south to the 4th Avenue Underpass, and extend into South 4th Avenue. This would provide a safe, pleasant bicycle connection from both the north and the south to all the major destinations in this part of Tucson.

Crossing Amphi School District property at Amphi Middle School for a short distance north of Prince Road, and then following a series of residential roads to the River, would be the most direct way to achieve the connection to the Rillito Path from the current terminus of the bike boulevard. An agreement with Amphi School District to let the bicycle boulevard path traverse their property could be negotiated to ensure this connection.



The 4th Avenue/Fontana bicycle boulevard would pass by a number of schools, parks and major destinations.



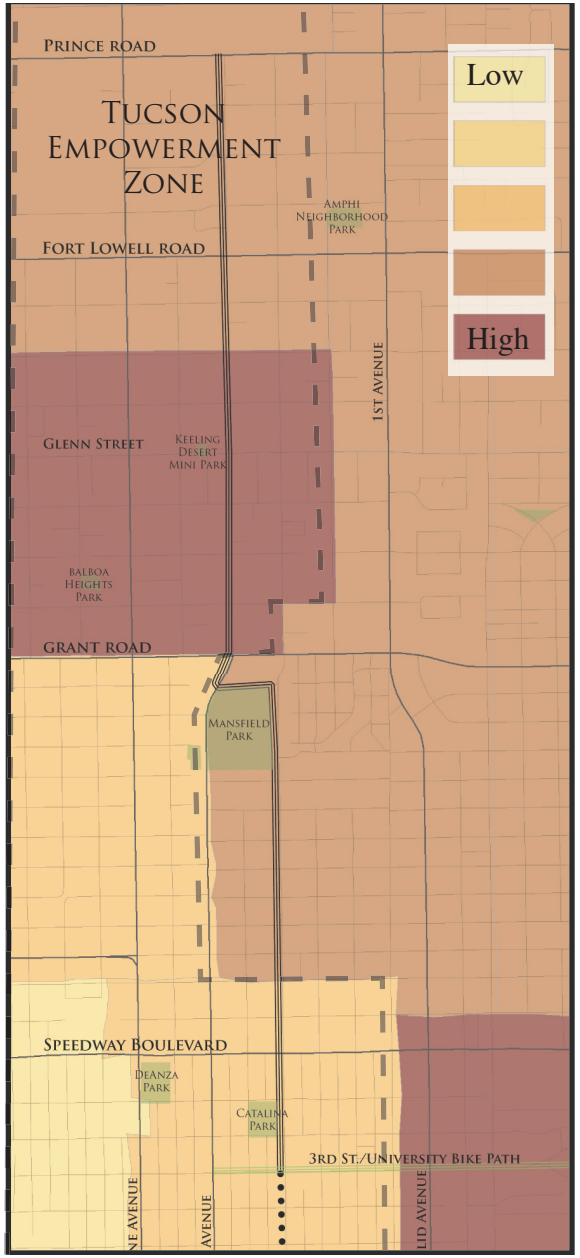
4th Avenue, Saguaro and Fontana Streets are either 36 feet or 48 feet wide along the intended bicycle boulevard corridor. While 36 foot streets will provide ideal space for parking and maintain traffic calming lane widths, the wider segments of the boulevard tend to encourage speeding if they are not visually narrowed.

4th Avenue's wide, straight configuration serves as an invitation to speeding and cut-through traffic.

Streets and Surfaces

A bicycle boulevard along 4th Avenue and Fontana would primarily move along existing road widths of 36 feet. This width is ideal for the safe shared use by bicycles and vehicles, while maintaining existing on-street parking for the neighborhoods. Maintaining on-street parking is particularly important in Feldman's Neighborhood where driveways and off-street parking is very scarce.

Segments of the route are very wide, however. Sections where the roadway is 48 feet wide are ripe for traffic calming and the visual narrowing of the roadway through chicanes, bulb-outs and street tree canopies.



The 4th Avenue/ Fontana Bike Boulevard is located almost entirely within the Tucson Empowerment Zone, and moves through some of the denser areas of Tucson.

Some stretches of 4th Avenue/Fontana bike boulevard are very open and exposed without street trees. A street tree program to create a continuous canopy cover would make the route more inviting and comfortable.

The existing road surface condition along the route is classified as fair to poor, and segments are scheduled for repaving. A bicycle boulevard would require the improvement and regular maintenance of surface conditions. The area with the most immediate need for resurfacing is that between Speedway and Seneca along 4th Avenue.

Traffic Speed and Volume

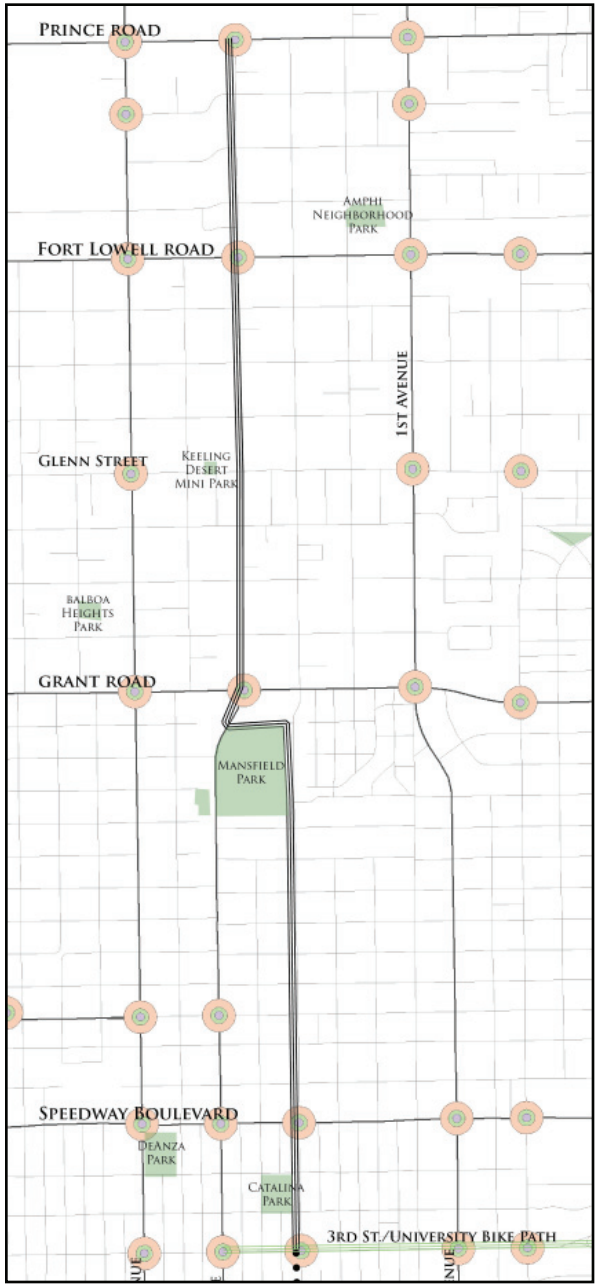
In 2007 Pima Association of Governments (PAG) counted 1,111 cars per day along Fontana Road between Grant and Prince Roads. While some traffic calming elements already exist in the area, additional traffic calming measures, as well as limiting cut-through access onto the bicycle boulevard, could help both reduce and slow vehicular traffic in the neighborhoods.

4th Avenue is currently being used as a neighborhood cut-through alternative to nearby 6th and Euclid/1st Avenues. This wide, open street invites speeds well above the posted 30 mile per hour speed limit, and traffic volumes on this stretch can be very high. Traffic calming, lowering the speed limit to 25 miles per hour in line with the residential character of the street, and vehicular entry restrictions should be implemented to deter non-local or speeding motor vehicle traffic from using this stretch of 4th Avenue.

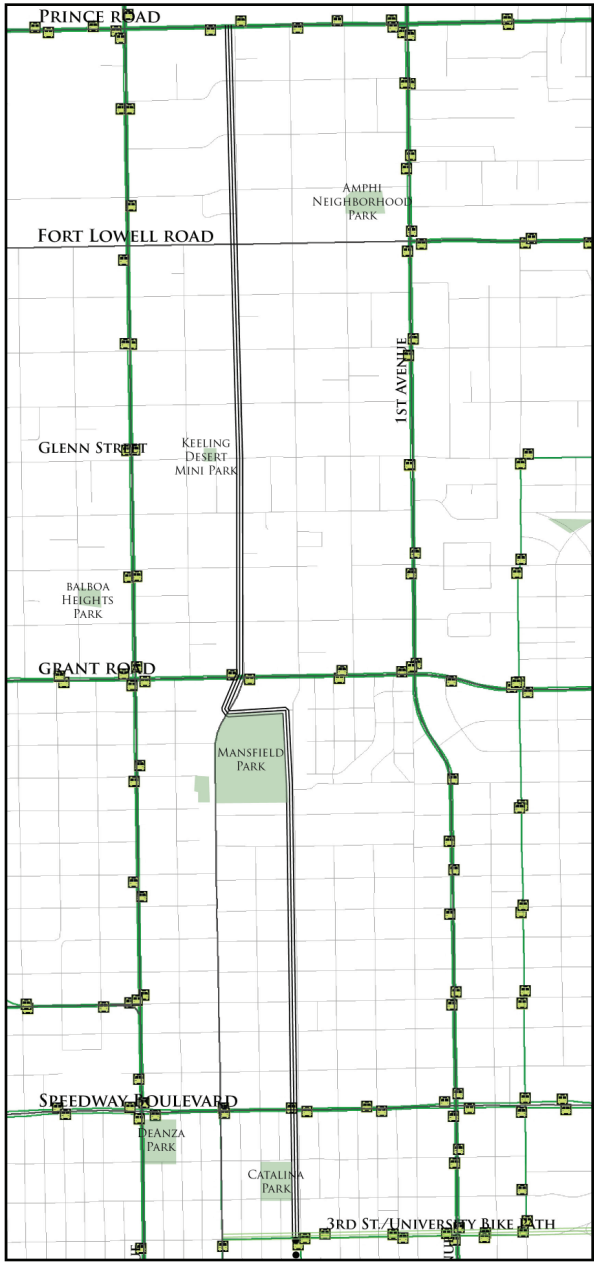
Crossings

Existing traffic lights control most of the larger street crossings along 4thAvenue/ Fontana. The Grant Road crossing is also scheduled for improvement as part of the Grant Road widening project scheduled for construction in the next several years. The main crossing barrier is found at Fontana and Glenn, where a lack of pedestrian and bicycle crossing facilities can cause long delays and

The intersection of Fontana and Glenn is a potential barrier as it is unmarked and unsignalized for pedesrians or bicycles.



Orange circles indicate the existing light-controlled intersections along the 4th Avenue/Fontana route.



Connections to the Sun Tran bus can be found along the route. University Avenue will become a significant hub once the modern streetcar begins operation there.

unsafe maneuvering for crossing traffic. Glenn can be expected to receive increasing traffic volumes particularly during the many years of planned construction associated with the Grant Road widening.

Connections to Transit

Connections to the Sun Tran bus system can be found along the route at University Avenue, Speedway Boulevard, Grant, and Prince Roads. University Avenue will become an even more significant hub once the modern streetcar begins operation to connect the University area with downtown and Rio Nuevo.

Treat Avenue

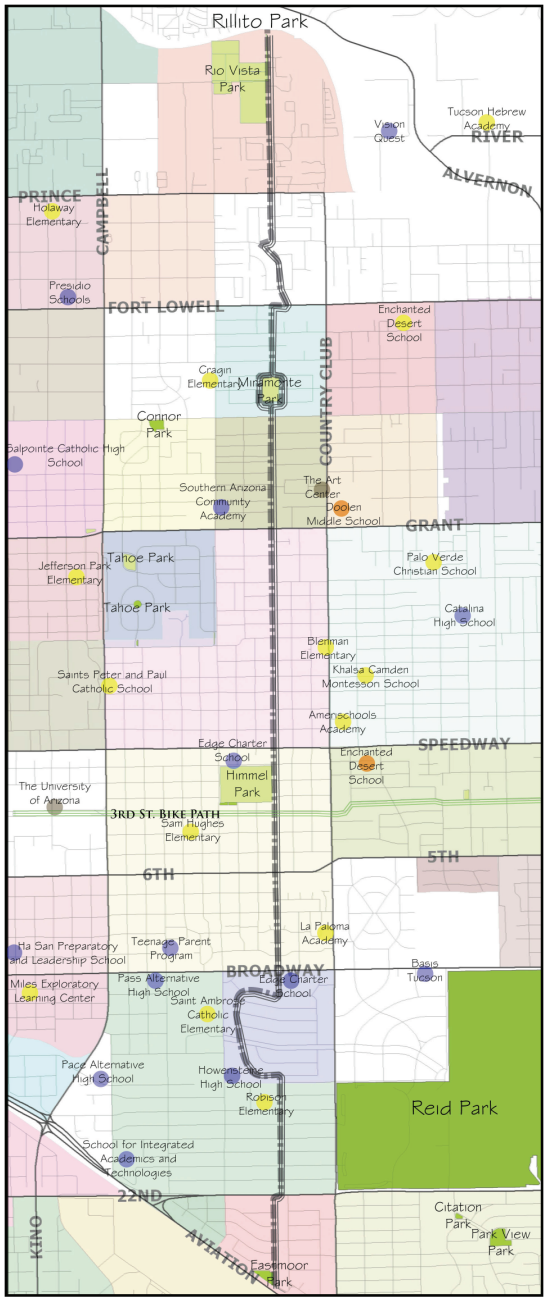
The Treat Avenue Bike Boulevard would extend from the Rillito River in the north, to Aviation Highway in the south, along Cactus, Christmas, Treat and Bristol.

This route fills a vital hole in quality north-south bicycle facilities in this area, and connects a myriad of schools, parks and commercial areas. This stretch of bike boulevard also connects major destinations such as the University of Arizona and Reed Park by way of is connection to the 3rd Street Bike Path and the proposed Arroyo Chico Greenway.

Connectivity

The route is within a quarter mile of

The Treat Bike Boulevard would provide a link between the popular Rillito River and Aviation Multi-Use Paths.



The Treat Avenue route provides connections to a number of schools, parks and popular bike paths.

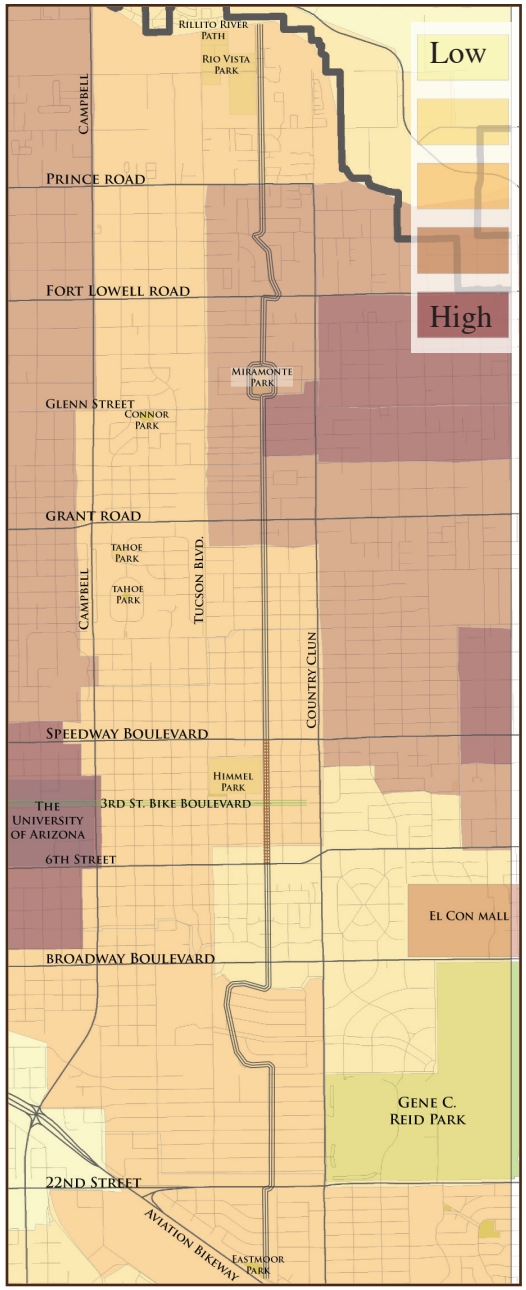
7 Elementary, 1 Middle and 4 High Schools. There are also multiple linkage opportunities to public parks along the route, the most significant being Reid Park, where the Zoo, golf course, ball fields and multi-use paths serve as a major draw for the city as a whole. Himmel Park, with its library, pool, tennis, ball fields and playgrounds, is also a draw for the surrounding neighborhoods, as are La Madera and Eastmoor Parks further north and south. At the northern extreme the path moves along the Rio Vista Natural Resources Park.

The Winterhaven Neighborhood, located between Ft. Lowell and Prince is itself a seasonal attraction. This neighborhood's lavish display of Christmas lights attracts visitors from the whole city every year.

The Treat route also proved great connection opportunities to existing popular bicycle routes. The 3rd Street Bike Path connects riders to The University of Arizona and has by far the greatest volume of bicyclists in town, as shown in the recent Tucson Bicycle Count included on the Appendix. At the southern end, the path connects to the Aviation Bikeway, and at the northern extreme the path connects with the Rillito River Path.

Streets and Surfaces

This bicycle boulevard would move along existing road widths of between 36 and 48 feet. As on 4th Avenue/Fontana, areas of with 48 feet of width are in need of traffic



The Treat Avenue route passes through areas of primarily medium to high population density.

The area between Broadway and Speedway along Treat Avenue has some serious surface problems, including potholes large enough to catch a bicycle wheel.

calming devices that help to visually narrow the street.

The existing road surface condition along the route are fairly good, but one segment are is in dire need for repaving. This area of rough paving and multiple hazardous potholes is along Treat in the Sam Hughes Neighborhood between Broadway and Speedway Boulevards.

Traffic Volume and Speed

Most of the Treat Bicycle Boulevard route moves along areas of relatively low traffic volume. Major exceptions can be found in the blocks around Speedway where local businesses to the north, and Himmel Park to the south attract more significant volumes.

Speeding and cut-through problems were also reported by neighbors in the blocks around La Madera Park, and in the blocks just north of 22nd Street. A particular focus on traffic calming and diversion may be appropriate in these areas.

Few traffic calming elements are currently employed along the proposed Treat Bicycle Boulevard corridor. Speed humps are used occasionally, but additional traffic calming measures, as well as limiting cut-through access onto the bicycle boulevard, could help both reduce and slow vehicular traffic in the neighborhoods.

Some stretches of Treat Avenue bike boulevard are very open and exposed without street trees. A street tree program to create a continuous canopy cover would make the route more inviting and comfortable.

Orange circles indicate the existing light-controlled intersections along the Treat Avenue route.

Cyclist at Treat or Bristol and 22nd Street may find the sudden, brief, disappearance of the bike route confusing or unsafe.

Crossings

Existing traffic lights control the street crossings at 22nd Street, Speedway Boulevard, and Grant Road. The crossings at the remaining larger roads, particularly at Prince, Ft. Lowell and Broadway are major barrier points for continuity and safety along this stretch. Heavy traffic and wide street widths on these roads can cause bicyclists long delays waiting for a safe opportunity to cross, or may spur cyclists and pedestrians alike to attempt unsafe maneuvers to cross with traffic. The three lanes of Glenn and four lanes of the 6th Street crossings also pose continuity problems, although these streets are less wide than the major arterials, and traffic flows are generally slower and less heavy during most of the day.

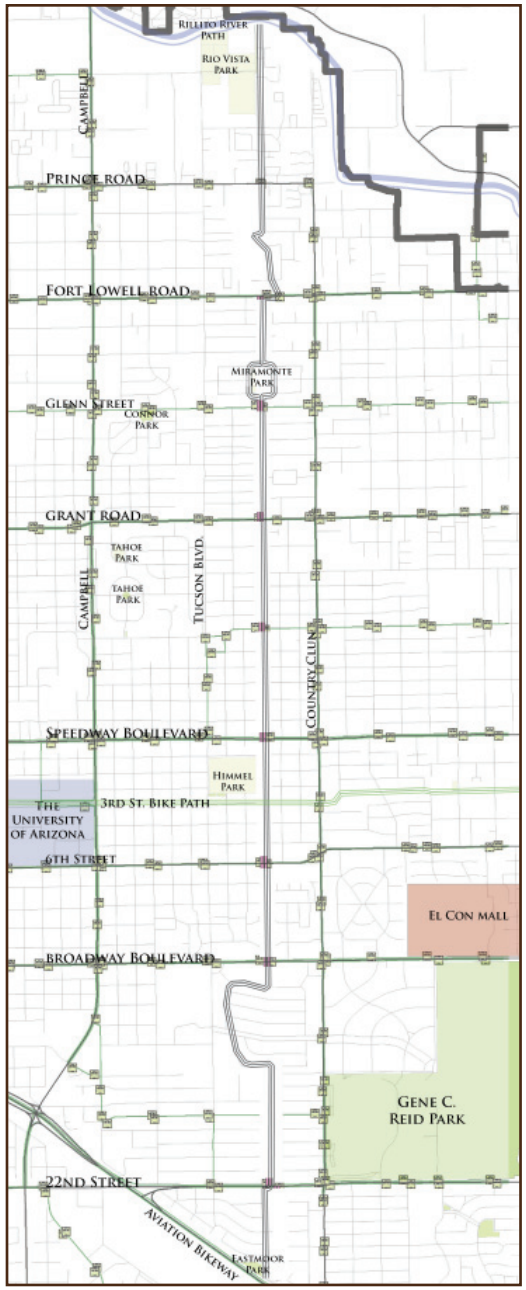
A continuity problem also exists at the HAWK crossing at 22nd Street. Here the proposed boulevard transitions from Bristol to Treat. Although a HAWK crossing at Treat greatly improves continuity, there is no clear path for cyclists to transition along 22nd the approximately 75 foot distance from Bristol to the HAWK crossing. Particularly as this crossing is used by Robison Elementary school students, this barrier point must be resolved by a successful bicycle boulevard design.

A similar barrier point exists at Ft. Lowell Road. Here the bicycle boulevard meets the Winterhaven eighborhood at a 'T.' The proposed path continues some 150 feet to the east along Christmas, but this connection is not clear, particularly to cyclists moving north.

Connections to Transit

A large number of connections to the Sun Tran bus system can be found along the route. Providing secure bicycle parking and system maps that include both the bike and the bus system at these stops could help improve users ability to combine networks.

A cyclist approaching the 'T' intersection at Treat and Ft. Lowell Road would not necessarily know how to proceed to continue northward.



The Treat Avenue route intersects with major east-west Sun Tran bus routes at the nine larger intersections.

Design Toolbox

The purpose of a bicycle boulevard is to improve bicycle safety and circulation through the achievement of:

- Low traffic volumes and speeds
- Continuous, safe routes and crossings
- A distinctive look and feel that makes users aware they are on a priority route for bicyclists

The vision of bicycle boulevards in Tucson is of an interconnected network of predominantly residential streets that provide safe, pleasant, convenient routes for both bicycling and walking, and help build a unique local character through regionally appropriate choices in vegetation and facility design. This Design Toolbox was developed in order to help guide the design of future bicycle boulevards and ensure the consistency and quality of the complete network.

The toolbox components are based on best-practices, standards and recommendations as developed by AASHTO, the City of Berkeley Bicycle Boulevard Design Tools and Guidelines, recommendations by local Tucson bicycle activists and the Tucson Department of Transportation, and the implications of the Literature Review and Case Study sections of this document. These come together here to establish and articulate the standards and characteristics of a future Tucson Bicycle Boulevard Network.

This toolbox describes minimum and general standards, while allowing some flexibility in individual route designs. For examples of application of these tools see the two pilot bicycle boulevard routes selected for design refinement and articulated in the Design chapter of this document.

