RESPONDING TO THE CHALLENGES OF BICYCLE CROSSINGS AT OFFSET INTERSECTIONS

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ABSTRACT

As our roadway system becomes increasingly multi-modal, one alternative is a bicycle boulevard. A bicycle boulevard is typically a residential roadway which is designed to encourage bicycle riding by installing treatments such as traffic circles and speed humps to slow down motor vehicles, changing the directions of stop signs to favor bicycle traffic, and installing specialized bicycle crossings at crossings of major roadways. In some jurisdictions, residential streets are designed to not be continuous across major roadways to discourage through traffic. In other words, the streets are offset resulting in two closely spaced tee intersections.

Since bicyclists are expected to behave as vehicles, these intersections are particularly challenging. Tucson, Seattle, and Portland have tried various treatments to address this issue. This presentation will summarize what various jurisdictions have done regarding this issue. In addition, the author will propose other alternatives to address this issue.

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By Michael Hendrix, P.E.

INTRODUCTION

When creating a bicycle route or bicycle boulevards on residential streets, engineers and planners are often faced with offset intersections. Unlike collectors and arterial roadways, residential streets are often offset at major roadways to minimize the amount of cut-through traffic. Although this is a common occurrence, there is little guidance on designing intersection improvements to accommodate bicyclists wishing to continue on these residential streets.

Three existing facilities were evaluated to determine how effective the designs accommodated bicyclists traveling through the offset intersections. In addition to these treatments, this paper will also propose three additional alternatives for future implementation and evaluation.

LITERATURE REVIEW

There is little information regarding offset intersections and bicycle/pedestrian concerns in the engineering literature. Bicycle and pedestrian planning and design manuals from Arizona, Florida, Minnesota, New Jersey, Oregon, Texas, and Wisconsin were reviewed. Additionally, guidance was sought from manuals from Canada and the Netherlands. None of these manuals referenced possible solutions to this problem.

Three documents, *The Bicycle Planning Book* (*1*), *Bicycle Facilities Design Guidelines* (*2*), and the Florida Department of Transportation's *Trail Intersection Design Handbook* (*3*) did reference potential solutions for offset intersections. Both *(2)* and *(3)* describe a median modified to allow bicycles to travel between offset intersections. Figure 1, from the (*3*), depicts this configuration. (*2*) portrays two alternatives for bicyclists crossing an offset intersection, including an exclusive bicycle left turn lane described in greater detail below and a median pathway similar to the treatment described in both *(1)* and *(3)*.