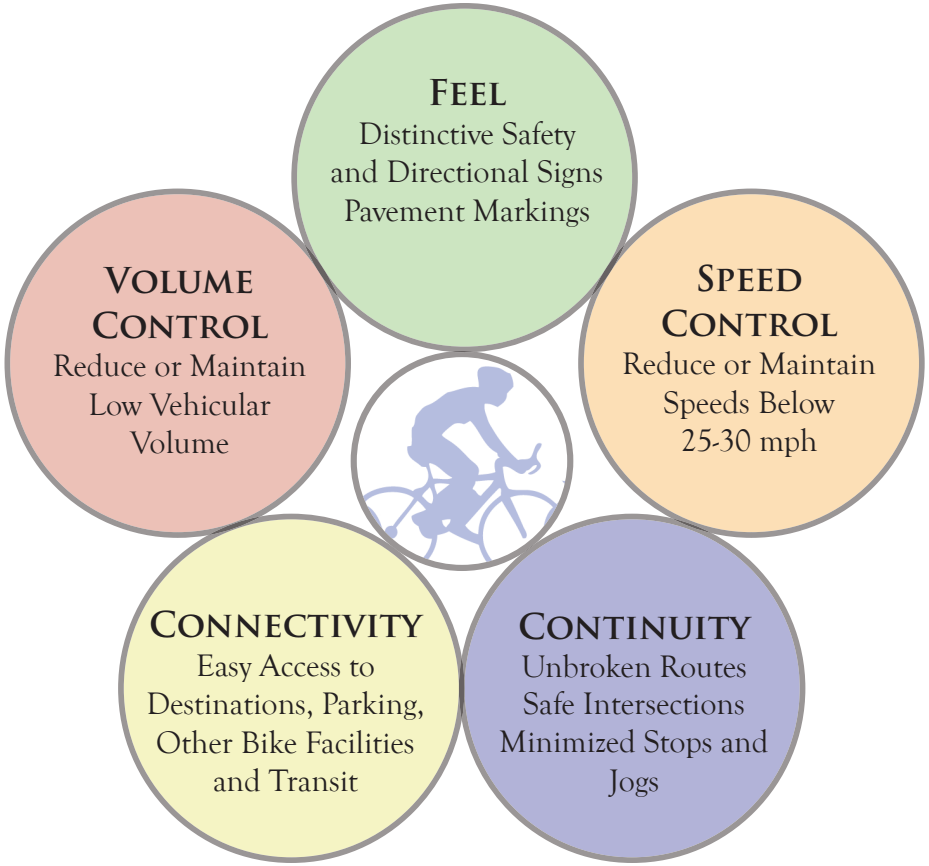


Figure1: The Basic Components of Bicycle Boulevards

Although each bicycle boulevard will require an individual design tailored to local conditions and needs, each should meet the standards outlined herein, and utilize an appropriate mixture of design elements to achieve the five basic components of a bicycle boulevard: distinctive feel, continuity, connectivity, low traffic volume and low traffic

On a bike boulevard sign such as those to advertise a school crosswalk should be consistent in use and placement with the practices of the City as a whole.

speed. These five components in turn guide the specific design treatments that help build successful bicycle boulevards.

Building a distinct feel focuses primarily on safety and directional signs and markings that improve the function of the corridor, as well as helping to establish a consistent, recognizable look for the network as a whole.

Continuity focuses on the integrity of the path itself, with improved comfort and safety at crossings, unbroken paths, and a minimum of stops and jogs for bicyclists.

Connectivity is based primarily in route selection, assuring access to popular destinations, other bicycle paths and facilities, as well as other modes of transit. Connectivity also includes the placement of hubs where other modes of transit, bicycle parking and/or amenities such as showers or drinking fountains may be combined with the bicycle boulevard route.

Traffic Volume focuses on the reduction or maintenance of low vehicular traffic volumes along the bicycle boulevard. This may be done most clearly through route selection of low-volume streets, or by restricting vehicular access through partial or full closures of sections of a bicycle boulevard.

Volume reduction may however also be a side effect of employing speed reduction and traffic calming elements. Traffic Speed measures generally focus on maintaining maximum speeds below 25 miles per hour through reduced speed limits if needed, and the use of speed humps, traffic circles, chicanes and other traffic calming measures. Volume reduction would then be achieved simply by discouraging non-essential or cut-through traffic in the area.

Distinctive Feel

The signage found along a bicycle boulevard should communicate clearly to all users that they are on a particular type of shared-use roadway--one where bicyclists are prioritized. It is important that signage communicate the unique nature of the path to cyclists, pedestrians and motorists, and that it be both clear and legible, as well as uniform and recognizable throughout the city. It is particularly important that vehicular drivers understand that on a bicycle boulevard cyclists share the main lane with cars, and that speeds are to be kept low and attention paid accordingly.

The attributes of a bicycle boulevard can be clearly communicated through highly visible and distinctive signs and pavement markings. Distinctive signs and markings also help brand and advertise the bicycle boulevard network, and help create an identifiable

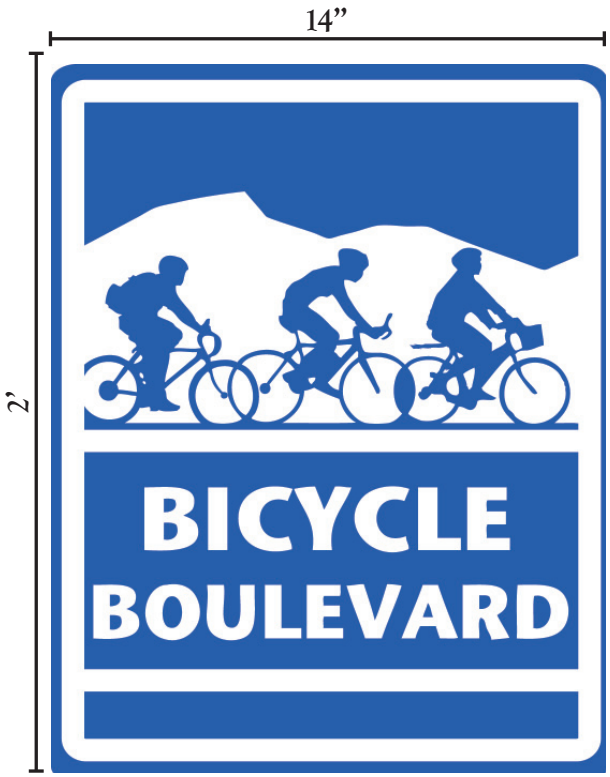


Figure 2: Bicycle Boulevard Identification Signs help with way-finding and continuity, and help brand the bike boulevard network.

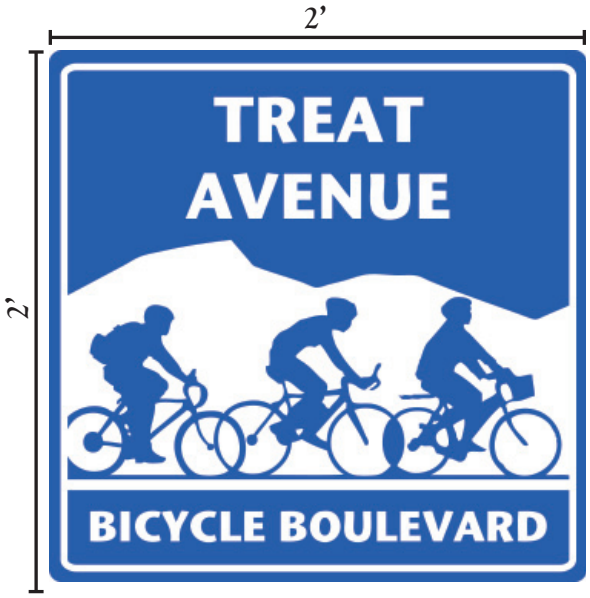


Figure 3: Path Identification Signs let the rider know which bicycle boulevard they are on, and helps both with way-finding and with advertising the network.

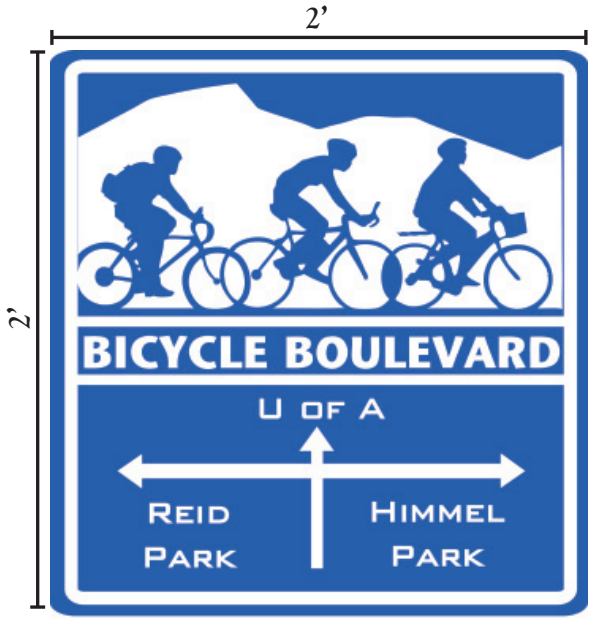


Figure 4: Bicycle Boulevard Intersection Signs are to be placed in the traffic circle at each bicycle boulevard crossing to indicate major destinations along the paths.

symbol of bicycling in Tucson.

Safety and Guide Signs

Adequate signing and marking are essential on shared roadways to alert bicyclists and motorists to potential conflicts, convey regulatory messages, and to help with effective way-finding. Both safety and guide signs should be uniform in style and application on all Tucson Bicycle Boulevards to help with way-finding, as well as to help brand and market the network.

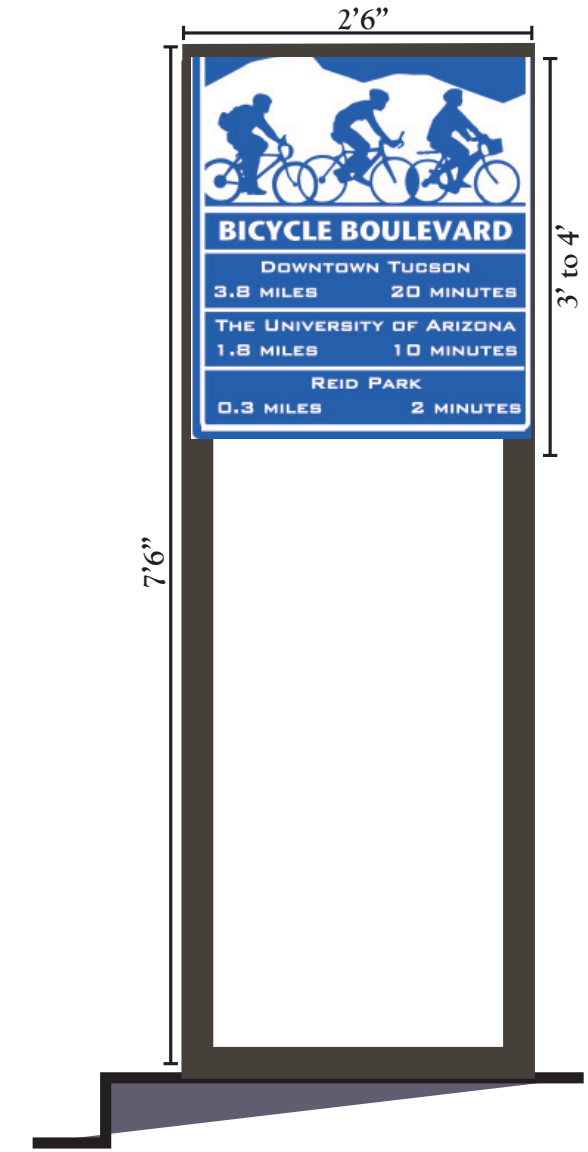
Safety Signs

General safety or warning sign such as those to help guide travelers around traffic circles or advertise upcoming speed humps, school zones etc. should be consistent in use and placement with the practices of the City as a whole.*

Way-Finding Signs

Way-finding or guide-signing includes Bicycle Boulevard Identification, Path Identification, Destination and Distance, Intersection Signs, Directional Arrow Signs, system maps, and street signs. Street signs are to remain at city standards, but priority for repair or replacement of missing or

* With the exception of Stop signs which are discussed in more detail under Continuity.



Design standards derived partially from: Berkeley Bicycle Boulevard Design Tools and Guidelines.

Figure 5: The Destination and Distance Bicycle Boulevard Signs are blue to distinguish them from other types of road signs. They should also be made of a retroreflective material and use text letters no smaller than 2 inches tall to ensure legibility.

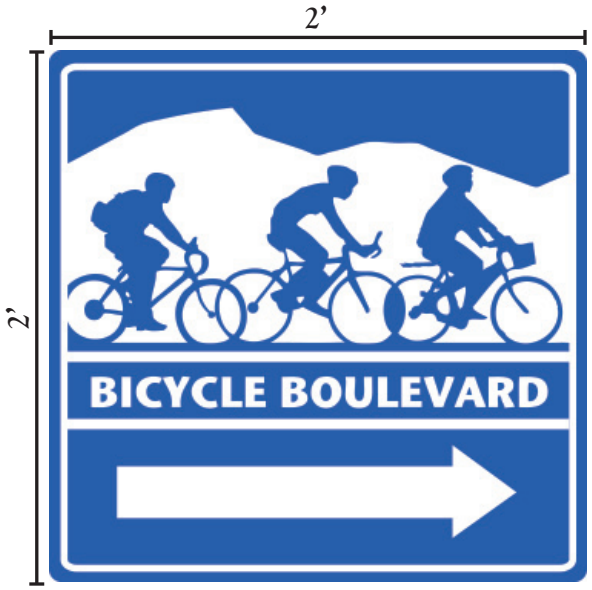


Figure 6: Bicycle Boulevard Directional Arrow Signs are to be placed where the path jogs or turns to aid in way-finding.

damaged signs should be higher along bicycle boulevards than on other residential streets.

All bicycle boulevard specific signs are to be made of a distinctive retroreflective blue with white lettering to distinguish them from other types of road signs. Signs may use text letters no smaller than 2 inches tall to ensure legibility.

Bike Boulevard Identification Signs (Figure 2)

Identification signs are the smallest of the bicycle boulevard signs and appear most frequently. These signs provide continuity, help with way-finding, reveal the network to motorists and bicyclists, and lend identifiable character to the system. Signs are to be placed at every other block corner, except where another bicycle boulevard sign is present.

Path Identification Signs (Figure 3)

Path Identification signs reveal the name of the particular bicycle boulevard a rider is on to aid in way-finding and trip planning. Signs are to be placed mid-block in each direction at every 1/4 mile, and just after any turn, jog or split in the bicycle boulevard route.

Bicycle Boulevard Intersection Sign (Figure 4)

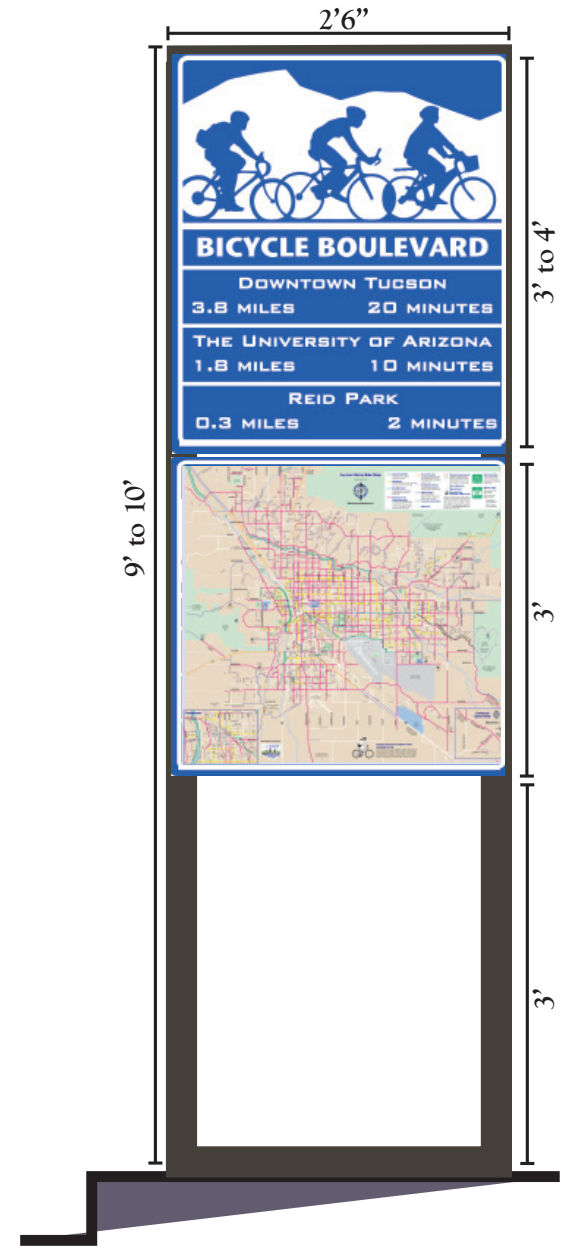
Intersection signs inform bicyclists that they are approaching a node where they may move on to another bicycle boulevard. Signs also indicate three main destinations along the three directional choices. Signs are to be placed mid-block in the block preceding the intersection of any two bicycle boulevards.

Destination and Distance Sign (Figure 5)

Destination and Distance Signs include major destinations along a boulevard route with distance and estimated bicycling time. These tools reveal the connectivity of the network, aid in way-finding, and help bicyclists plan their trip and budget time accordingly. Signs are to be placed every 1/4 mile, prior to signalized intersections, and in the block prior to the junction of two bicycle boulevards.

Directional Arrow Sign (Figure 6)

Although jogs and turns are to be generally avoided along bicycle boulevards,



Design standards derived partially from: Berkeley Bicycle Boulevard Design Tools and Guidelines.

Figure 7: Direction and Destination sign system with System Map mounted below.

Guidelines for Way-Finding Signs Along Tucson Bicycle Boulevards:

1. Signs are a distinctive blue to distinguish them from other traffic and road signs.

2. Signs are made with retroreflective material for improved visibility.

3. Lettering on signs may be no less than two inches high.

4. Maps of the Tucson bicycle system are to be included at all hubs and near the intersections of two bicycle boulevards.

5. Path Identification Signs will be placed every 1/4 mile, and just after any turn, jog or split in the bicycle boulevard path.

6. Destination and Distance Signs will be placed every 1/4 mile, prior to signalized intersections, and in the block prior to the junction of two bicycle boulevards.

7. Bike Boulevard Identification Signs will be placed at every-other corner, except where another bicycle boulevard sign is present.

8. Bicycle Boulevard Intersection Signs will be placed in the block preceding the intersection of two bicycle boulevards.

9. Signs may not be obscured by vegetation or other visual impediments.

occasionally they are advisable or unavoidable for a variety of reasons. In such cases, recognizable bicycle boulevard signs with directional arrows help direct bicyclists and aid in way-finding. Signs are to be placed anywhere the bike boulevard path jogs or turns.

System Map (Figure 7)

Each hub station will include a full scale map of the Tucson bicycle system. System maps will also be included near the junction of two bicycle boulevards. System maps should be included on the Destination and Distance poles placed in the block leading up to the junction of two bicycle boulevards.

Whenever possible a six foot by seven foot box should be set aside in the parking lane directly in front of the system map. This set-aside is to accommodate bicyclists who pull over to consult the map. This box would be labeled with white 4 inch diagonal stripes on the pavement surface and a yellow stripe on the curb to discourage vehicular parking in this area.

Including signs that indicate distances and directions, and including maps of the entire bike system at regular intervals will help aid in flexible trip planning, and help encourage the use of the entire system for both transportation and recreation.

Pavement Markings

Pavement markings supplement signs, serving to remind users that they are on a bicycle boulevard, that cyclists take the lane, and help aid cyclists in way-finding. The two main pavement treatments are lane stripes and bicycle boulevard-specific pavement markings.

Lane Stripes

Roadway sections with heavy use of on-street parallel parking shall include a high visibility 12-inch wide white Type 1 tape or thermoplastic parking lane stripe placed 7 or 8

Figure 8: Bicycle boulevard pavement markings are to placed in the center of the drive lane to clarify that bicyclists take the lane and help aid in way-finding.

feet from the edge of curb. The thermoplastic tape is to include 10 percent crushed glass to increase the coefficient of friction on the surface. This will help define where cars may park, help visually alert drivers and cyclist that a car is moving in to the lane, and provide a visual buffer between parking and drive lanes.

A 4-inch wide solid yellow center line stripe should also be used to separate opposite directions of travel where passing by cars or bicycles should be discouraged. This may be particularly beneficial where heavy volumes of bicycles are particularly common and where curves restrict sight distance.

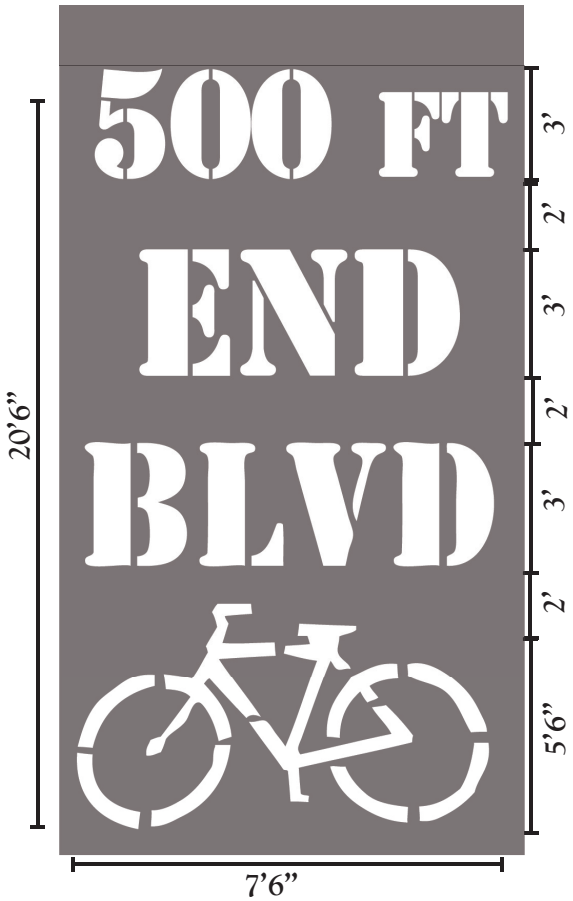


Figure 9: Advance warning of the end of a bicycle boulevard should be indicated on the pavement surface.

Bike Boulevard Pavement Markings

Bicycle boulevard pavement markings are car-sized white pavement markings that depict a bicycle, the abbreviation of 'boulevard' and a directional arrow. These markings are to are to be applied directly to the road surface, in the center of the drive lane, with a 4 to 6 inch wide white thermoplastic paint. Markings are to be placed in each direction of traffic just after every intersection, near high volume driveways or other potential conflict points, and at no more than 200 foot intervals.

The directional arrow should point straight, as in Figure 8, except where the bicycle boulevard turns or jogs. In these places the arrow should be turned 45 or 90 degrees in the appropriate direction so as to help aid in way-finding.

Bicycle Boulevard End

Bicycle boulevard pavement markings can also advertise an upcoming path end. When needed these should be located in the same place as standard pavement markings, and with sufficient advance warning to allow bicyclists to process the information and make appropriate decisions prior to the change. Advance warning of the end of a bicycle boulevard is indicated on the pavement surface with "END" replacing the arrow, and a count in feet until the end of the path as shown in Figure 9. These should be placed 500 and 200 feet prior to the end of a bicycle

Guidelines for Pavement Markings Along Tucson Bicycle Boulevards:

1. On-street parallel parking shall include a 12-inch wide high visibility white Type 1 tape or thermoplastic parking lane stripe placed 7 feet from the edge of curb.

2. A 4-inch solid yellow center line stripe is to be used to separate opposite directions of travel where out-of-lane passing by cars or bicycles should be discouraged.

3. Pedestrian crosswalk lines should be included at all non-residential scale street crossings along a bicycle boulevard.

4. White thermoplastic Bicycle Boulevard pavement markings are to be placed in the center of the drive lane after intersections and in conflict areas at no more than 200 foot intervals.

5. White thermoplastic Bicycle Boulevard End pavement markings are to be placed in the center of the drive lane 500 and 200 feet prior to the end of a bicycle boulevard.

General Design Guidelines for Tucson Bicycle Boulevards:

1. Paving and Surface Maintenance: Schedule should be increased to levels of arterial roads.

2. Bicycle Activated Signals: Include bike buttons, infrared motion detectors, pressure mats or other technology-activated, traffic light regulated crossings at every major and minor arterial road.

3. Refuge Islands: Must be sized to accommodate a bicycle and trailer, and several bicyclists simultaneously with a minimum width of 8 feet, and 6 feet in length.

4. Shared-Use Path Segments: Should be used only where necessary. Minimum width is 8 feet, 10-14 feet is preferred for two-way traffic.

5. Stop Signs: Existing 'Stop' signs are to be minimized along bike boulevard routes through removal, turning or conversion to 'Yield' signs as possible.

6. Bicycle Parking: Secure parking should be provided at regular intervals along bicycle boulevards as they traverse commercial or business areas.

7. Closures and Diverters: Barriers must be illuminated or reflective. Openings in barriers must be a minimum of 4 feet wide.

8. Traffic Circles: Placed at all intersections of two bicycle boulevards and regularly as supported by the surrounding neighborhood. All traffic circles are to be controlled by a four-way yield.

9. Speed Humps and Tables: 3-4 inches high, 12 to 22 feet long preferred, but no less than 3.5 feet. Spacing no greater than 275 feet, with at least two humps in a series. The first in a series placed 50 to 200 feet from a small radius curve or stop sign. Include advance warning signs.

10. Chicanes: Should include vegetation and passive water harvesting of run-off when possible.

11. Crosswalks: 10 to 20 foot high-visibility or raised platform crosswalks are to be employed at pedestrian crossings to schools and parks located on bicycle boulevards.

12. Vegetation: Must either be low growing shrubs or ground covers that, when mature, will not exceed 2 feet in height, or trees with a lower canopy height of no less than 7 feet.

Bike buttons are to be placed at either the right hand side of the roadway, or on a bicycle island so that bicyclists need not dismount or cross travel lanes to reach the button.

boulevard

Continuity

Continuity focuses on the integrity of the path itself, with improved comfort and safety at intersections, and a minimum of stops and jogs for bicyclists. The design guidelines below should be considered on a case-by-case basis and should always be evaluated with regard to the safest overall method for accommodating all users.

Bicycle boulevards in Tucson should include a light regulated crossing for pedestrians and bicyclist at every arterial and collector crossing. In addition high-visibility or raised platform crosswalks are to be employed at the main pedestrian crossings to schools and parks.

Paving and Surface

The paving and surface maintenance schedule of bicycle boulevards should be increased to levels of arterial roads to ensure a safe, comfortable surface for bicycling.

Bicycle Activated Signals

In Tucson HAWKs (High Intensity Activated Crosswalk) are the most common pedestrian and bicycle crossing improvements. These signals are on/off units activated by buttons. For all HAWK intersections along bike boulevards bike buttons are to be placed at either the right hand side of the roadway, or on a bicycle island placed just to the left of a vehicular right-turn-only lane, so that bicyclists need not dismount or cross travel lanes to reach the button.

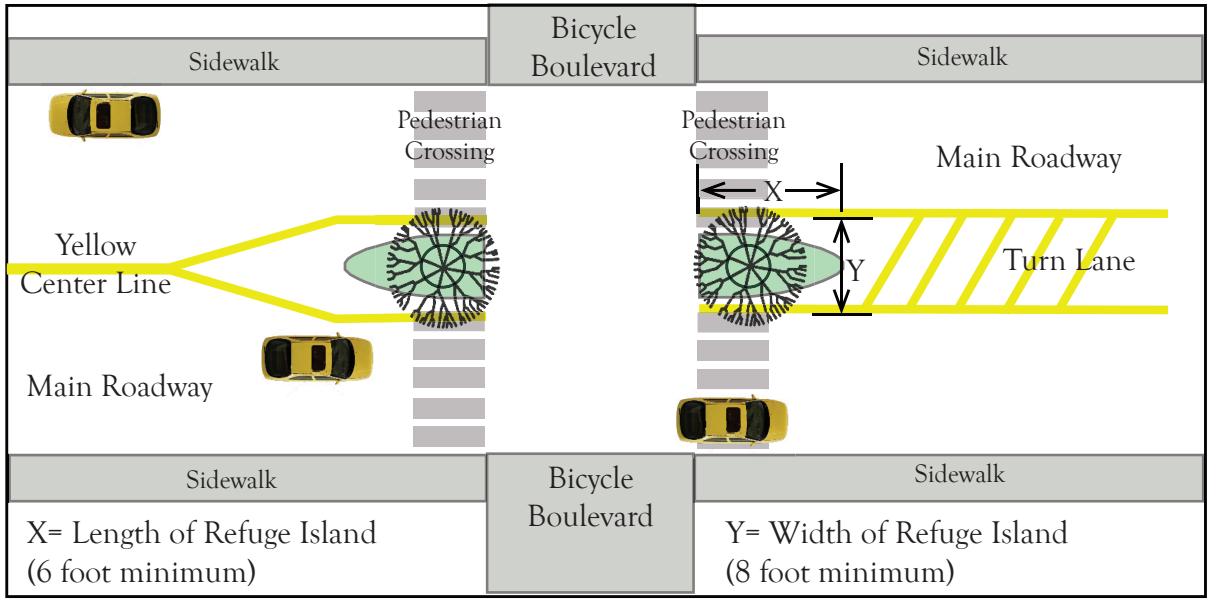
Bike Boxes

Bike boxes may be used at busier intersections where motor vehicle traffic on the bike boulevard may be heavy. Bike boxes along bike boulevards are to follow existing Tucson city standards for design.

Where bike-buttons are placed on the side of the roadway, a bicycle box should be provided to aid in easy and safe access to the button and ensure that motorists have a better chance to see bicyclists.

Refuge Islands

Crossings at multi-line or high volume streets can be facilitated by providing medians



Design standards derived from: AASHTO, 1999.

Refuge islands allow crossers to focus on traffic from one direction at a time. Refuge island can also serve as a partial closure by creating a pinch point that prevents cars form moving straight through the intersection.

that serve as pedestrian and bicyclist refuge islands. Refuge islands increase feelings of safety and allow a crosser to focus their attention in only one direction at a time.

Refuge islands are particularly relevant at intersections where regular traffic patterns do not necessarily warrant a HAWK or other traffic signal treatment, yet where crossing may still pose a connectivity problem for bicyclists and pedestrians during certain times. These islands also help calm traffic and can provide space for street trees or other landscaping.

Refuge islands must be sized to accommodate a bicycle and trailer, and several bicyclists simultaneously. The minimum width of the median is 8 feet, but 10 to 12 feet is preferable when possible.

Shared Use Paths Segments

In rare instances a brief section of Shared Use path may have to be incorporated into a bicycle boulevard in order to maintain safe and comfortable path continuity. In such cases, the expected pedestrian activity on site and the width required for a safe shared use path is the primary design consideration.

Under most conditions, the recommended standard paved width for a two-directional shared use path is 10 feet. A reduced width of 8 feet can be adequate, however. This reduced width should be used only where absolutely necessary, and where pedestrian use of the facility is not expected to be much more than occasional.

When such a Shared Use path

is located adjacent to a roadway, a wide separation between the path and the adjacent road is desirable. When this is not possible, and the distance between the edge of the shoulder and the shared use path is less than 5 feet, a suitable physical barrier is recommended. The barrier should be a minimum of 42 inches high, to prevent bicyclists from toppling over it. The barrier should not impair sight distance at intersections, and should be clearly visible and otherwise designed to not be a potential hazard to pedestrians, bicyclists or motorists.

Stop Signs

Stop signs serve as impediments to continuity as they increase the time and energy needs of bicyclists. Non-compliance is therefore common. Motorists also become frustrated by stop signs, and may fail to comply or compensate by speeding between stops. Bicyclist should ideally be able to travel the length of the bicycle boulevard without having to stop once unnecessarily.

At 3rd Street and Campbell Avenue cars must turn left or right and only bicyclists are allowed to continue straight across the intersection to stay on the bikeway.

Existing 'Stop' signs are to be minimized along bike boulevard routes through turning or removal as possible, and by converting four-way 'Stops' to four-way 'Yields' at traffic circles. Only stop signs that assign right of way to the bicycle boulevard will be installed. Any anticipated increase in motor vehicle volume or speeds should be mitigated a priori with traffic calming or vehicular restrictions.

Connectivity

Connectivity is based primarily in route selection, assuring access to popular destinations, other bicycle paths and facilities, as well as other modes of transit. Connectivity also includes the placement of hubs where other modes of transit, bicycle parking and/or amenities such as showers or drinking fountains may be combined with the bicycle boulevard route.

Route Selection

Route selection is to be based on access to important and popular destinations, the populations to be served, and the relative cost of improving existing conditions along a given route. Routes with many existing safe, traffic-light regulated crossings may, for example, be given preference over other routes.

Hubs

Three hub typologies are outlined here, respectively appropriate for regional, local and neighborhood contexts.

Regional hubs should be located in significant centers that have the potential for the highest levels of population and employment densities, or that generate the highest levels of travel demand, such as the Tucson airport or at transportation centers in downtown.

Regional hubs should provide access to several modes of transportation, food service, commercial areas and employment centers. Facilities should include motor vehicle parking, covered, secure long-term and short-term bicycle parking, showers and rest rooms. Primary hubs should also include weather, tourism and other information, WIFI internet access, bicycle repair facilities and supplies, and a bike share or rental program.

Local hubs are major activity centers

A multitude of shapes and styles work well for bicycle parking, but the rack should have no sharp edges or moving parts, and require little maintenance.

or destinations such as the city's malls, The University of Arizona, and large parks such as Reed Park. Local hubs should aid in flexible, safe and secure movement between different paths or modes of transportation, and significant destinations. Facilities should include covered, secure bicycle parking, a bike share or rental program, bicycle repair facilities and supplies, drinking fountains, tourism and other information and rest rooms Showers should be included as feasible and appropriate.

Neighborhood hubs are small transit hubs. These might be located in denser residential areas, at a commercial center, by a park or school, or at bus stops along a bicycle boulevard. These hubs should aid in flexible, safe and secure movement between different paths or modes of transportation, and provide bicycle parking. A vending machine with bicycle repair and other practical supplies may be included as appropriate.

Hubs of all three categories should provide a map of the city-wide bicycle system, impart a strong sense of place, prioritize the comfort of pedestrians and bicyclists and provide shade and shelter.

Bicycle Parking

Bicycle parking along bicycle boulevards should be placed so that it is:

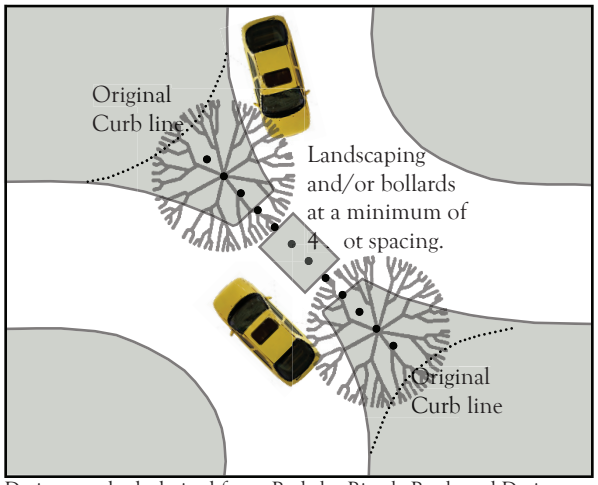
- Easily accessible from the bicycle boulevard
- Easily accessible from the sidewalk
- Outside pedestrian traffic movement
- Visible to passers-by
- Protected from motor vehicles

Bicycle parking along bicycle boulevards should be designed so that it:

- Does not bend wheels or otherwise damage bicycles
- Has as few moving parts as possible
- Is simple to operate
- Accommodates securing the frame and both wheels without the need to remove the front wheel from the bicycle
- Accommodates a wide range of bicycle shapes and sizes, including trailers
- Accommodates 'U'-locks
- Is covered, particularly where users are expected to leave their bikes for extended periods
- Is illuminated with solar powered lights, particularly in areas without street lights, or where users are expected to leave their bikes for extended periods.
- Works with, or imparts, character to the parking location, or ties in to the larger bicycle boulevard network

Traffic Volume and Speed

Reduction or maintenance of low vehicular traffic volumes may be done most clearly through route selection of low-volume streets, and/or by restricting vehicular access through partial or full closures of sections of a bicycle boulevard. Volume reduction may



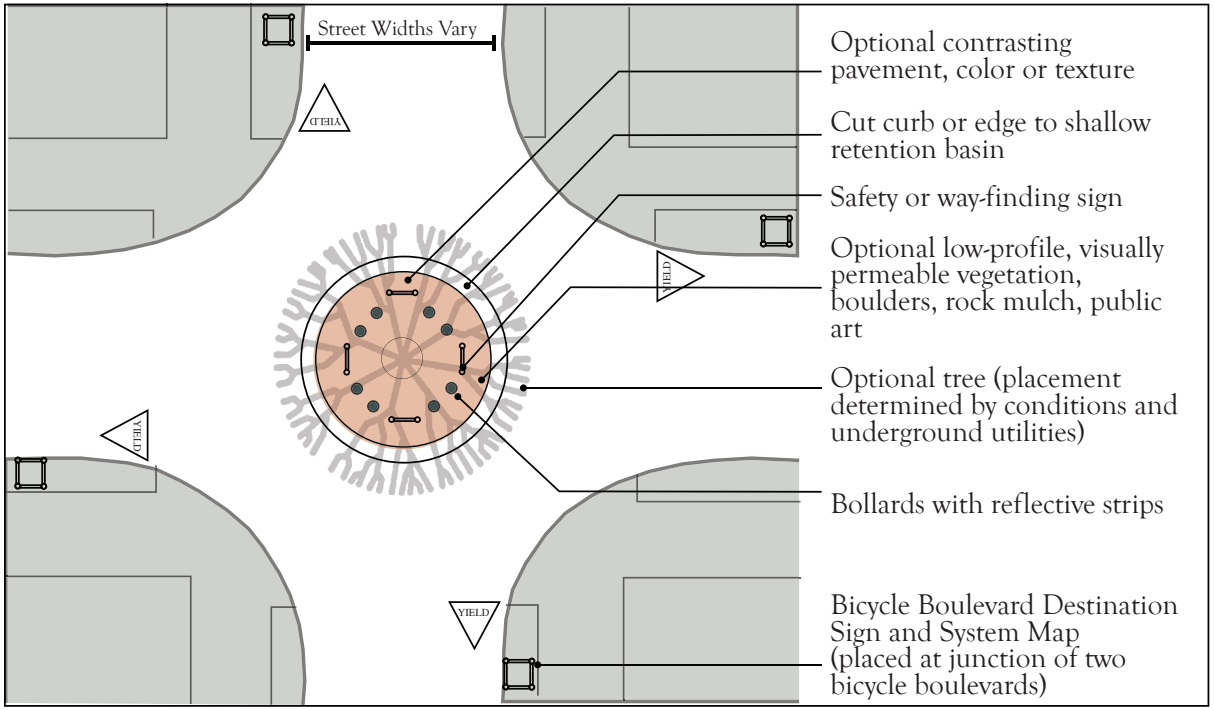
Design standards derived from: Berkeley Bicycle Boulevard Design Tools and Guidelines.

A Diverter reduces vehicular through-traffic by extending curbs and placing a block in the intersection that reduces the passable space to a size that prevents the passage of cars, but allows bicyclists to move through.

however also be a side effect of employing traffic calming design elements such as speed humps, traffic circles, chicanes and street trees. Volume and speed reduction may both be achieved through the site-appropriate implementation of design features that discourage non-essential or cut-through traffic while maintaining speeds at or below 25 miles per hour in the area. Both volume and calming design elements must be supported by neighborhood residents.

Closures and Diverters

Motor vehicle volume reduction can be achieved through street closures or diverters in careful consultation with the interested parties in the affected



Design standards derived from: Pedestrian and Bicycle Facilities in California: A Technical Reference, Technology Transfer Synthesis for Caltran's Planners and Engineers and Berkeley Bicycle Boulevard Design Tools and Guidelines and TDOT standards.

All traffic circles along Tucson bicycle boulevards are to be four-way yield controlled.

neighborhoods.

Physical barriers or regulations may bar vehicular traffic flow, create a cul-de'sac for motor vehicles with a bicycle cut-through, or close lanes to through traffic and force a turn by motor vehicles. In all cases the intersection should include 'Do Not Enter' signs with 'Bicyclists Exempt' signs posted underneath.

Openings in physical barriers must be a minimum of four feet wide to accommodate bicyclists. Barriers must also be illuminated or include reflective material to increase visibility and prevent injury.

Traffic Circles

Traffic circles are to be placed at all intersections of two bicycle boulevards where they can both mark the junction and help calm two boulevards at once. Circles should also should be employed at regular intervals, preferably every other block, along bicycle boulevards, as supported by the surrounding neighborhood.

Neighborhood support is important, as a cooperative maintenance agreement between the city and the neighborhood must be created for irrigation of vegetation and the upkeep of circles. Traffic circles should still be considered even when neighborhoods are uninterested in entering such an agreement however. Maintenance needs can be minimized with circles that feature sculpture, distinctive paving, bollards, or other non-living, low-maintenance elements.

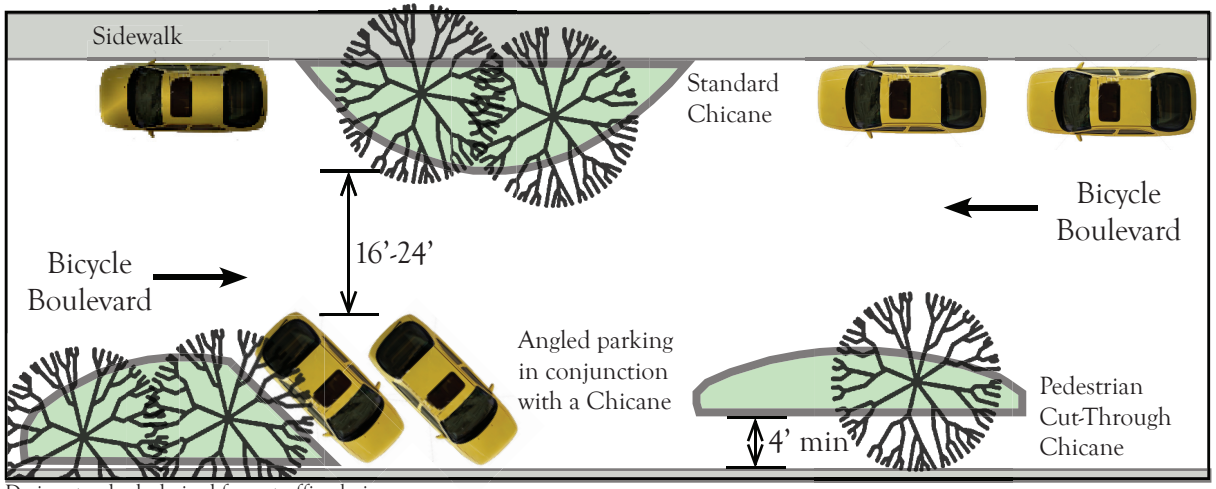
When needed, circles can be modified in size according to AASHTO standards to facilitate the passage of wide-chassis emergency vehicles such as fire trucks. Larger vehicles may have to make a left turn in front of the traffic circle.

All traffic circles are to be controlled by a four-way yield.

Speed Humps and Tables

Speed humps and tables may be used as needed to reduce traffic speeds in areas where traffic circles or other traffic calming

Traffic circles are some of the most effective traffic calming devices and maintain continuity and connectivity for both cars and bicyclists.



Design standards derived from: trafficcalming.org

Chicanes are a particularly attractive traffic calming device where the roadway is very wide and/or where space for street trees is otherwise limited.

devices do not receive neighborhood support, or where speeding or traffic volume problems are particularly pronounced.

Spacing of humps and tables is critical to their success as wide spacing may actually encourage motorists to speed up between humps. Where employed, spacing should be no greater than every 275 feet, and should include at least two humps in a series. The first speed hump in a series should be placed 50 to 200 feet from a small radius curve or stop sign. If installed on a street with a significant grade, the first hump in a series should be placed at the top of the grade.

Advanced signing must be installed to alert drivers and riders to upcoming humps or tables. Retroreflective pavement markings should be used to increase visibility, particularly in the evening. Minimum speed hump length is 12 feet, but gradual, longer humps or tables of 15 to 22 feet are preferable for a bicycle boulevard due to increased bicyclist comfort.

If an existing hump along a bicycle boulevard has a length that is shorter than the wheel base of a bicycle (3.5 feet), the hump must be no higher than 2 inches so that the bicyclist's toes or pedals do not strike the humps.

Chicanes

Chicanes are a particularly attractive traffic calming device on stretches where the roadway is very wide, on-street parking is ample for neighborhood needs, where sidewalk space is non-existent or very narrow, and/or where space for street trees is limited.

When providing a buffer for pedestrian traffic on stretches without sidewalks, a 4 foot separation should be maintained between the chicane and the curb to allow for pedestrian through movement.

When vegetated, chicanes should be slightly sunken or curb-cut to harvest street run-off during storm events as already done along stretches of 9th and 10th Streets in Tucson. Vegetation must maintain height standards outlined under Landscaping.

If needed, center lines or median barriers may be installed to keep motorists from crossing into the oncoming lane of traffic to avoid the lateral shift.

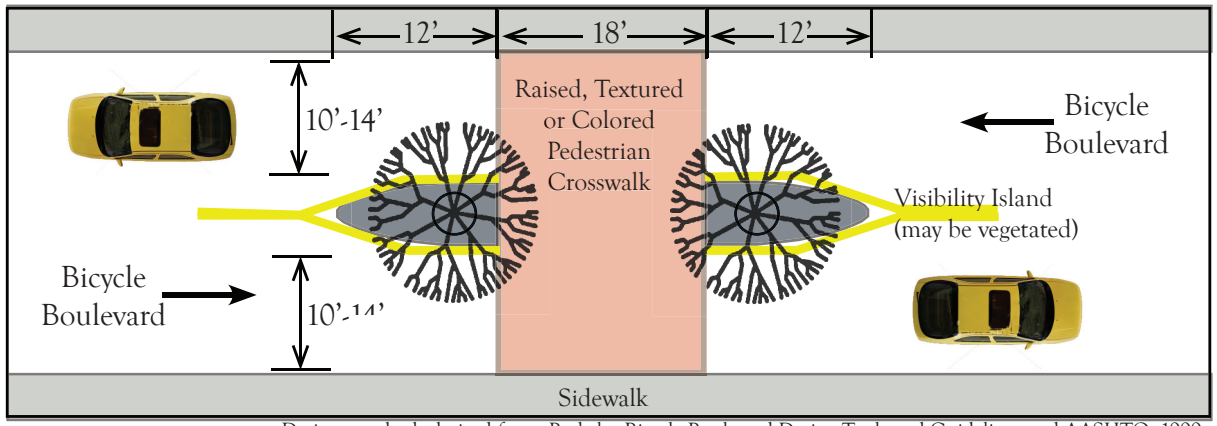
Bulbouts

Bulbouts or Curb Extensions may be used to help slow traffic and bridge crossings at higher volume intersections and mid-block crossings. Bulbouts are particularly useful design treatments if extra space is needed for bicycle parking, a drinking fountain, a system map or other bicycle boulevard feature.

When vegetated, bulbouts should be slightly sunken and curb-cut to harvest street run-off during storm events. Vegetation must maintain height standards outlined under landscaping and Street Trees.

Pedestrian Amenities

Design features such as street trees, and traffic calming used to improve bicycle boulevards can greatly benefit pedestrians as well. As such, design efforts should be made to assure that these benefits are readily available to pedestrians. Safe, pleasant, continuous 'pedestrian boulevards' are to



Design standards derived from: Berkeley Bicycle Boulevard Design Tools and Guidelines and AASHTO, 1999.
A high visibility crosswalk should be used where pedestrian traffic is heavy, and where pedestrians may come in to conflict with higher motor vehicle volumes or speeds, such as at parks or schools.

move along the length of Tucson bicycle boulevards. Of particular importance is the provision of continuos sidewalks or pedestrian paths, improved crosswalks, landscaping, pedestrian scale lighting and occasional seating as feasible and appropriate.

To help further reduce speeds for pedestrians in particularly sensitive areas, 10 to 20 foot high-visibility or raised platform crosswalks are to be employed at the main pedestrian crossings to schools and parks located on bicycle boulevards. High-visibility crosswalks may feature medians, refuge islands, bulb-outs or special paver or pavement colors or textures. Raised platform crosswalks can have the same characteristics as high visibility crosswalk, raising the pavement surface 3 to 4 inches, and also function as a speed table.

High visibility crossings should use retroreflective pavement markings and warning signs to provide advance warning for motorists and bicyclists alike. Contrast and tactile warning strips should also be placed along crossing to aid the visually impaired.

When needed, crossing can be modified to facilitate the passage of wide-chassis emergency vehicles such as fire trucks.

Lighting

Fixed-source lighting to improve visibility along paths and at intersections allows the bicyclist to see the path direction, surface conditions and obstacles. Lighting for bicycle boulevards is thus important and should be considered particularly where night usage is expected, such as on paths serving large populations of college students or commuters, at highway intersections, through underpasses or tunnels, and where nighttime security could be an issue.

Depending on the location, average maintained horizontal illumination levels of 5 lux to 22 lux should be considered. Where special security problems exist, higher illumination levels may be considered. Light standards and poles should meet the City recommended horizontal and vertical clearances for pedestrians and evenly illuminate the entire boulevard path.

Public Art

Public art helps create the unique feel and look of a bicycle boulevard, and can bring increased interest and involvement from the community at-large.

Public art should be incorporated into traffic calming devices and hubs at regular intervals. The specific form and type of art should be determined in conjunction with the surrounding neighborhoods, and must meet all relevant requirements of the City. Art should also be weather, theft and vandalism resistant.

Art should be locally commissioned or produced as the result of a local competition, and address themes of bicycling, or relate to the local history or character of the location at which it is placed. Art may also be themed along a corridor to provide continuity and interest.

Artistic or decorative bicycle racks and parking shelters may also be used, as long as all general parking standards are met.

Landscaping

This design recommendations of this toolbox focus on plant selections that

emphasize a sense of place in the Sonoran Desert, attract native birds and butterflies and are water conscious and desert appropriate. If properly planted and maintained, these plants should be easy care, water efficient, and attractive. List of appropriate trees, shrubs, groundcovers, cacti and wildflowers can be found in the Appendix.

Street Trees

Street trees along a bicycle boulevard corridor can significantly reduce surface temperatures. This is particularly important in a hot, arid climate such as Tucson's. In addition to increasing the comfort and aesthetic qualities of a bicycle boulevard, street trees are known to have a traffic calming effect.

Street trees should be planted between sidewalks and roadways where possible to provide maximum shade for both bicyclists and pedestrians. A minimum of three feet of planting space is required for healthy tree growth. Medians should also include shade trees as long as there is a minimum of five feet of width, and mature tree canopies won't interfere with the movement of traffic.

The tree species identified in the Appendix are all suitable for the climate and conditions found in Tucson, but have other comparative advantages and disadvantages to be weighed carefully prior to selection and planting. The selection of a single species for distinguishing individual bicycle boulevards or setting apart the whole network can be an effective design strategy, particularly if the species selected has a seasonal color or significant bloom to showcase. Mono-plantings may however be inadvisable if the species selected is at all susceptible to diseases or pests, as the entire corridor could suffer from one infestation or outbreak. It is also difficult to achieve the intended design effect, at least in the short to medium term, if already existing street trees are of another species.

In order to maintain clear sight lines and maintain safety and security on the roadway and in public areas, trees must have a lower canopy height of no less than 7 feet.

Shrubs and Groundcovers

Vegetating medians, bulb-outs, chicanes and traffic circles is a straightforward way to improve the aesthetic qualities of the path and bring a flavor of the surrounding ecosystem into the riders experience.

A wide variety of low-growing shrubs, succulents and groundcovers can be utilized to beautify Tucson's bicycle boulevards. Species must be relatively low maintenance, have an appropriate growth rate and life cycle, and maintain a suitable size and shape for their location. They should also harmonize with their surroundings, and lend a distinctive, local character to the network.

Selecting exotic species, even when hardy, drought resistant, and seemingly noninvasive should be done very carefully as some non-natives may naturalize, and their foreign character can compromise what might otherwise be the unique regional flavor of the boulevard.

At least some of the public art placed along the bicycle boulevard should have a bicycle theme.

In order to maintain clear sight lines and maintain safety and security on the roadway and in public areas, all vegetation used along bicycle boulevards must either be low growing shrubs, succulents or groundcovers that, when mature, will not exceed 2 feet in height. Exceptions may be made for highly visually penetrable species.

Irrigation and Water Harvesting

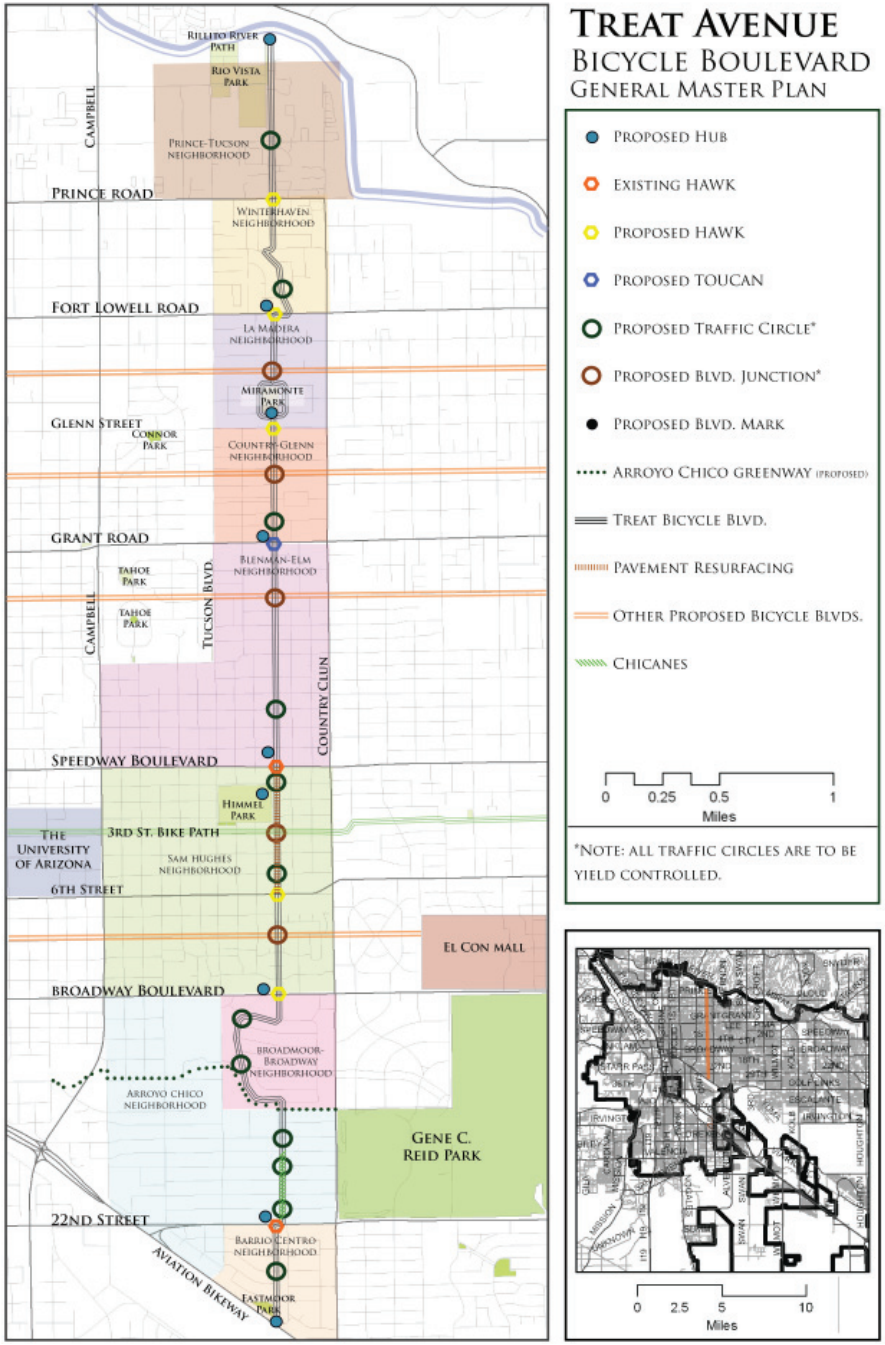
Curb extensions, chicanes, medians and street tree plantings along bicycle boulevards should all include water harvesting elements. Basins, swales, and curb cuts should be included, as appropriate, feasible, and desired by the surrounding neighborhood, with all bicycle boulevard improvements.

Design

The Fourth Avenue/Fontana and Treat Bicycle Boulevards are pilot projects for Tucson. They will serve as active models of the bicycle boulevard concept for users, residents and visitors to the city. As such, the success and popularity of these routes may be critical to realizing the future expansion of a Tucson Bicycle Boulevard network.

The plans presented here seek to present two complete bicycle boulevards that not only serve bicyclists, but also pedestrians and the general neighborhoods they traverse, with amenities such as shade, safer crossings, calmed streets, and drinking fountains. Expressed community and neighborhood support for the general concept of bicycle boulevards in Tucson, as well as these specific bicycle boulevard routes, was based partially on the concepts shown here, and as such this design vision should not be compromised.

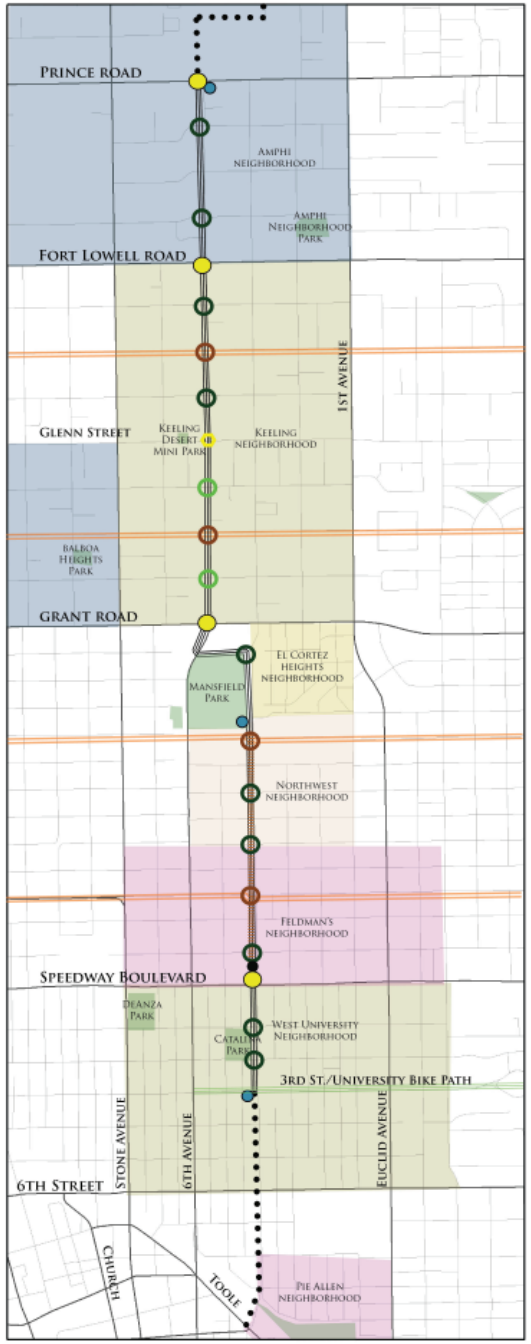
That said, many of the design treatments proposed here require neighborhood support either in the form of consent, such as for partial street closures, or in joint maintenance agreements, such as with vegetated traffic circles. The process of selecting appropriate pubic art to grace the corridor should also invite further community participation, particularly from the neighbors most directly affected.



Tucson Bicycle Boulevard Section, Typical
The Tucson Bicycle Boulevard network envisioned here consists of safe, connected, continuos routes with on-street parking, street trees, distinctive way-finding signs and pavement markings, traffic calming devices, and water harvesting elements.

The conceptual Master Plans for 4th Avenue/Fontana and Treat Avenue shown here indicate the placement of design elements intended to bridge barriers to walking and cycling along the selected routes. The placement of traffic calming and volume control measures, hubs, crossing lights, and boulevard markers are all indicated on the plans. Larger versions of these master plans can be found in the Appendix. In order to illustrate the conceptual plans, both specific designs and typical design treatments are shown in greater detail in the pages that follow.

The bicycle boulevards envisioned here consists of calm, residential streets where bicycling, as well as walking, are prioritized. Bicyclists utilize the full vehicular lane along the entirety of the routes, and cater to all levels and types of cyclists. On-street parking is maintained, street trees are abundant, distinctive way-finding signs and pavement markings are used, water harvesting elements are implemented as feasible, and both continuity and connectivity are emphasized.

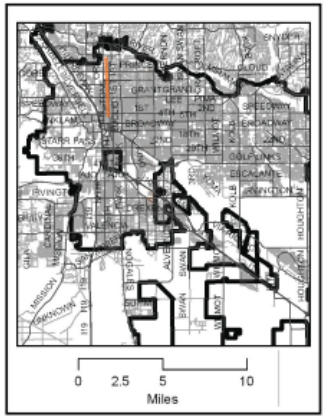


4th Ave/Fontana Bicycle Boulevard General Master Plan

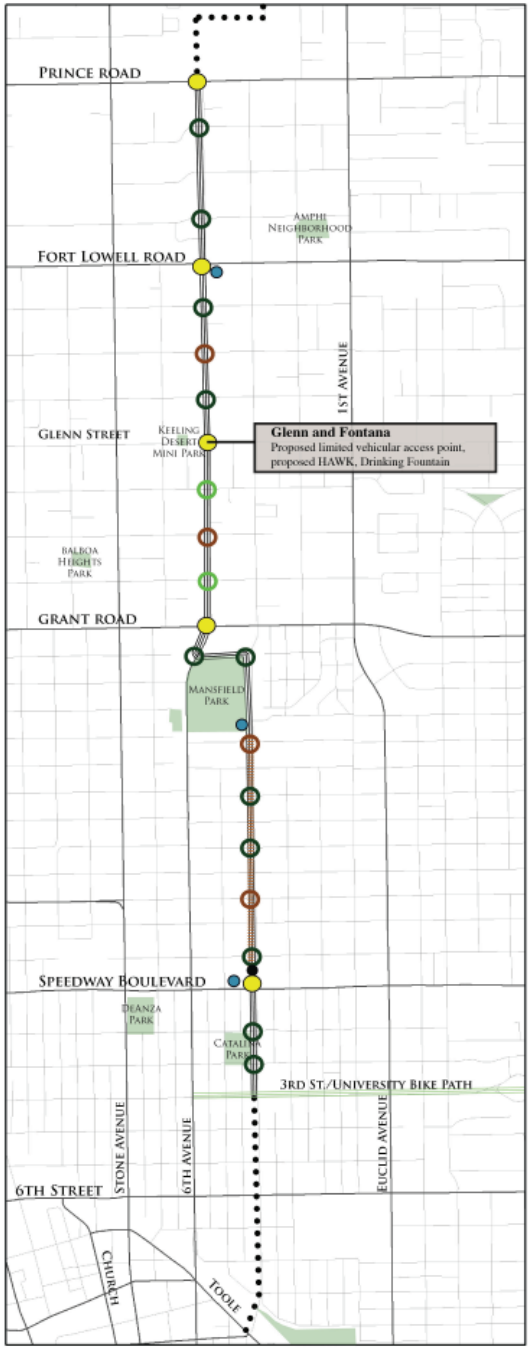
- Proposed Hub
- Existing HAWK
- Proposed HAWK
- Proposed TOUCAN
- Existing Traffic Circle*
- Proposed Traffic Circle*
- Proposed Blvd. Junction*
- Proposed Blvd. Mark
- Proposed Diverter
- 4th Ave./Fontana Bicycle Blvd.
- Pavement Resurfacing
- Other Proposed Bicycle Blvds.
- Future Route Extension

0 .25 .5 Miles

*Note: all traffic circles are to be yield controlled.



Crossing at Fontana and Glenn Street
The current intersection of Fontana and Glenn is a potential barrier as it lacks both a pedestrian and bicycle crossing. The design helps break this barrier by including painted cross walks, safety and way-finding signs, proposed limited vehicular entry access, and a pedestrian beacon.



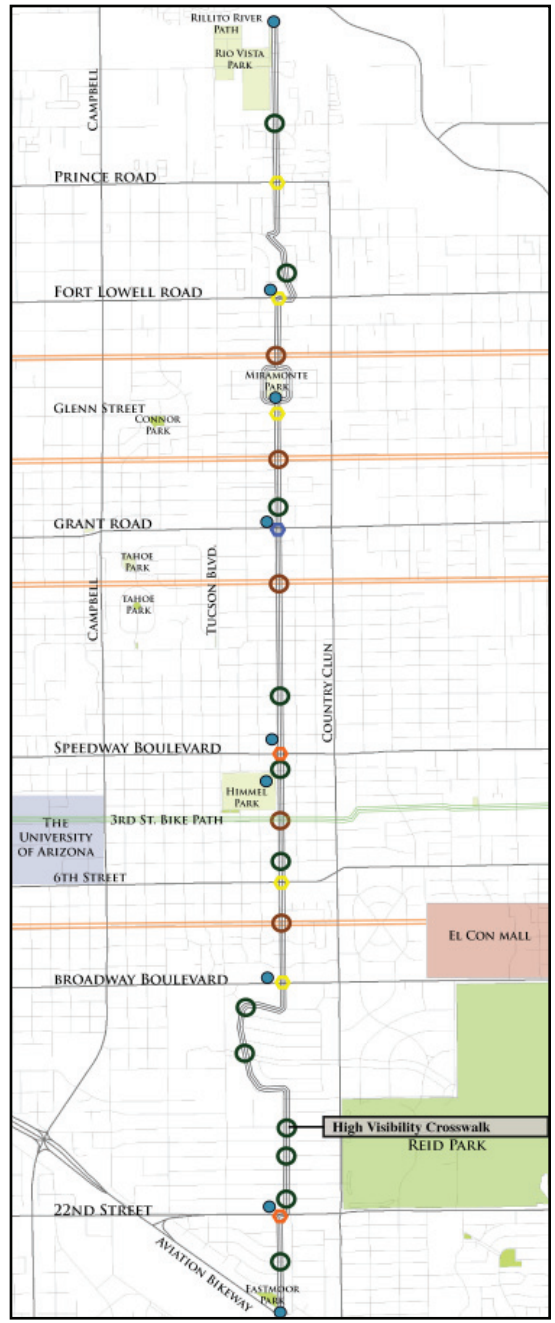
Major Vehicular Crossings

Crossing heavily trafficked roads is one of the main barriers to continuity, connectivity and comfort. Waiting long periods of time to cross can frustrate riders and lead to unsafe maneuvering. As such traffic light controls and bike buttons at all larger intersections along bicycle boulevard routes is critical to their function and success.

Highly visible crossings on roads with larger traffic volumes also help to visually highlight the presence of bicycle boulevards, advertising the facilities to potential users, and raising awareness of the presence of bicyclists on the streets.

Existing traffic lights control most of the larger street crossings along 4thAvenue/Fontana. The main crossing barrier on this route is found at Fontana and Glenn. The Treat Avenue corridor has several difficult crossing points, and the crossing improvements proposed in the Master Plan are essential.

High Visibility Crossing at Treat and 18th Street at Robison Elementary School



Bicycle Boulevard Crossings

Highly visible crossings of bicycle boulevards serve the dual purpose of helping pedestrians cross the road safely, and functioning as a traffic calming element for the bicycle boulevard route itself.

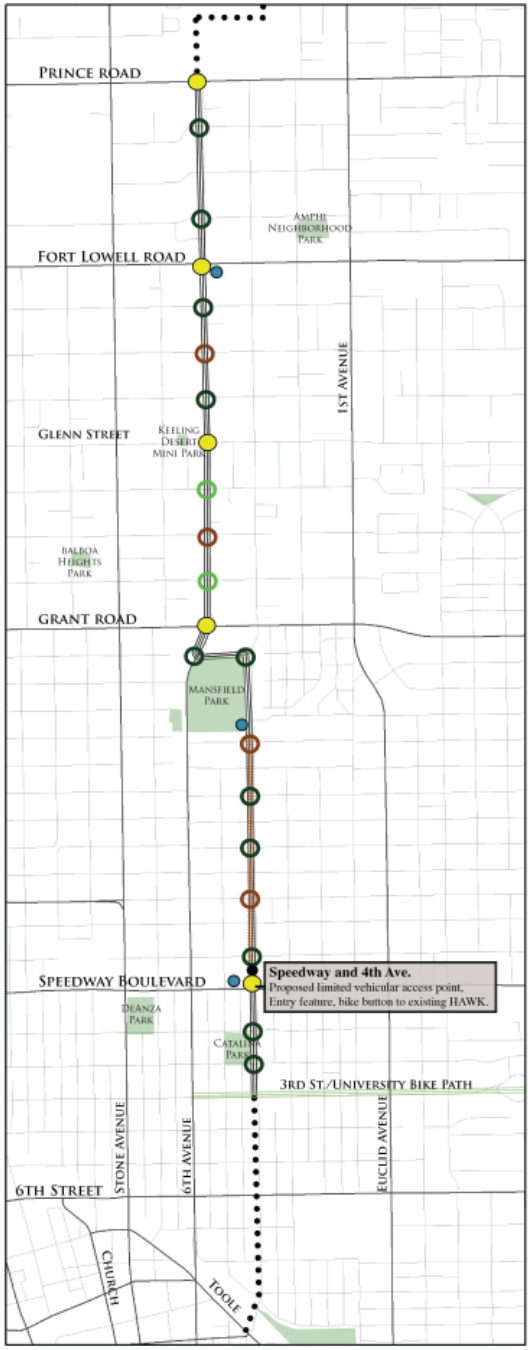
These design treatments are best reserved for crossings with high pedestrian volumes that lead directly to destinations such as schools and parks, or that are placed parallel to heavily trafficked streets. In these locations the highly visible crosswalk helps increase the visibility of pedestrians and reduce conflicts with both bicyclists and motor vehicles, while also helping to call attention to the distinctive bicycle boulevard it crosses.

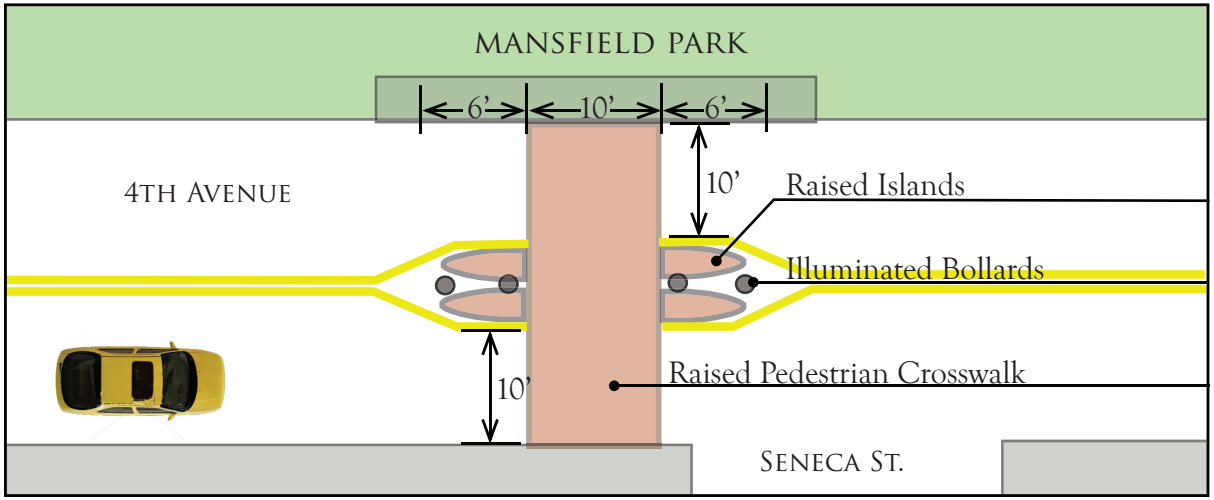
Speedway and 4th Avenue
By restricting north-bound vehicular traffic and limiting south-bound traffic to right-turn-only, as well as providing a more visible crosswalk, the design improves both pedestrian and bicycle safety and connectivity. The bicycle boulevard entry feature helps calm traffic and simultaneously advertises the presence of a bicycle boulevard to all who traffic this popular stretch of busy Speedway Boulevard.

Bicycle Boulevard Entry Feature at Speedway and 4th Avenue

Speedway and 4th Avenue Looking North

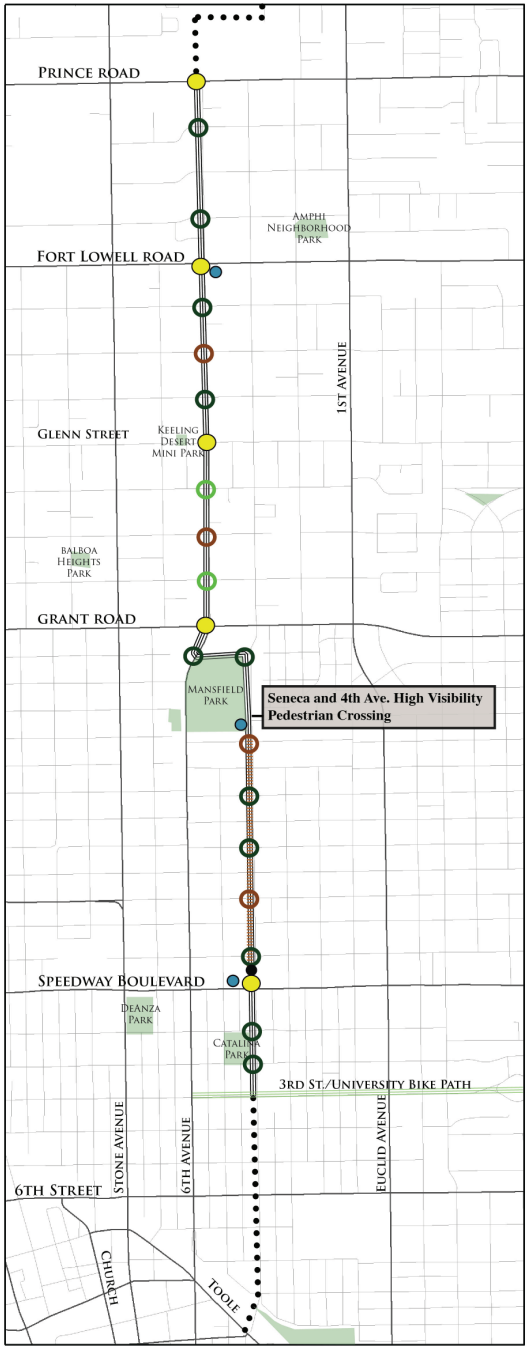
The north-bound intersection includes pavement markings and a proposed limited vehicular entry access, forcing motor vehicles to turn, while allowing bicycle traffic to continue straight.

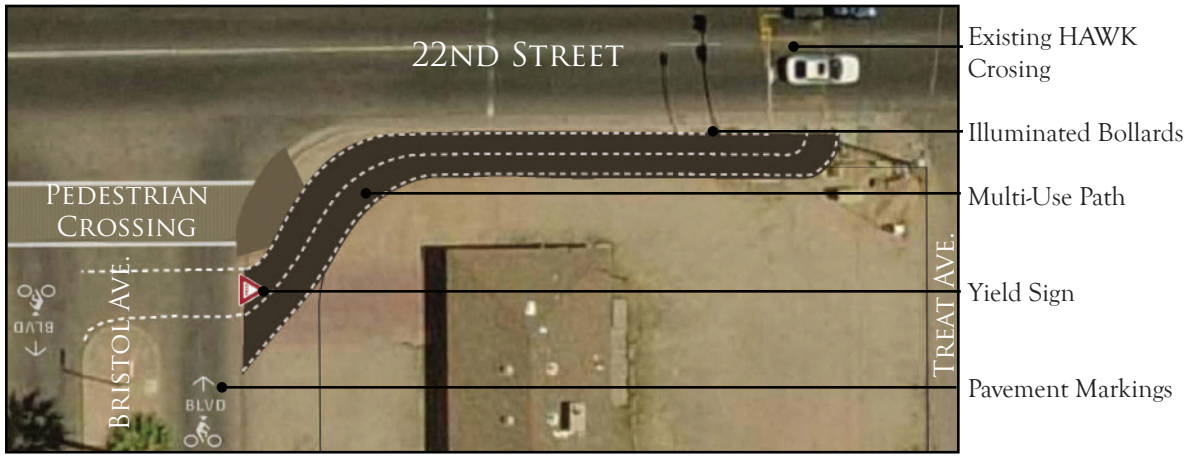




Seneca and 4th Avenue High Visibility Crosswalk
The raised, high visibility crossing and illuminated bollards help slow traffic and improve safety along Mansfield Park and a wide, straight section of the 4th Avenue/Fontana Bike Boulevard route.

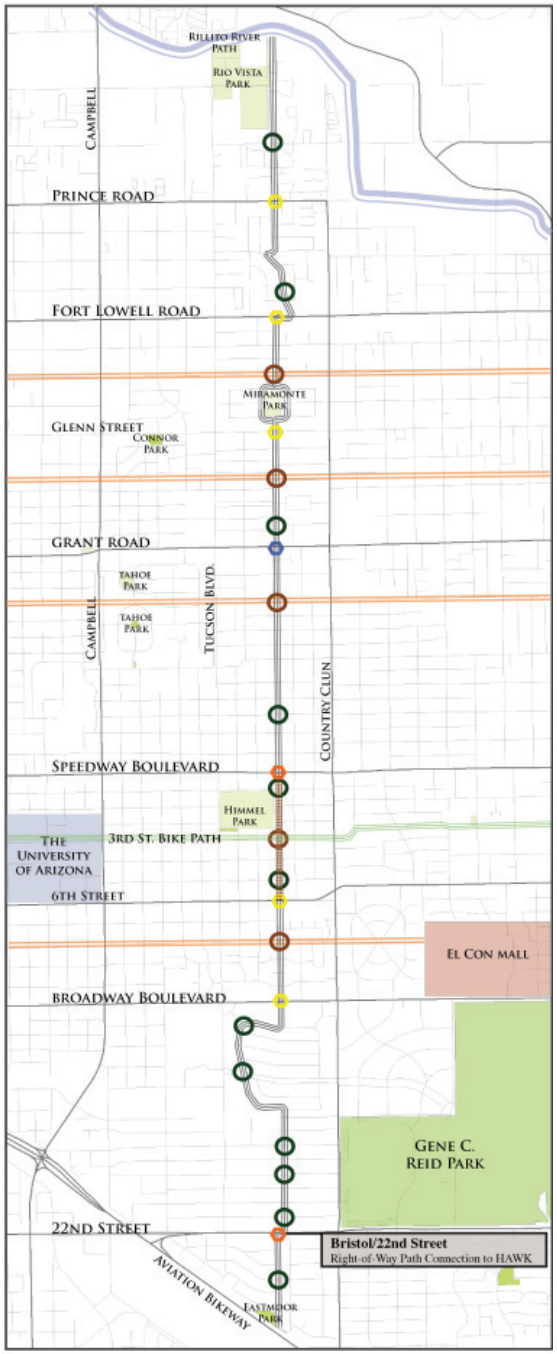
Seneca and 4th Avenue Looking North
The raised, high visibility crossing will help calm traffic as it moves along the eastern edge of Mansfield Park, improving the safety of crossers to and from El Cortez Heights neighborhood.





22nd Street and Treat to Bristol
A short stretch of multi-use path makes the transition between the HAWK and the bicycle boulevard clear. Curb cuts, bollards, and pedestrian crosswalk improvement also minimize conflicts and increase accessibility.

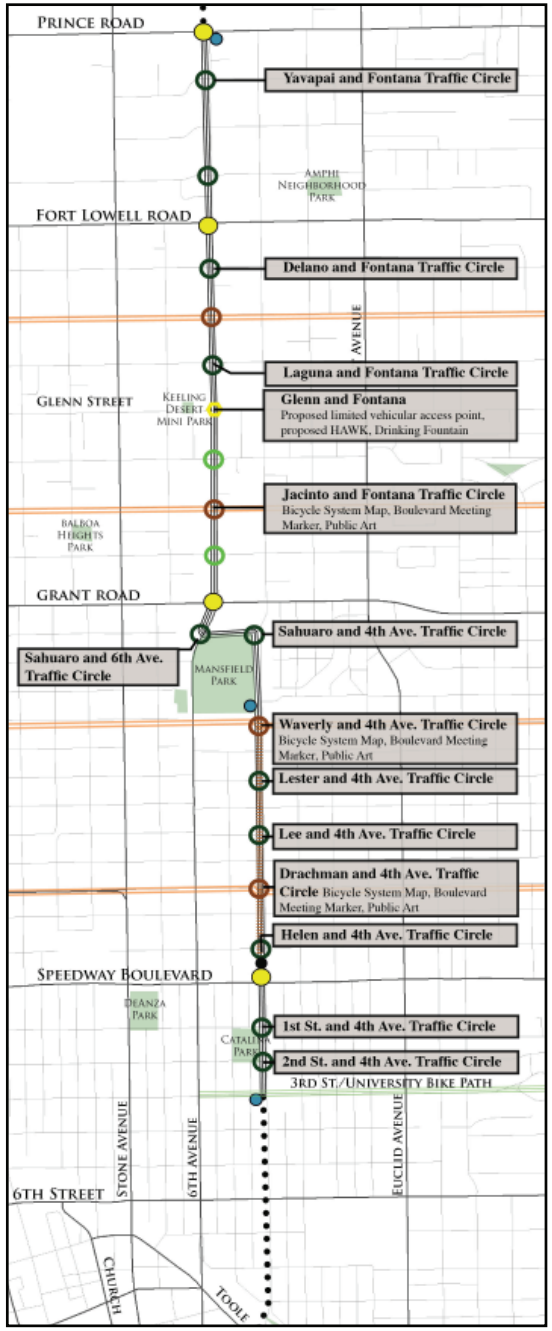
22nd Street and Treat to Bristol
A multi-use path in the 10 foot right-of-way helps to bridge the connection and provide a safe and easy-to-follow route from the 22nd Street HAWK to Bristol Avenue.



Traffic Circle Treatment, Typical
Features pavement markings, four-way yield signs, and vegetated or non-vegetated traffic circle, with or without bollards.

Traffic Circle at Manchester and Stratford
A slightly sunken, curbless traffic circle will collect street run-off, and provides an entry feature for the Broadmoor-Broadway neighborhood. .

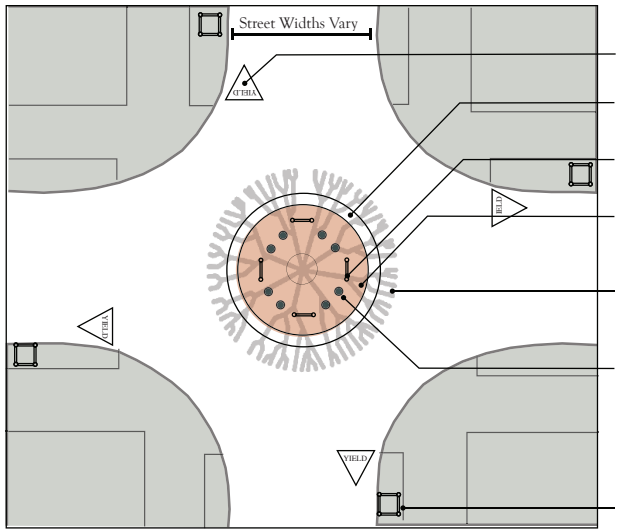
Public Art
Traffic circles provide a good place to display public art, particularly with a bicycle theme, and serves to beautify the neighborhood while lending character to the route.



Traffic Circles Along 4th Avenue/Fontana

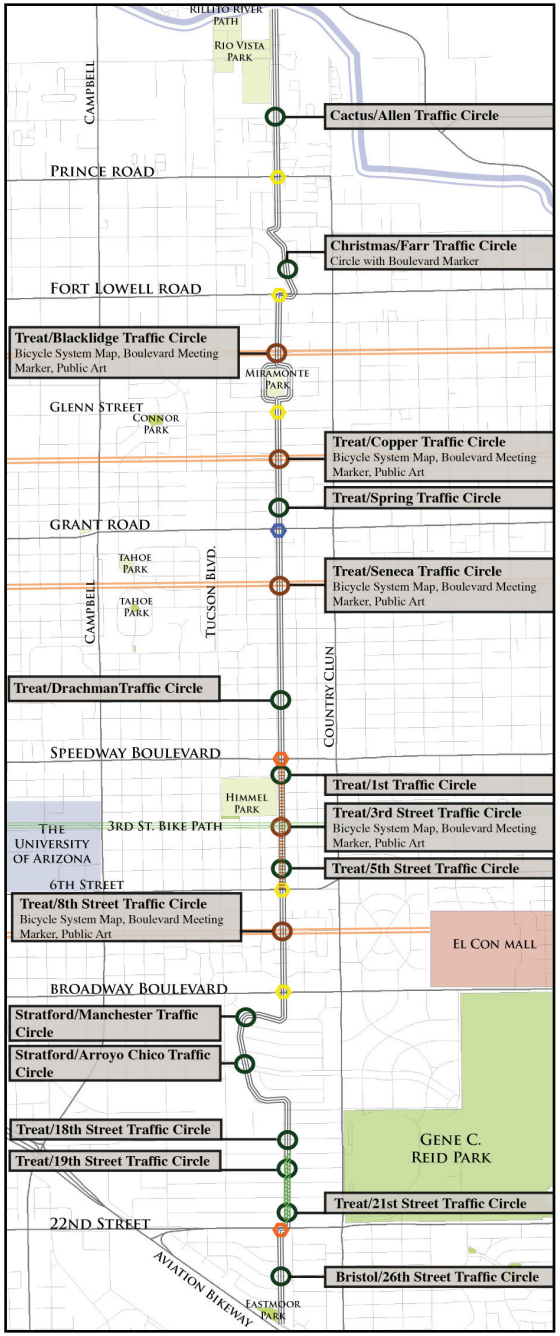
Traffic Circle at Junction of Bicycle Boulevards, Typical

Features pavement markings, way-finding and branding signs, a bicycle system map, four-way yield signs, and a vegetated or non-vegetated traffic circle, with or without bollards.



- Four-way yield
- Water harvesting cut curb, or shallow retention basin
- Bicycle boulevard crossing sign
- Low-profile, visually permeable, native and desert adapted, low-water-use vegetation, rock mulch
- Tree (placement determined by conditions and underground utilities)
- Bollards with reflective strips
- Bicycle Boulevard Destination Sign and System Map

Traffic Circle at Junction of Bicycle Boulevards, Typical



Traffic Circles Along Treat Avenue

Street Configuration

Stretches of overly-wide streets are found along both 4th Avenue/ Fontana and Treat Avenue routes, but can be traffic calmed and visually narrowed through the use of chicanes. By cutting the curb of these traffic calming elements street run-off can be captures to help irrigate street trees which help to further the visual narrowing of the street and calm traffic.

Chicanes do utilize some of the space available for on-street parking, but when vegetated with trees can also help provide shady parking spots. This design treatment is best reserved for those wide street segments where neighborhood parking is not at a premium. Alternatively, angled parking can be placed between chicanes to increase parking capacity, although these spaces should be back-

Wide Street with Chicanes, Typical
Overly-wide stretches of the bicycle boulevards are visually narrowed through the use of chicanes.

48 Foot Street, Typical

Mid-Block Treatment, Typical
Including parking stripe, way-finding pavement markings and sign, 25 mile per hour speed limit and street trees.

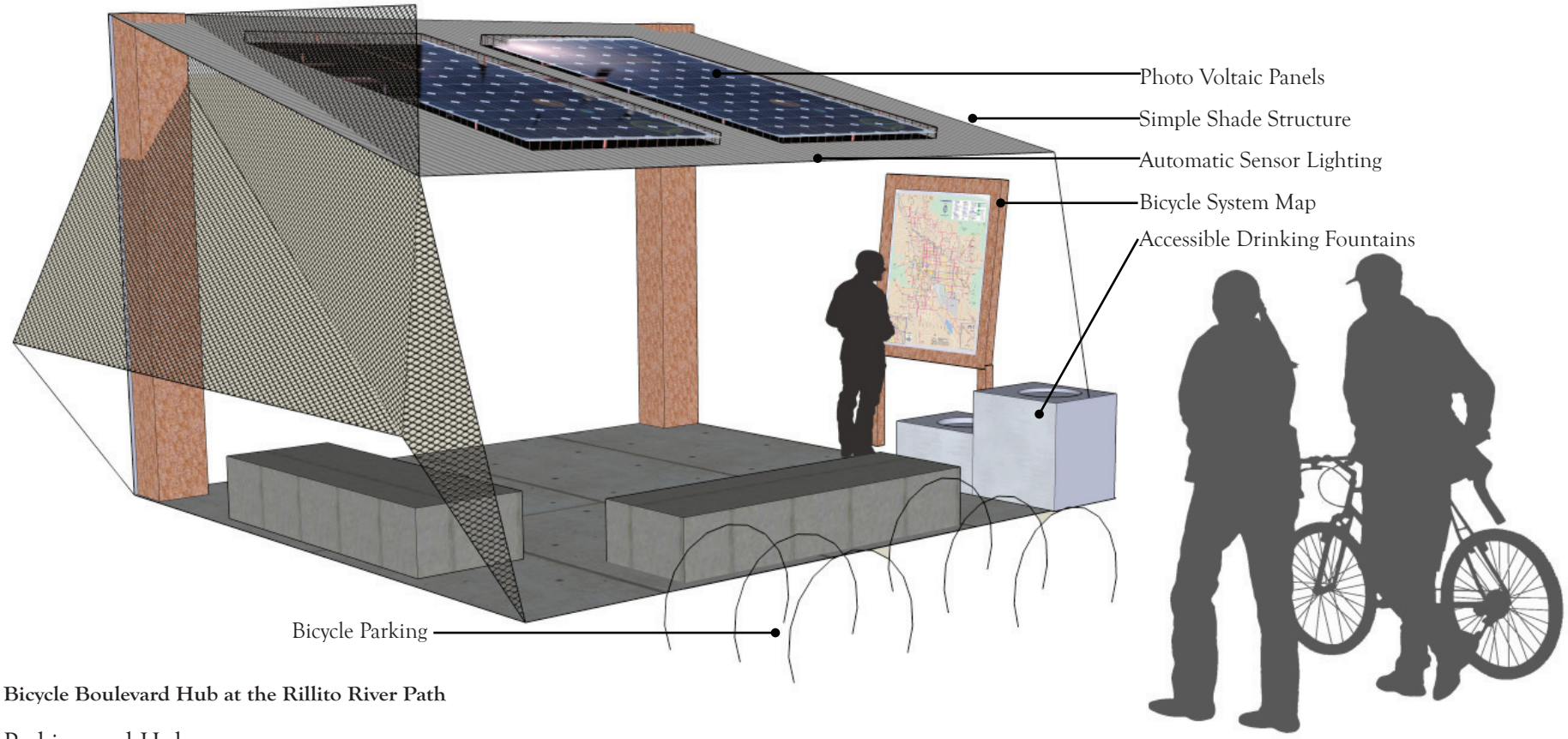
Saguaro North of Mansfield Park
Proposed parking stripes and way-finding pavement markings will help clarify traffic movement and highlight bicyclist's presence on this stretch of dense parking and occasionally heavy traffic.

Treat and Helen
Proposed parking stripes, way-finding pavement markings and street trees can help calm and direct traffic at one of the busiest sections along this route.

in parking only for bicycle safety.

Stretches of heavy on-street parking are found along both the 4th Avenue/ Fontana and Treat Avenue routes. These areas should include 12-inch wide parking stripes to delineate the parking area from the main roadway. Pavement markings that clarify that bicyclists utilize the whole vehicular lane are particularly important in these zones to help cyclists avoid opening car doors and merging traffic, as well as to remind drivers that this roadway is shared with many bicyclists.

The angled parking on the south side of Saguaro along the 4th Avenue/Fontana route should be converted to back-in parking only for bicycle safety.

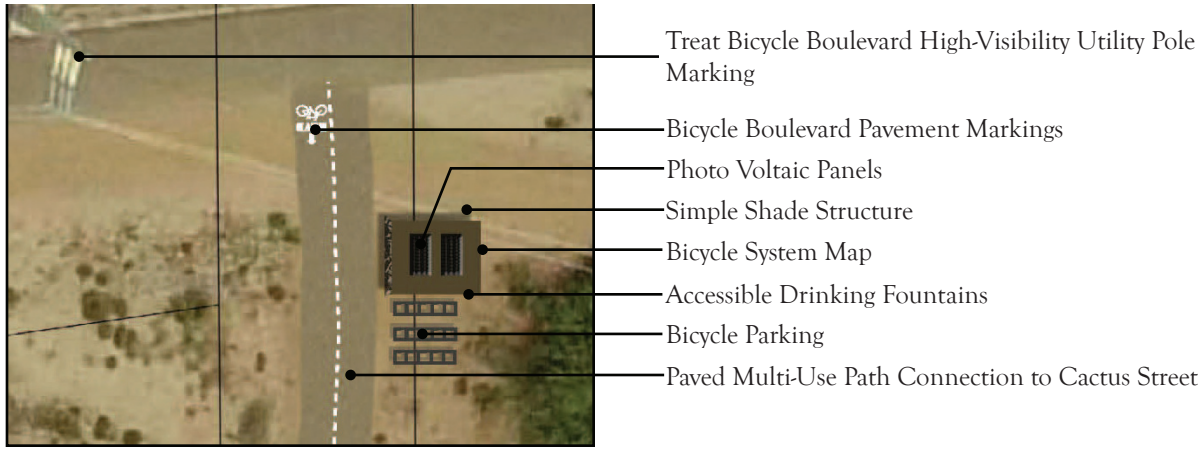


Bicycle Boulevard Hub at the Rillito River Path

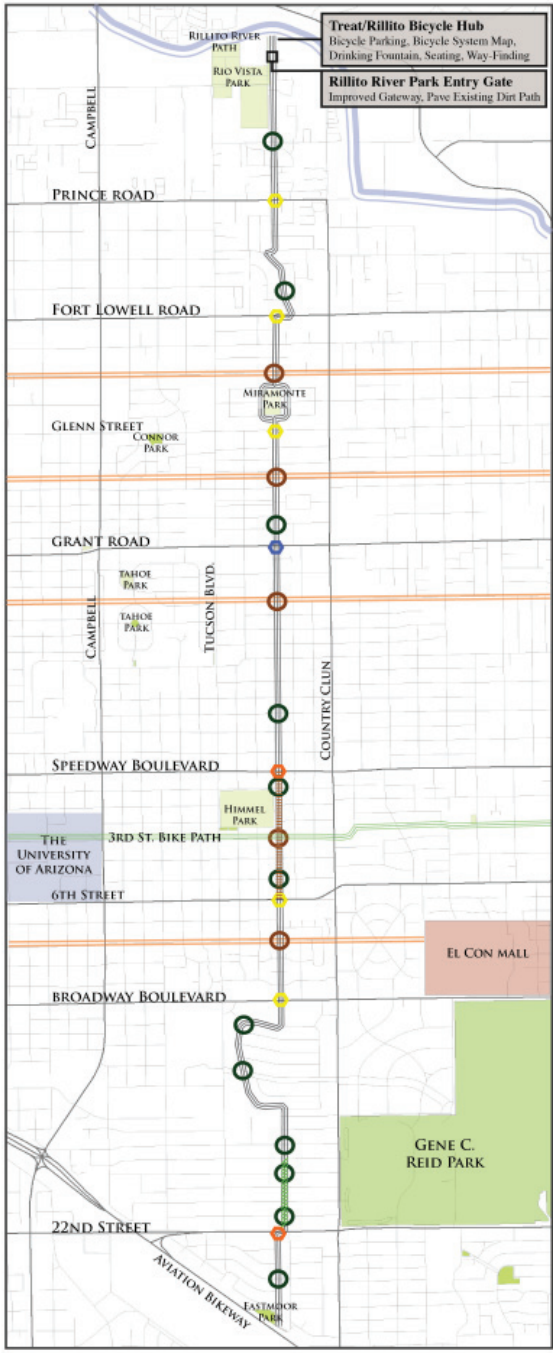
Parking and Hubs

Several spots are identified on the Master Plans as intended bicycle hubs. These vary from simple bicycle racks with bicycle system maps to larger bicycle corrals or covered parking, to hubs that provide drinking fountains, shade, seating and photo voltaic-powered lights.

On future stretches of bicycle boulevards larger scale hubs that include rest rooms, showers, lockers, bicycle repair stations, food, and other services may be appropriate.

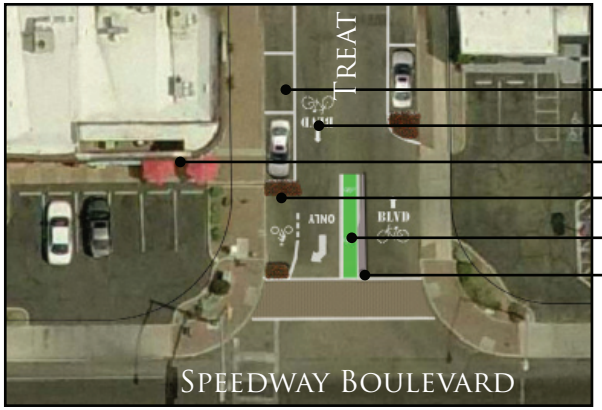


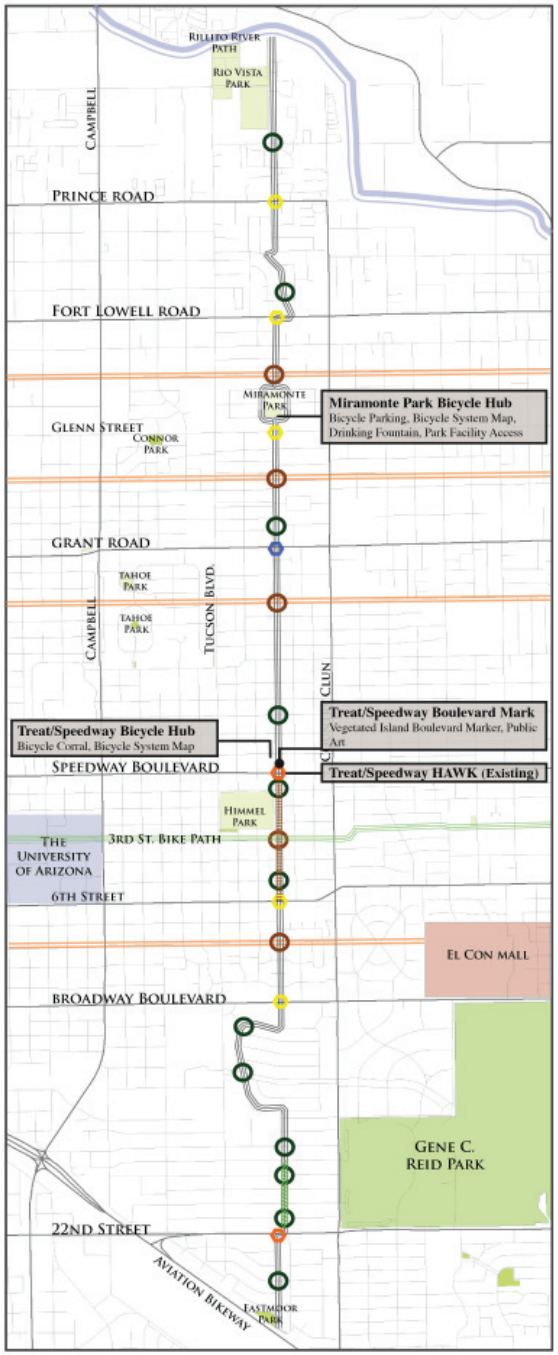
Bicycle Boulevard Hub at the Rillito River Path
Pavement markings with directional arrows, the highly visible Utility Pole Marking, and the bike system map help make the connection between the Rillito River Path and the Treat Bicycle Boulevard.



Treat Avenue and Speedway
By providing an easy-reach bicycle button, a bicycle stacking box, a right-turn-only lane for cars, a more visible crosswalk and ample bicycle parking, the design improves both pedestrian and bicycle safety and connectivity.

The bicycle parking corral provides ample bicycle parking and easy access to the popular commercial area along Speedway. Taking advantage of this heavily trafficked area to help increase the visibility of the bicycle boulevard, the bright green stacking box also clarifies where bicyclists may wait or a green light while cars turn right. Left turns and continuing traffic are eliminated to minimize conflicts between bikes and cars in the intersection. This busy intersection is also improved for pedestrians with a more visible pedestrian crosswalk. This helps clarify where pedestrians can go to continue on a sidewalk, as the sidewalk ends on the west side of the street at Baggins restaurant.





Treat Avenue and Florence at La Madera Park

By providing ample bicycle parking, shaded seating and a bicycle system map, this small hub allows bicyclists secure and convenient access to park amenities such as drinking fountains, and helps with way-finding and trip planning.

4th Avenue and University Boulevard Bicycle Corral

Ample bicycle parking allows bicyclists secure and convenient access to area stores, restaurants and other destinations, and serves the area during special event such as the 4th Avenue Street Fair. A bicycle corral the size of one parking space provides parking for 21 bicycles. A bicycle system map helps with way-finding and trip planning.

Conclusion

The work presented in this document attempts to understand the complex conglomeration of reasons why bicycling and walking compose such a small part of transportation mode share in the United States, and to investigate a method for improving this mode share. The method employed here does so by identifying and then specifically targeting barriers to biking and walking in a realistic, cost-effective way through the placement and development of bicycle boulevards that also include pedestrian amenities.

The main gains of this work focus on specific implications for building a bicycle boulevard network in Tucson, but the designs, guidelines, and methods developed for this application can also be modified to apply beyond this limited context.

Design

The route designs described in the Design chapter help in envisioning and guiding the implementation of the two first bicycle boulevard routes in Tucson. Although generally site-specific treatments, many of the elements of these conceptual designs can also be used as examples of 'typical' design treatments for other bicycle boulevards. They can also be used as illustratives for other cities where interest may be growing in implementing a bicycle boulevard network.

Design Toolbox

The Toolbox is intended to guide the eventual development of a consistent, high-quality, regionally appropriate bicycle boulevard network for Tucson. Guidelines are generally descriptive instead of prescriptive to allow for future route design flexibility in response to local conditions and community input, while still maintaining standards and continuity for the network as a whole. This flexibility also allows the Toolbox guidelines to integrate well with a potential variety of planning and design needs in other cities developing a bicycle boulevard network.

GIS Model

The GIS Model presented in the Analysis and Assessment chapter of this document produced two summary analysis maps: Bicycle Boulevard Suitability and Barrier Identification. The Suitability Map can help guide the placement of new bicycle boulevards, or evaluate the potential impact of a proposed route. It can also be helpful in determining prioritization levels and target areas for implementation. The Barrier Map can help determine the level and types of treatment that might be required to achieve a successful bicycle boulevard along a given stretch, thereby giving an indication of the cost of development.

Both summary components of the model are portable, scalable, flexible and adaptable to other cities and conditions, assuming the existence of quality GIS data. Changes in individual input weights of the model can, for example, be made to emphasize potential target goals such as providing bicycle boulevards in areas with particularly high concentrations of children under the age of 18, or focusing improvements on areas with the highest density of bicycle accidents. The analysis should be updated with the 2010 Census when this becomes available.

Impacts

As automobile dependency tends to create destructive patterns of land use, high personal transportation costs, sedentary lifestyles, congestion, pollution and fossil fuel dependence, an increase in bicycle ridership in Tucson could have significant positive impacts on human health, the environment, and social equity. One indicator of the potential benefits of targeted improvements to the bicycling network in Tucson is the

local carbon footprint. Carbon emissions are not only linked with the destructive forces of climate change, but may become a commodity in the near future under a proposed cap-and-trade system. Finding ways to reduce the carbon load of the City of Tucson may therefore become not only good for the environment, but good for the City budget.

Professor Julia Cole and colleagues at the University of Arizona (U of A) used data collected by the U of A Parking Service during 2007 and 2008, along with the Campus Carbon Calculator developed by the non-profit organization Clean Air Cool Planet to determine that U of A employees produce an average of .73 tons of carbon per person per academic year commuting to work. Extrapolating this to a full calender year produces an average of .97 tons. These numbers include all forms of transportation: walking, bicycling, driving and taking public transport, and are therefore low estimates of the actual emissions produced by any one driver. Nonetheless, applying this ratio to the context of the city as a whole can be used to create a conservative estimate of the carbon loads of commuters in general.

The 2000 Census counts 155,837 Tucson workers as commuting to work alone by car. These drivers thus produce at least 151,162 tons of carbon emissions per year. If a bicycle boulevard network could help capture a percentage of these drivers equivalent to levels of work-related bicycle ridership in Berkeley (6%), this increase in Tucson ridership would amount to a reduction of approximately 9,350 cars on the road, or almost 9,070 tons of carbon per year. That is equivalent to planting approximately 3,488 acres of trees (Nowak 1993).

Extensions

Although the popularity and success of bicycle boulevards have been lauded based on overall bicycling numbers, user feedback, and smaller studies, few academic studies or pre- and post-construction evaluations have specifically targeted the impacts of bicycle boulevards. More scientific study of the effects of bicycle boulevards on ridership, perceptions of safety, security and comfort, accident and crime rates, and traffic volumes and speeds would be a valuable addition the understanding of the field.

The fact that the bicycle boulevards proposed here would be pilot projects in the City of Tucson allows for an excellent opportunity for evaluation. Pre- and post-construction evaluation of bicycle boulevards should include survey work, measurements of traffic speeds and volumes, bicycle counts, and the collection of accident and crime statistics.

Survey questions should focus on users, non-users and neighbors and include demographic characteristics, user evaluation of specific features and zones along the route, perceived effects of the bicycle boulevard on the neighborhood and on traffic conditions, and perceptions of route safety, comfort, connectivity and continuity.

There has been little direct study of the effects of bicycle boulevards on traffic conditions along nearby streets, collectors and arterials, and for many community members knowing these effects is critical to determining their support of bicycle boulevards in their neighborhoods. Pre- and post-construction measurements of vehicular traffic speeds and volumes should therefore be made on both bicycle boulevards and on nearby streets.

In order to more accurately measure the effects of bicycle facility changes, the method by which the Tucson Bicycle Count is conducted should also be improved to capture more locations along both bicycle routes and non-route control streets, as well as to distinguish between routes. Current counting methods focus exclusively on bicycle routes, and place counters at intersections to lump riders on both north-south and east-west routes together and confound the data. These improvements are needed to accurately evaluate bicycle ridership numbers, patterns and safety in general, as well as on the different routes and route types.

The potential impacts of a bicycle boulevard network are significant on many levels, from individual biker safety to the environment. The work presented here seeks to fulfill this exciting potential through a comprehensive package of evaluation, standards, and application that addresses each of these levels, and create a functional, realistic and effective final product.

Appendix

City of Tucson Bicycle Count
November, 2008

LOCATION		VOLUME			
Regional Location	Location	AM Total	PM Total	Total	Volume Rank
UA	3rd & Campbell	559	670	1229	1
UA	Park & University	475	583	1058	2
UA	Mountain & Helen	400	425	825	3
UA	6th St & Highland Ave	197	304	501	4
UofA Total		**1631**	**1982**	**3613**	
Downtown	Stone & University	177	162	339	6
Downtown	Snake Bridge (Bdwy/Aviation)	134	135	269	8
Downtown	St.Mary & Santa Cruz River	90	108	198	11
Downtown	7th St & 7th Ave	68	106	174	12
Downtown	Congress & Granada	32	46	78	27
Downtown	18th ST./6TH Ave.	28	32	60	32
Downtown	9th Ave./6th St.	25	33	58	33
Downtown Total		**554**	**622**	**1176**	
Urban Core	Mountain/Blacklidge	195	177	372	5
Urban Core	Mountain & River Park	162	177	339	7
Urban Core	Oracle & Rillito Pathway	110	138	248	9
Urban Core	Tucson/Elm	129	94	223	10
Urban Core	Glenn/Treat	84	78	162	13
Urban Core	Speedway/Treat	74	73	147	14
Urban Core	Pima/Columbus	63	75	138	15
Urban Core	ALV/B'WAY	48	68	116	16
Urban Core	Campbell/Grant	29	78	107	17
Urban Core	3rd & Swan	44	50	94	20
Urban Core	Price & Fairview	45	46	91	22
Urban Core	St.Mary's/Anklam	42	48	90	23
Urban Core	Kolb & 22nd	37	50	87	24
Urban Core	Broadway/Wilmont	39	48	87	25
Urban Core	Alvernon/ Ft. Lowell	32	39	71	28
Urban Core	Sabino Canyon & River	47	17	64	29
Urban Core	Tanque Verde/Kolb	31	32	63	30
Urban Core	Mission /Ajo	45	16	61	31
Urban Core	Craycroft & Golf Links	22	34	56	34
Urban Core	Broadway & Houghton	20	27	47	35
Urban Core	Tucson /Arroyo Chico	19	27	46	36
Urban Core	Catalina Hwy & Tanque Verde	32	14	46	37
Urban Core	4th Ave and Lester	16	28	44	38
Urban Core	Old Spanish / Kenyon	27	12	39	39
Urban Core	River & Campbell	18	21	39	40
Urban Core	Silverbell & Ironwood Hill	24	14	38	41
Urban Core	Escalante&Pantano	18	16	34	42
Urban Core	10th Ave & 43rd	14	19	33	43
Urban Core	Kolb/Valenica	16	10	26	46
Urban Core	Nogales / Valencia	9	8	17	49
Urban Core Total		**1491**	**1534**	**3025**	

	AM Total	PM Total	Total	
Regional Total	3979	4337	8316	

GENDER		AGE			OTHER ATTRIBUTES			PERCENTAGES									
Female	Male	<18	18-65	>65	Wearing Helmet	Wrong-Way Riding	Sidewalk Riding	AM %	PM %	Female %	Male %	<18 %	18-65 %	>65 %	Helmet %	Wrong-Way %	Sidewalk %
358	871	89	1088	52	389	14	27	45.5%	54.5%	29.1%	70.9%	7.2%	88.5%	4.2%	31.7%	1.1%	2.2%
345	713	5	1024	29	242	10	19	44.9%	55.1%	32.6%	67.4%	0.5%	96.8%	2.7%	22.9%	0.9%	1.8%
260	565	2	804	19	282	33	25	48.5%	51.5%	31.5%	68.5%	0.2%	97.5%	2.3%	34.2%	4.0%	3.0%
171	330	9	483	9	112	55	136	39.3%	60.7%	34.1%	65.9%	1.8%	96.4%	1.8%	22.4%	11.0%	27.1%
1134	**2479**	**105**	**3399**	**109**	**1025**	**112**	**207**	**45.1%**	**54.9%**	**31.4%**	**68.6%**	**2.9%**	**94.1%**	**3.0%**	**28.4%**	**3.1%**	**5.7%**
109	230	5	331	3	161	7	12	52.2%	47.8%	32.2%	67.8%	1.5%	97.6%	0.9%	47.5%	2.1%	3.5%
57	212	4	263	2	148	18	32	49.8%	50.2%	21.2%	78.8%	1.5%	97.8%	0.7%	55.0%	6.7%	11.9%
49	149	19	173	6	125	11	28	45.5%	54.5%	24.7%	75.3%	9.6%	87.4%	3.0%	63.1%	5.6%	14.1%
45	129	0	169	5	79	12	3	39.1%	60.9%	25.9%	74.1%	0.0%	97.1%	2.9%	45.4%	6.9%	1.7%
13	65	0	76	2	26	4	22	41.0%	59.0%	16.7%	83.3%	0.0%	97.4%	2.6%	33.3%	5.1%	28.2%
11	49	3	57	0	15	5	13	46.7%	53.3%	18.3%	81.7%	5.0%	95.0%	0.0%	25.0%	8.3%	21.7%
11	47	3	41	14	24	5	0	43.1%	56.9%	19.0%	81.0%	5.2%	70.7%	24.1%	41.4%	8.6%	0.0%
295	**881**	**34**	**1110**	**32**	**578**	**62**	**110**	**47.1%**	**52.9%**	**25.1%**	**74.9%**	**2.9%**	**94.4%**	**2.7%**	**49.1%**	**5.3%**	**9.4%**
115	257	22	350	0	224	7	7	52.4%	47.6%	30.9%	69.1%	5.9%	94.1%	0.0%	60.2%	1.9%	1.9%
82	257	3	333	3	260	0	0	47.8%	52.2%	24.2%	75.8%	0.9%	98.2%	0.9%	76.7%	0.0%	0.0%
58	190	0	236	12	174	7	18	44.4%	55.6%	23.4%	76.6%	0.0%	95.2%	4.8%	70.2%	2.8%	7.3%
74	149	2	219	2	133	4	9	57.8%	42.2%	33.2%	66.8%	0.9%	98.2%	0.9%	59.6%	1.8%	4.0%
42	120	10	149	3	102	1	0	51.9%	48.1%	25.9%	74.1%	6.2%	92.0%	1.9%	63.0%	0.6%	0.0%
46	101	21	119	7	81	6	17	50.3%	49.7%	31.3%	68.7%	14.3%	81.0%	4.8%	55.1%	4.1%	11.6%
23	115	0	138	0	74	10	4	45.7%	54.3%	16.7%	83.3%	0.0%	100.0%	0.0%	53.6%	7.2%	2.9%
21	95	0	116	0	57	16	28	41.4%	58.6%	18.1%	81.9%	0.0%	100.0%	0.0%	49.1%	13.8%	24.1%
31	76	2	103	2	41	22	42	27.1%	72.9%	29.0%	71.0%	1.9%	96.3%	1.9%	38.3%	20.6%	39.3%
20	74	7	86	1	52	5	11	46.8%	53.2%	21.3%	78.7%	7.4%	91.5%	1.1%	55.3%	5.3%	11.7%
5	86	8	80	3	13	13	26	49.5%	50.5%	5.5%	94.5%	8.8%	87.9%	3.3%	14.3%	14.3%	28.6%
19	71	6	84	0	73	1	2	46.7%	53.3%	21.1%	78.9%	6.7%	93.3%	0.0%	81.1%	1.1%	2.2%
7	80	48	38	1	28	29	57	42.5%	57.5%	8.0%	92.0%	55.2%	43.7%	1.1%	32.2%	33.3%	65.5%
6	81	8	79	0	51	16	26	44.8%	55.2%	6.9%	93.1%	9.2%	90.8%	0.0%	58.6%	18.4%	29.9%
13	58	5	65	1	28	18	20	45.1%	54.9%	18.3%	81.7%	7.0%	91.5%	1.4%	39.4%	25.4%	28.2%
13	51	3	58	3	54	2	1	73.4%	26.6%	20.3%	79.7%	4.7%	90.6%	4.7%	84.4%	3.1%	1.6%
6	57	2	59	2	46	6	15	49.2%	50.8%	9.5%	90.5%	3.2%	93.7%	3.2%	73.0%	9.5%	23.8%
6	55	0	61	0	55	3	3	73.8%	26.2%	9.8%	90.2%	0.0%	100.0%	0.0%	90.2%	4.9%	4.9%
4	52	1	52	3	33	9	12	39.3%	60.7%	7.1%	92.9%	1.8%	92.9%	5.4%	58.9%	16.1%	21.4%
11	36	5	41	1	32	2	5	42.6%	57.4%	23.4%	76.6%	10.6%	87.2%	2.1%	68.1%	4.3%	10.6%
16	30	2	42	2	24	4	5	41.3%	58.7%	34.8%	65.2%	4.3%	91.3%	4.3%	52.2%	8.7%	10.9%
6	40	0	46	0	46	0	0	69.6%	30.4%	13.0%	87.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%
16	28	3	41	0	11	1	0	36.4%	63.6%	36.4%	63.6%	6.8%	93.2%	0.0%	25.0%	2.3%	0.0%
9	30	8	30	1	30	3	5	69.2%	30.8%	23.1%	76.9%	20.5%	76.9%	2.6%	76.9%	7.7%	12.8%
9	30	0	39	0	32	0	5	46.2%	53.8%	23.1%	76.9%	0.0%	100.0%	0.0%	82.1%	0.0%	12.8%
2	36	5	33	0	23	3	1	63.2%	36.8%	5.3%	94.7%	13.2%	86.8%	0.0%	60.5%	7.9%	2.6%
3	31	19	14	1	9	12	19	52.9%	47.1%	8.8%	91.2%	55.9%	41.2%	2.9%	26.5%	35.3%	55.9%
7	26	4	29	0	10	6	9	42.4%	57.6%	21.2%	78.8%	12.1%	87.9%	0.0%	30.3%	18.2%	27.3%
1	25	0	25	1	22	1	3	61.5%	38.5%	3.8%	96.2%	0.0%	96.2%	3.8%	84.6%	3.8%	11.5%
0	17	1	16	0	11	3	2	52.9%	47.1%	0.0%	100.0%	5.9%	94.1%	0.0%	64.7%	17.6%	11.8%
671	**2354**	**195**	**2781**	**49**	**1829**	**210**	**352**	**49.3%**	**50.7%**	**22.2%**	**77.8%**	**6.4%**	**91.9%**	**1.6%**	**60.5%**	**6.9%**	**11.6%**
Female	Male	<18	18-65	>65	Wearing Helmet	Wrong-Way Riding	Sidewalk Riding	AM %	PM %	Female %	Male %	<18 %	18-65 %	>65 %	Helmet %	Wrong-Way %	Sidewalk %
2177	**6139**	**357**	**7726**	**233**	**3813**	**415**	**728**	**47.8%**	**52.2%**	**26.2%**	**73.8%**	**4.3%**	**92.9%**	**2.8%**	**45.9%**	**5.0%**	**8.8%**

Tucson Precipitation, Temperatures and Solar Angles

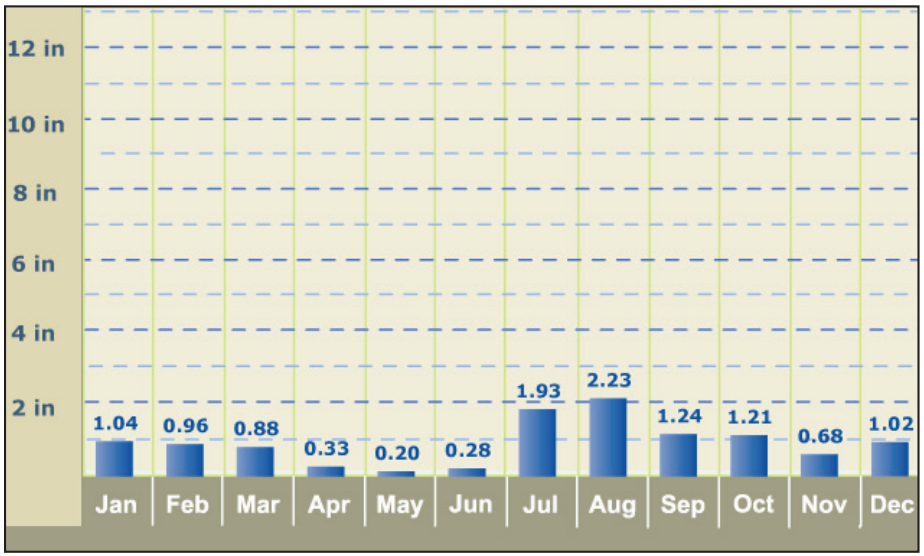
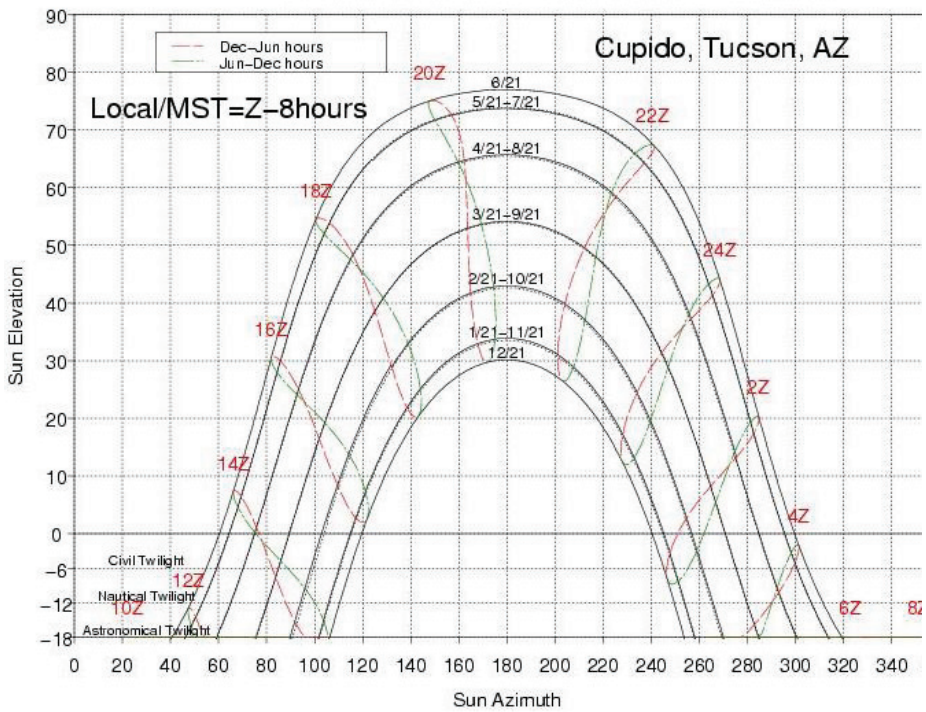


Image: www.weather.com



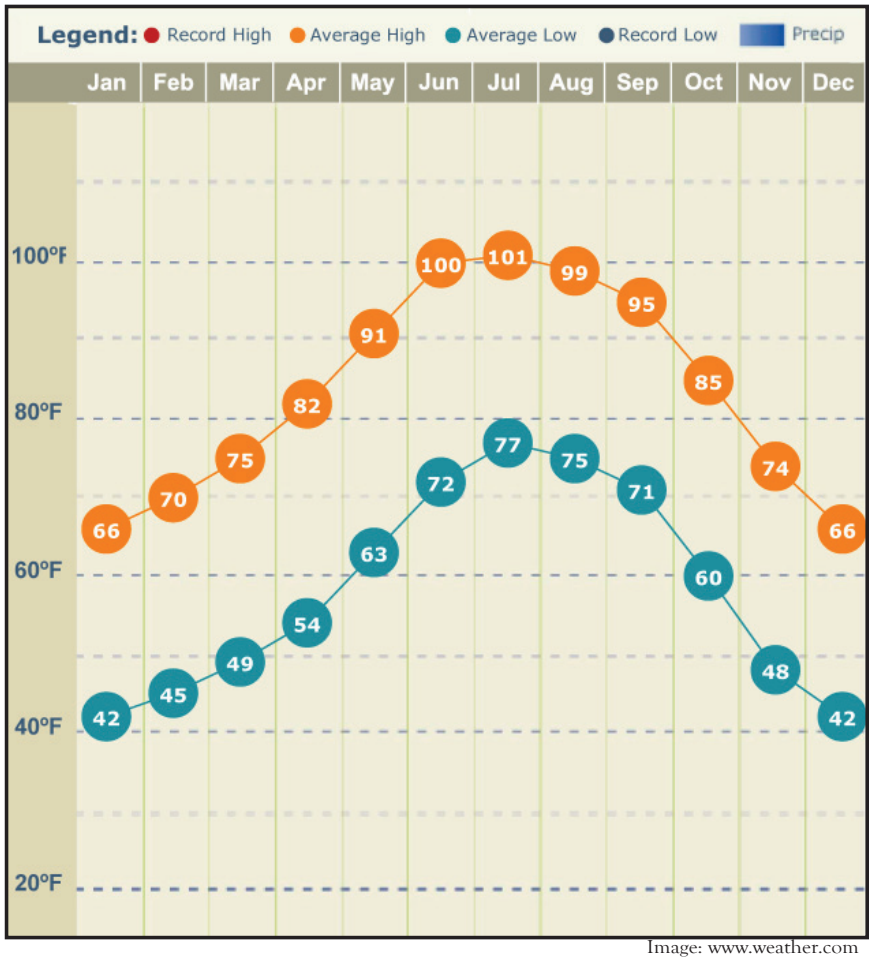


Image: www.weather.com

Tucson experiences five months of average temperatures above 90 degrees Fahrenheit.

Street Trees

Street trees will be subject to a great number of stresses, from limited soil allowances to polluted street runoff, exposure to the elements, the heat island effect, and vandalism.

When selecting street trees for an arid desert climate with significant temperature fluctuation, the following characteristics are most critical: Size, water use, shade cover, hardiness, and maintenance requirements.

Photo: http://upload.wikimedia.org/wikipedia/commons/3/31/Acacia_smallii_3.jpg

Acacia smallii ~ Sweet acacia
Native: Yes
Thorns: Yes
Size: 15-25 feet tall and wide
Hardy: To 15° F
Deciduous: Semi-evergreen, may retain leaves in warm winters
Bloom: 1/2in bright yellow puffballs, fragrant, profuse, February-March.
Water: Deep 1-2 times/month during growing season.
Note: Requires some pruning, produces litter.

Photo: http://ag.arizona.edu/pima/gardening/aridplants/images/Cercis_occidentalis_March.jpg

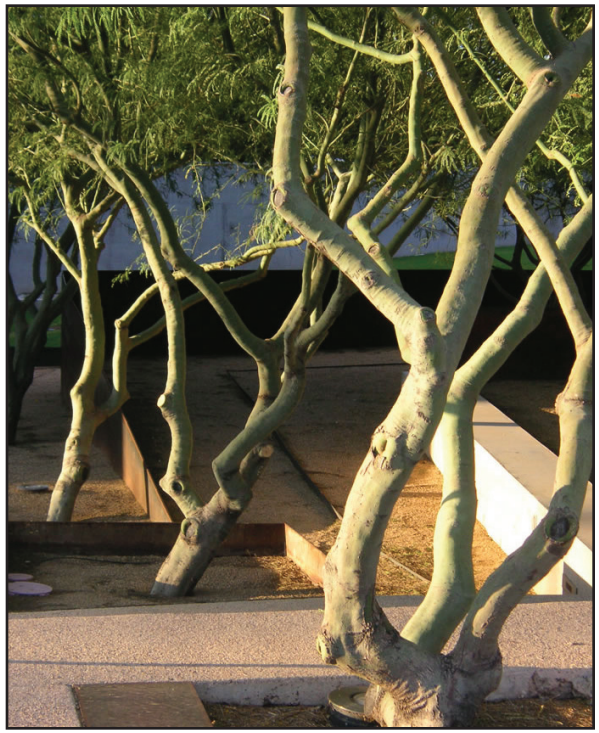
Cercis occidentalis ~ Western redbud
Native: No. Chihuahuan desert, found in washes
Thorns: No
Size: 15ft tall with equal spread
Hardy: to 10°F
Deciduous: In winter.
Bloom: Spring, vibrant pinkish-purple and pea-shaped. Fall leaf color.
Water: Drought resistant; soak root zone once/month when established
Note: Maintenance low. Is a shrub, but can be trained to single or multi-stemmed tree.

Photo: http://arboretum.arizona.edu/images/taxa_images/Chilopsis_linearis_Warren_Jones/chilopsis_linearis_warren_Jones_flrs2.jpg

Chilopsis linearis ~ Desert Willow
Native: Yes (along dry, sandy washes)
Thorns: No
Size: 25 feet tall and wide
Hardy: To at least 0° F
Deciduous: In winter, seed pods hang on.
Bloom: Late spring to early fall, clusters of fragrant orchid-like blossoms, white to pink.
Water: drought tolerant; any supplemental watering should be deep and infrequent
Note: Suckers at the base, requires some pruning and shaping for a walk-under canopy.

Photo: http://ag.arizona.edu/pima/gardening/aridplants/images/Fraxinus_velutina.jpg

Fraxinus velutina ~ Arizona ash
Native: Yes
Thorns: No
Size: 30-50 feet tall and 15-30 wide
Hardy: To at least 0° F
Deciduous: In winter.
Bloom: Not ornamental
Water: Deep 2-3 times/month during growing season.
Note: Maintenance low, prune to develop shape Moderately susceptible to Texas Root Rot, also prone to nematodes, chlorosis.



Pjoto: http://arboretum.arizona.edu/images/taxa_images/Parkinsonia_x_Desert_Museum/par%20x%20asdm%20trunk.jpg

Parkinsonia desert museum ~
Desert Museum Paloverde
Native: Yes (hybridized in 1987)
Thorns: No
Size: 25 feet tall and wide
Hardy: To 17° F
Bloom: Late spring to early fall, yellow. Longer bloom period and larger flowers than other Paloverdes
Water: Deep 1-2 times/month during growing season.
Note: Requires some pruning and shaping for a walk-under canopy.

Photo: http://benafiaflora.files.wordpress.com/2008/05/img_1143.jpg

Parkinsonia floridum ~ Blue paloverde
Native: Yes
Thorns: Yes
Size: 30 feet tall and wide
Hardy: To 15° F
Deciduous: In drought and cold.
Bloom: Late spring to early fall, masses of yellow. Blooms first of all the Palo Verdes.
Water: Deep 1-2 times/month during growing season.
Note: Requires some pruning and shaping for a walk-under canopy. No severe pruning in summer, exposed trunks can get sunburned.

Photo: http://www.delange.org/ChinesePistache/Dsc02523.jpg

Pistacia chinensis ~ Chinese pistache
Native: No
Thorns: No
Size: 30 feet tall and 20 wide, moderate growth rate
Hardy: To low teens
Deciduous: In winter.
Bloom: Not ornamental, great fall leaf color.
Water: Heat and drought tolerant; 1-2 deep irrigations per month in hottest season
Note: Maintenance low, seed drop on female trees can be messy.

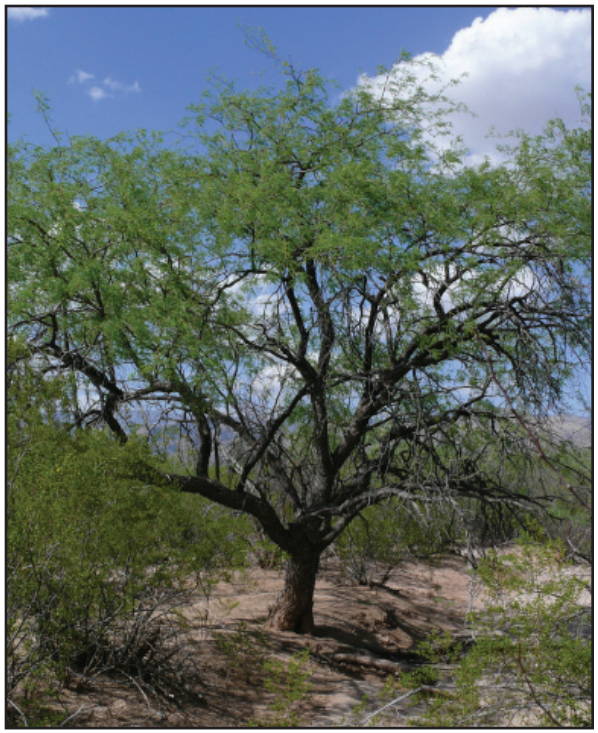


Photo: http://upload.wikimedia.org/wikipedia/commons/5/5c/Velvet_mesquite.jpg

Prosopis velutina ~ Velvet mesquite
Native: Yes
Thorns: Yes
Size: 30 feet tall and wide
Hardy: To at least 30° F
Deciduous: In winter.
Bloom: White or pale yellow 2-3in long, hangs downward; bloom in early summer
Water: Deep 1-2 times/month during growing season.
Note: Prune to shape when young.

Photo: http://allergy.peds.arizona.edu/southwest/trees_shrubs/images/oak4.h1.jpg

Quercus virginiana ~ Southern live oak
Native: No
Thorns: No
Size: 40-60ft with equal spread
Hardy: to 15°F
Deciduous: No
Bloom: Not noticable
Water: Supplemental water needed; deep watering once per month or every few weeks
Note: Maintenance low; pruning, removal of occasional basal suckers.

Photo: http://www.horticultureunlimited.com/images/plants

Chaparral Sage- *Salvia clevelandii*

Shrubs:

Autumn Sage- *Salvia greggii*
Brittlebush- *Encelia farinosa*
Chaparral Sage- *Salvia clevelandii*
Chuparosa- *Justicia californica*
Fairy Duster- *Calliandra eriophylla*
Green Feathery Cassia- *Cassia nemophila*
Mexican Honeysuckle- *Justicia spicigera*
Mount Lemmon Marigold- *Tagetes lemmonii*
Texas Sage- *Leucophyllum frutescens*

Photo: http://www.azbids.com/customers/plants/chuparosa.jpg

Justicia californica - Chuparosa

Photo: http://www.magnoliagardensnursery.com/productdescrip/pictures300/Chrysactinia_Damianita1300.jpg

Damianita Daisy- *Chrysactinia mexicana*

Groundcovers:

Damianita Daisy- *Chrysactinia mexicana*
Flattop Buckwheat- *Eriogonum fasciculatum*
Sandpaper Verbena- *Verbena rigida*
Trailing Acacia- *Acacia redolens*
Trailing Dalea- *Dalea greggii*
Trailing Lantana- *Lantana montevidensis*

Photo: http://www.plantcare.com/oldSite/httpdocs/images/namedImages/Encelia_farinosa.jpg

Encelia farinosa - Brittlebush

Photo: http://www.paradisegardentx.com/Salvia%20greggii.jpg

Autumn Sage- *Salvia greggii*

Cacti and Succulents:

Desert Spoon- *Dasylirion wheeleri*
Englemann's Prickly Pear- *Opuntia englemannii*
Fishhook Barrel Cactus- *Ferocactus wislizenii*
Golden Barrel Cactus- *Echinocactus grusonii*
Green Spoon- *Dasylirion acrotritche*
Ocotillo- *Fouqueria splendens*
Octopus Agave- Agave vilmoriniana
Parry's Agave- *Agave parryi*
Purple Prickly Pear- *Opuntia santa-rita*

Photo: http://www.azarboretum.org/plantlist/flattopbuckwheat.jpg

Eriogonum fasciculatum - Flattop Buckwheat

Photo: http://www.hickerphoto.com/data/media/185/colourful-wildflowers_12965.jpg

Wildflowers:

Apache Plume
Arizona Poppy
Blue Phacelia
Brown-Eyed Evening Primrose
Chia
Cliffrose
Cave Primrose
Desert Chicory
Desert Dandelion
Desert Five-Spot
Desert Globemallow
Desert Lily
Desert Lupine
Desert Mariposa Lily
Desert Marigold
Desert Paintbrush
Desert Pincushion
Desert Sunflower
Devil's Claw
Dune Evening Primrose
Ghost Flower
Popcorn Flower
Prickly Poppies
Showy Four O'Clock
Spanish Needles
Western Wallflower
Woolly Daisy
Yellow Beeplant

Native and desert adapted low-water use plants will require little to no irrigation once established, but when newly planted health, growth and ultimate success will depend on a period of supplemental irrigation, particularly during the hottest months of the year.

Watering intervals for newly planted desert-adapted plants in Tucson should be:

Summer

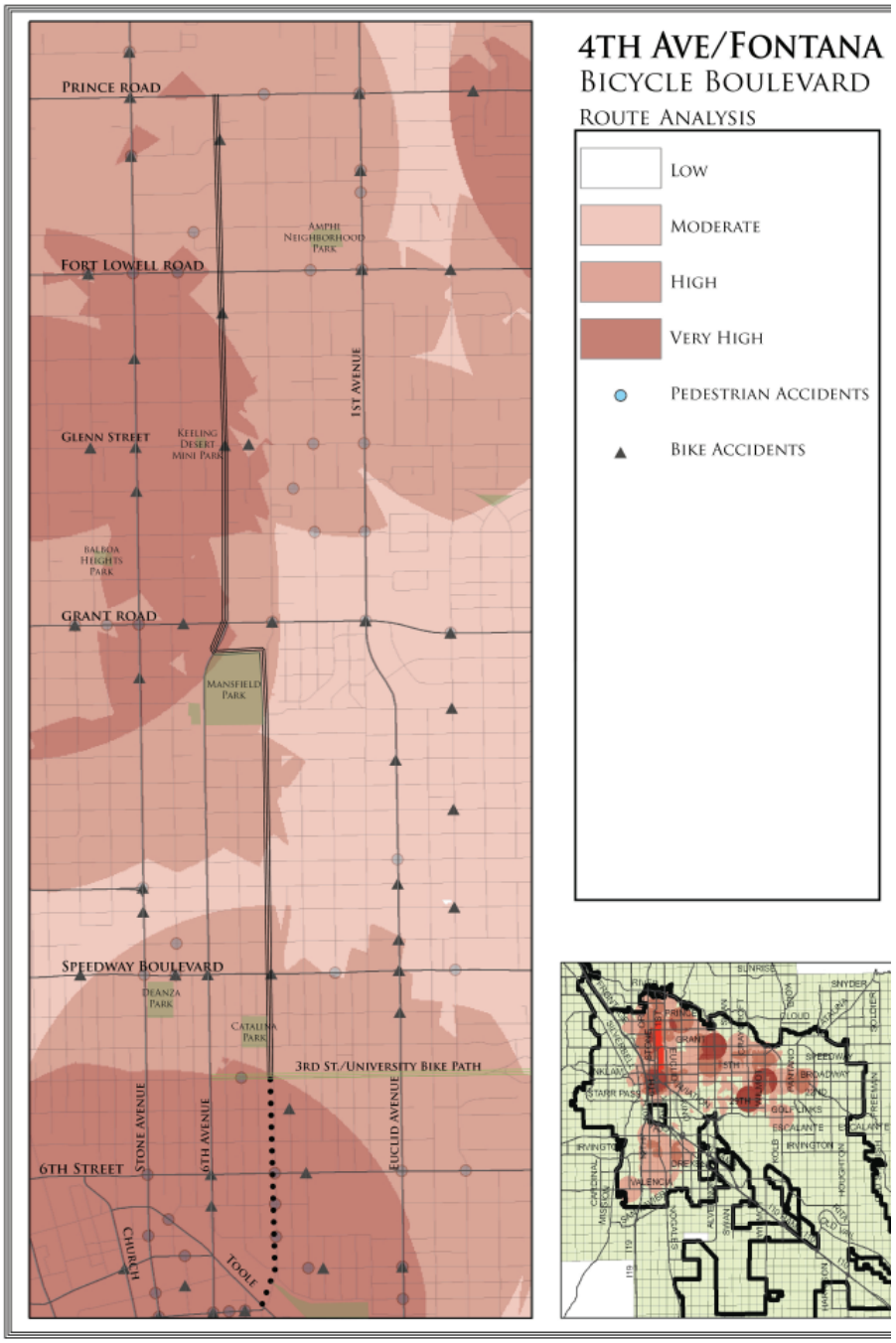
Weeks 1 & 2: 1-2 days
Weeks 3 & 4: 3-4 days
Weeks 5 & 6: 4-6 days
Weeks 7 & 8: 7 days

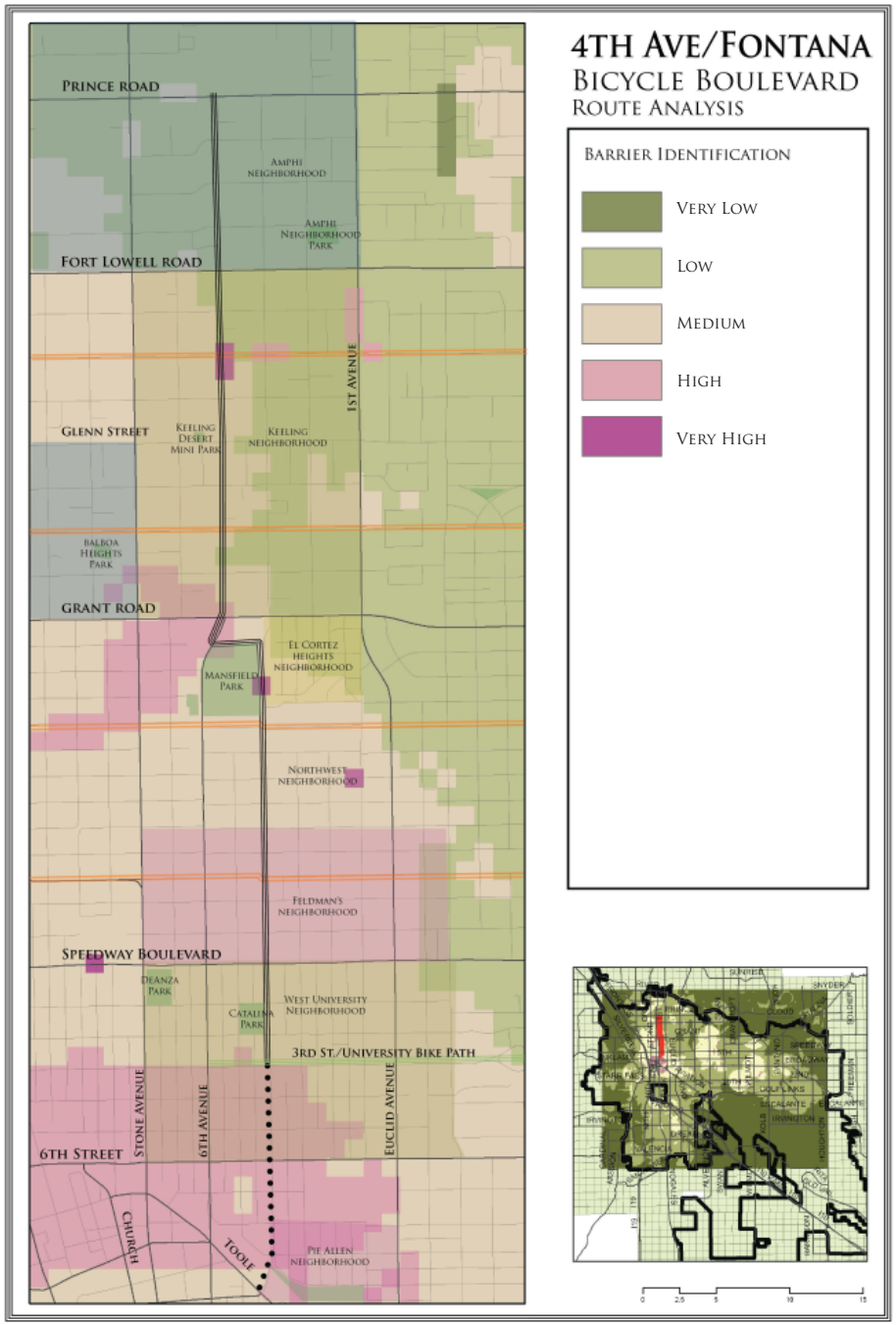
Fall through Spring

Weeks 1 & 2: 3-4 days
Weeks 3 & 4: 6-7 days
Weeks 5 & 6: 7-10 days
Weeks 7 & 8: 10-14 days

After week 8 time between irrigations should be gradually extended until plants are established.

It usually takes one year to establish small plants, two years for shrubs, and three years for trees.


4TH AVE/FONTANA
BICYCLE BOULEVARD
ROUTE ANALYSIS
LOW
MODERATE
HIGH
VERY HIGH
PEDESTRIAN ACCIDENTS
BIKE ACCIDENTS
PRINCE ROAD
FORT LOWELL ROAD
GLENN STREET
GRANT ROAD
SPEEDWAY BOULEVARD
6TH STREET
1ST AVENUE
STONE AVENUE
6TH AVENUE
EUCLID AVENUE
CHURCH
TOOLE
3RD ST./UNIVERSITY BIKE PATH
AMPHI NEIGHBORHOOD PARK
KEELING DESERT MINI PARK
BALBOA HEIGHTS PARK
MANSFIELD PARK
DEANZA PARK
CATALINA PARK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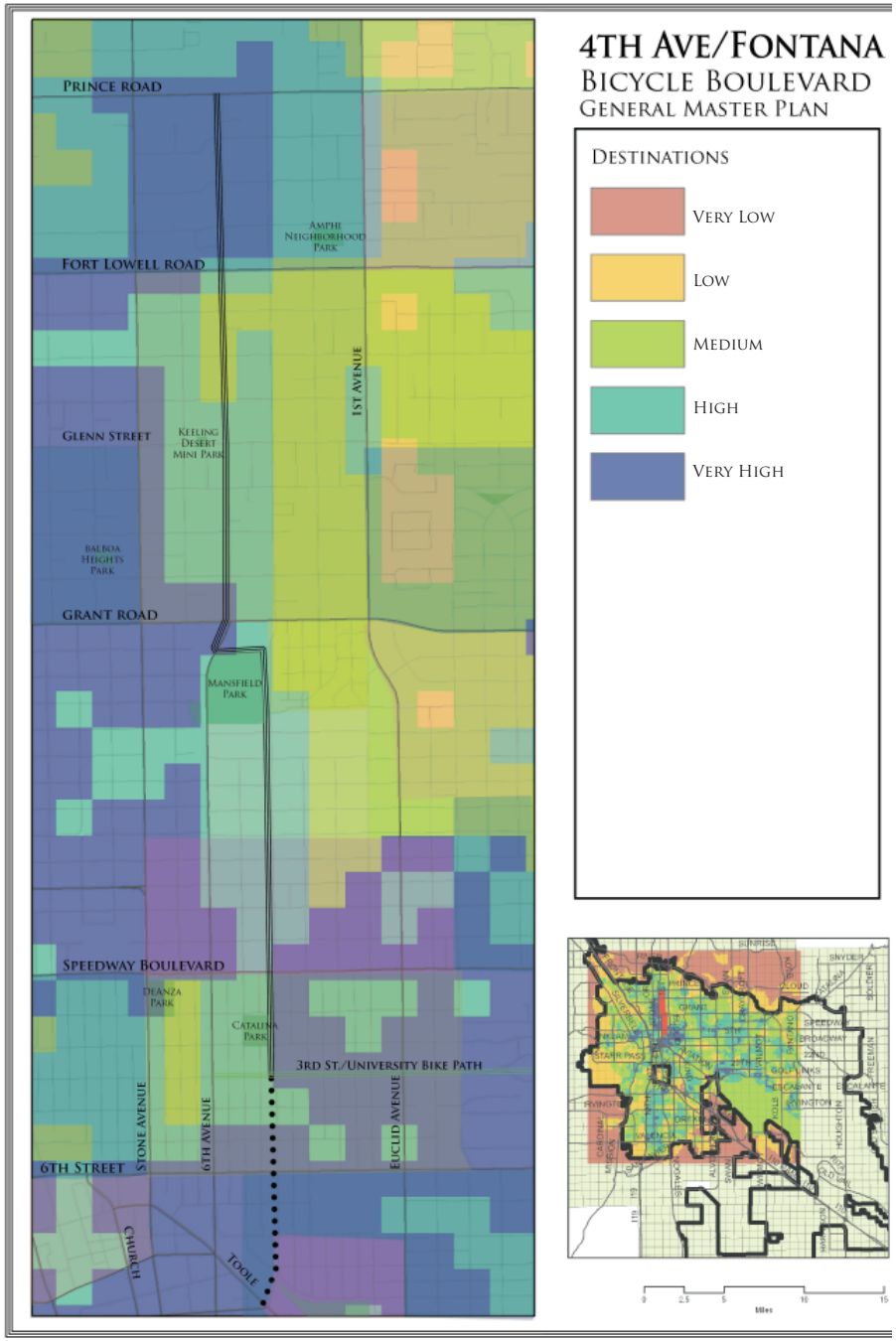
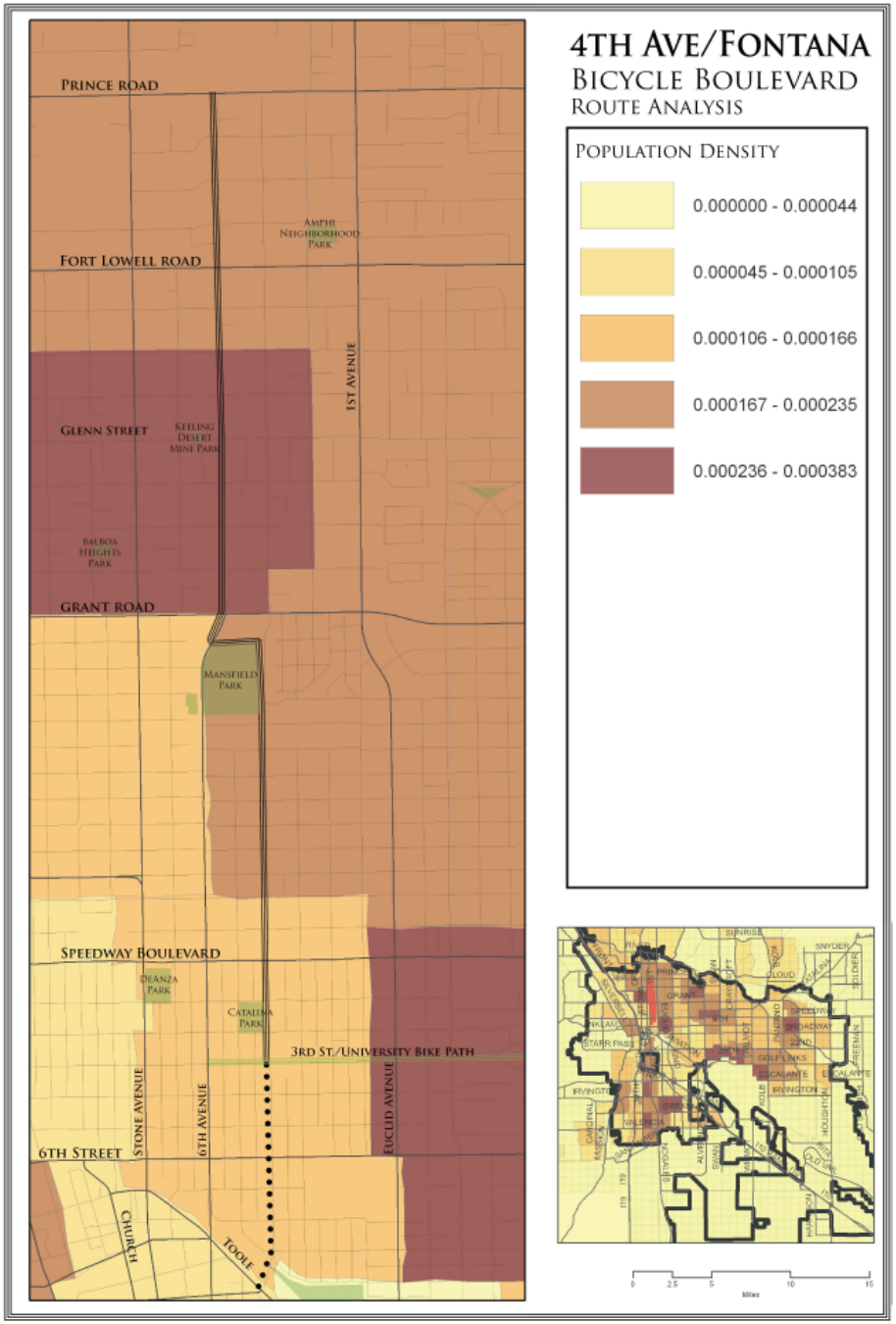
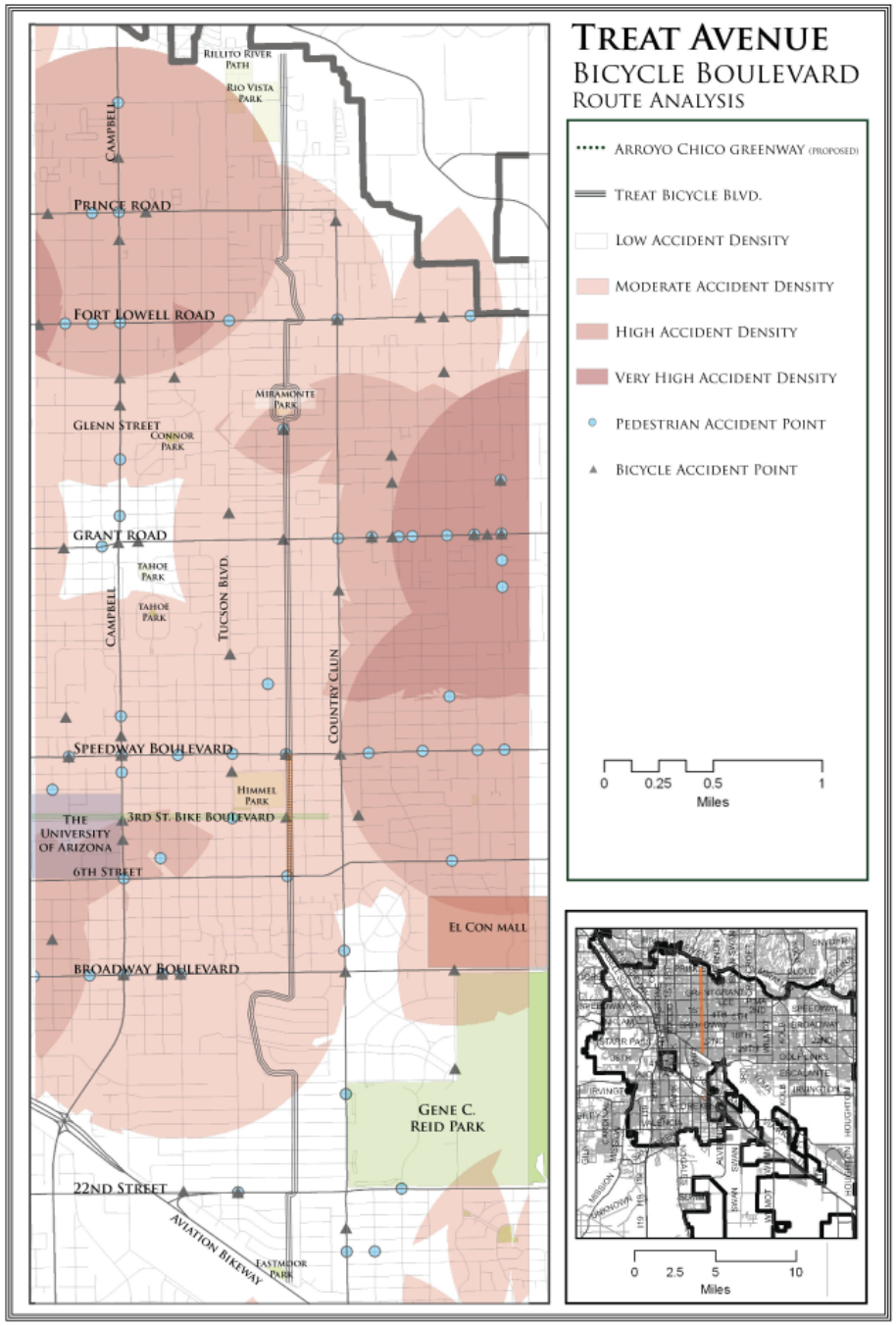
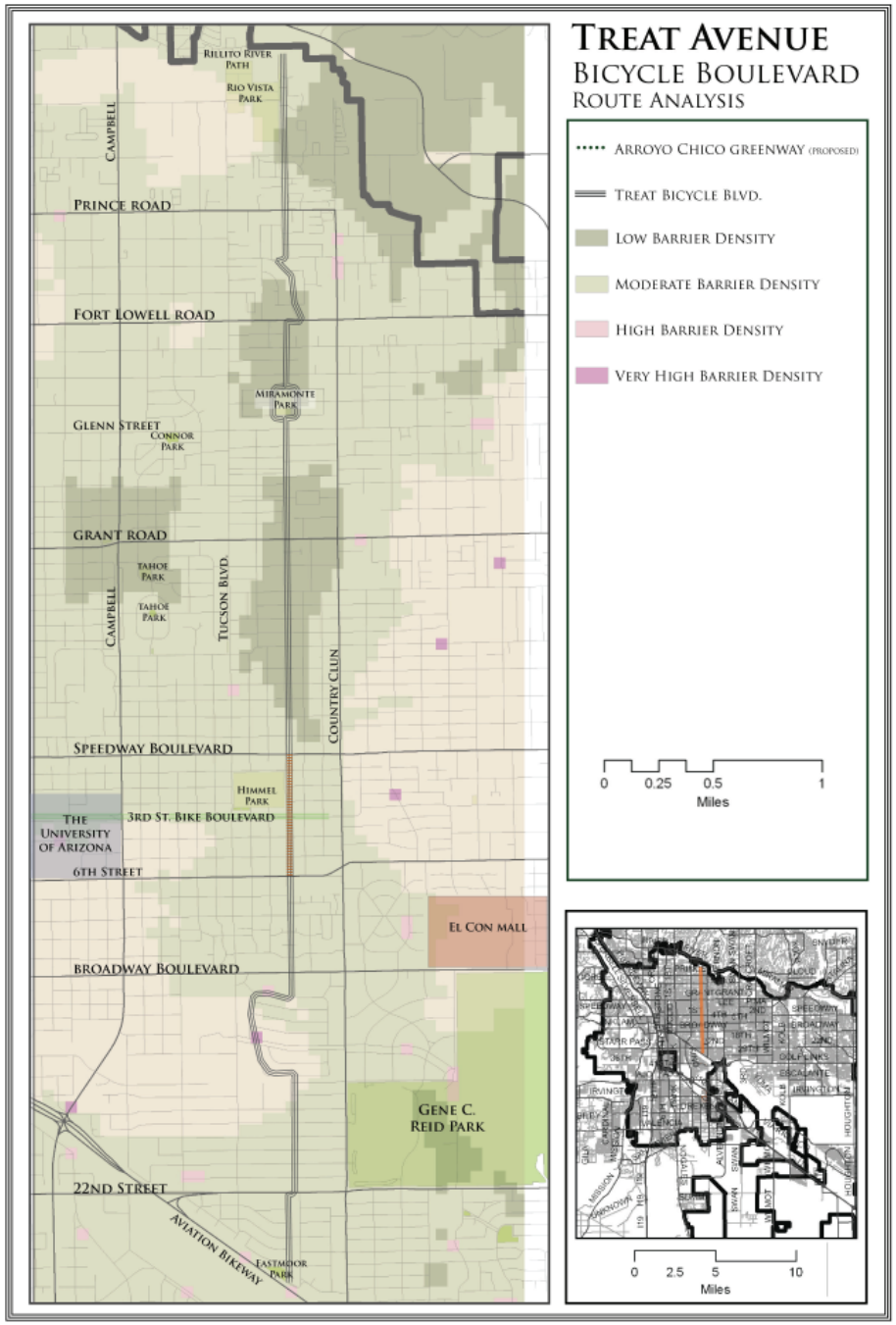
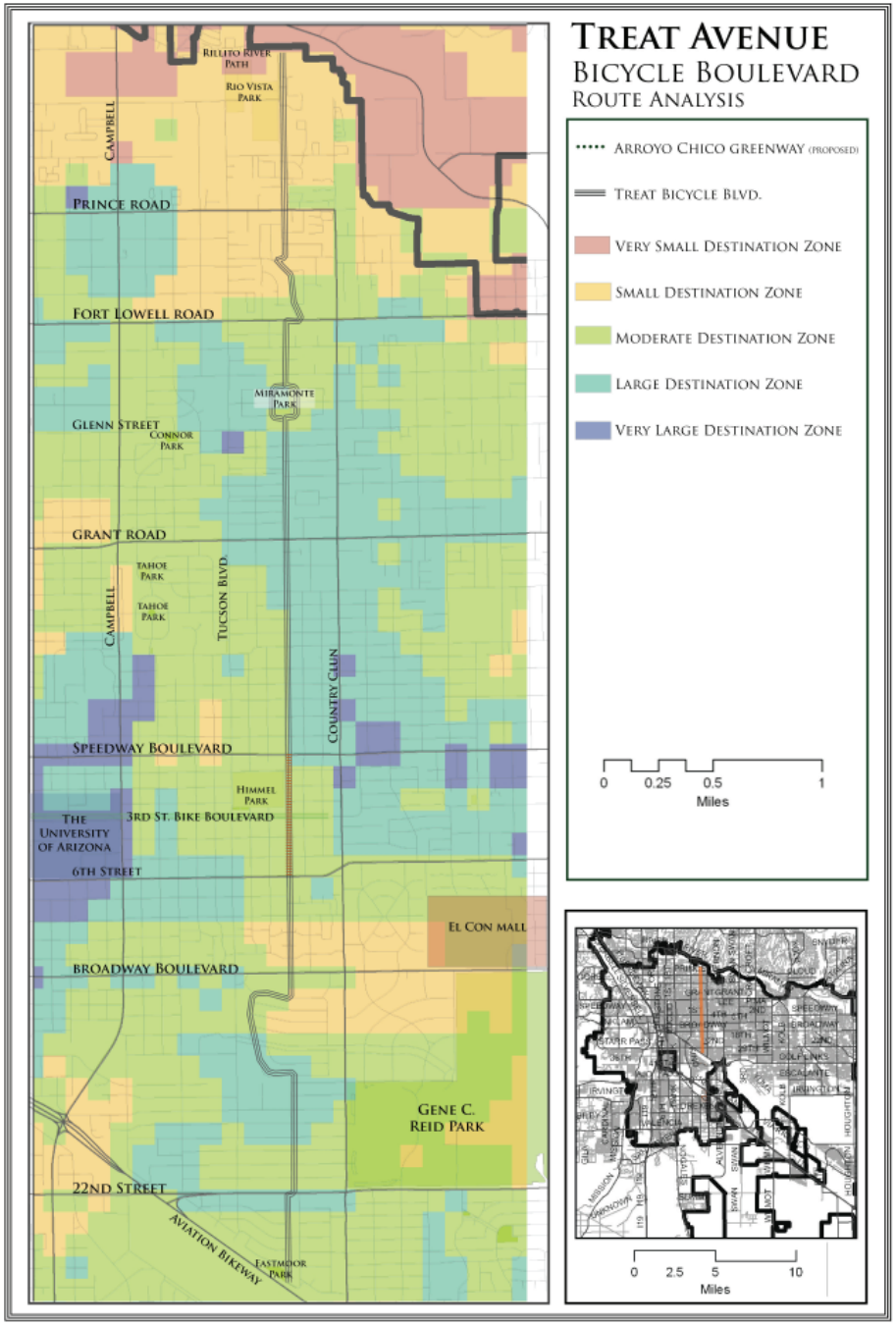
BICYCLE BOULEVARD
ROUTE ANALYSIS
BARRIER IDENTIFICATION
VERY LOW
LOW
MEDIUM
HIGH
VERY HIGH
PRINCE ROAD
FORT LOWELL ROAD
GLENN STREET
GRANT ROAD
SPEEDWAY BOULEVARD
6TH STREET
1ST AVENUE
STONE AVENUE
6TH AVENUE
EUCLID AVENUE
CHURCH
TOOLE
3RD ST./UNIVERSITY BIKE PATH
AMPHI NEIGHBORHOOD
AMPHI NEIGHBORHOOD PARK
KEELING DESERT MINI PARK
KEELING NEIGHBORHOOD
BALBOA HEIGHTS PARK
EL CORTEZ HEIGHTS NEIGHBORHOOD
MANSFIELD PARK
NORTHWEST NEIGHBORHOOD
FELDMAN'S NEIGHBORHOOD
DEANZA PARK
WEST UNIVERSITY NEIGHBORHOOD
CATALINA PARK
PIE ALLEN NEIGHBORHOOD


4TH AVE/FONTANA
BICYCLE BOULEVARD
GENERAL MASTER PLAN
DESTINATIONS
VERY LOW
LOW
MEDIUM
HIGH
VERY HIGH
PRINCE ROAD
FORT LOWELL ROAD
GLENN STREET
GRANT ROAD
SPEEDWAY BOULEVARD
6TH STREET
1ST AVENUE
STONE AVENUE
6TH AVENUE
EUCLID AVENUE
CHURCH
TOOLE
3RD ST./UNIVERSITY BIKE PATH
AMPHI NEIGHBORHOOD PARK
KEELING DESERT MINI PARK
BALBOA HEIGHTS PARK
MANSFIELD PARK
DEANZA PARK
CATALINA PARK


4TH AVE/FONTANA
BICYCLE BOULEVARD
ROUTE ANALYSIS
POPULATION DENSITY
0.000000 - 0.000044
0.000045 - 0.000105
0.000106 - 0.000166
0.000167 - 0.000235
0.000236 - 0.000383
PRINCE ROAD
FORT LOWELL ROAD
GLENN STREET
GRANT ROAD
SPEEDWAY BOULEVARD
6TH STREET
1ST AVENUE
STONE AVENUE
6TH AVENUE
EUCLID AVENUE
CHURCH
TOOLE
3RD ST./UNIVERSITY BIKE PATH
AMPHI NEIGHBORHOOD PARK
KEELING DESERT MINI PARK
BALBOA HEIGHTS PARK
MANSFIELD PARK
DEANZA PARK
CATALINA PARK


Treat Avenue
Bicycle Boulevard
Route Analysis
Arroyo Chico Greenway (proposed)
Treat Bicycle Blvd.
Low Accident Density
Moderate Accident Density
High Accident Density
Very High Accident Density
Pedestrian Accident Point
Bicycle Accident Point
0 0.25 0.5 1
Miles
0 2.5 5 10
Miles
Rillito River Path
Rio Vista Park
Campbell
Prince Road
Fort Lowell Road
Miramonte Park
Glenn Street
Connor Park
Grant Road
Tahoe Park
Tucson Blvd.
Country Club
Speedway Boulevard
Himmel Park
The University of Arizona
3rd St. Bike Boulevard
6th Street
El Con Mall
Broadway Boulevard
Gene C. Reid Park
22nd Street
Aviation Bikeway
Eastmoor Park


Treat Avenue
Bicycle Boulevard
Route Analysis
Arroyo Chico Greenway (proposed)
Treat Bicycle Blvd.
Low Barrier Density
Moderate Barrier Density
High Barrier Density
Very High Barrier Density
0 0.25 0.5 1
Miles
0 2.5 5 10
Miles
Rillito River Path
Rio Vista Park
Campbell
Prince Road
Fort Lowell Road
Miramonte Park
Glenn Street
Connor Park
Grant Road
Tahoe Park
Tucson Blvd.
Country Club
Speedway Boulevard
Himmel Park
The University of Arizona
3rd St. Bike Boulevard
6th Street
El Con Mall
Broadway Boulevard
Gene C. Reid Park
22nd Street
Aviation Bikeway
Eastmoor Park


Treat Avenue
Bicycle Boulevard
Route Analysis
Arroyo Chico Greenway (proposed)
Treat Bicycle Blvd.
Very Small Destination Zone
Small Destination Zone
Moderate Destination Zone
Large Destination Zone
Very Large Destination Zone
0 0.25 0.5 1
Miles
0 2.5 5 10
Miles
Rillito River Path
Rio Vista Park
Campbell
Prince Road
Fort Lowell Road
Miramonte Park
Glenn Street
Connor Park
Grant Road
Tahoe Park
Tucson Blvd.
Country Club
Speedway Boulevard
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6th Street
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Gene C. Reid Park
22nd Street
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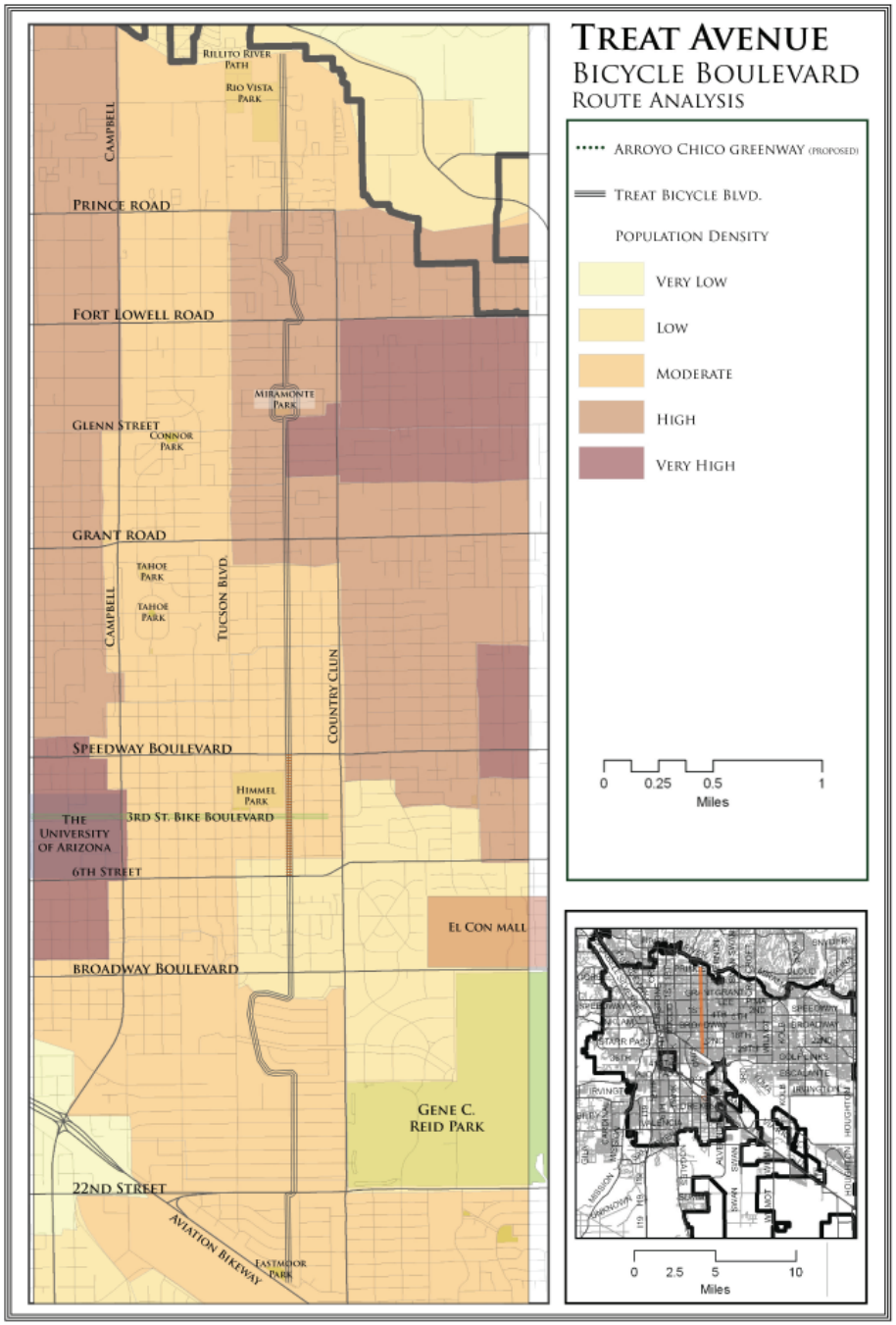
Eastmoor Park


Treat Avenue
Bicycle Boulevard
Route Analysis
Arroyo Chico Greenway (proposed)
Treat Bicycle Blvd.
Population Density
Very Low
Low
Moderate
High
Very High
0 0.25 0.5 1
Miles
0 2.5 5 10
Miles
Rillito River Path
Rio Vista Park
Campbell
Prince Road
Fort Lowell Road
Miramonte Park
Glenn Street
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Country Club
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Himmel Park
The University of Arizona
3rd St. Bike Boulevard
6th Street
El Con Mall
Broadway Boulevard
Gene C. Reid Park
22nd Street
Aviation Bikeway
Eastmoor Park

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Images

All graphics, maps, and photos by author unless otherwise noted.

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Spring 2009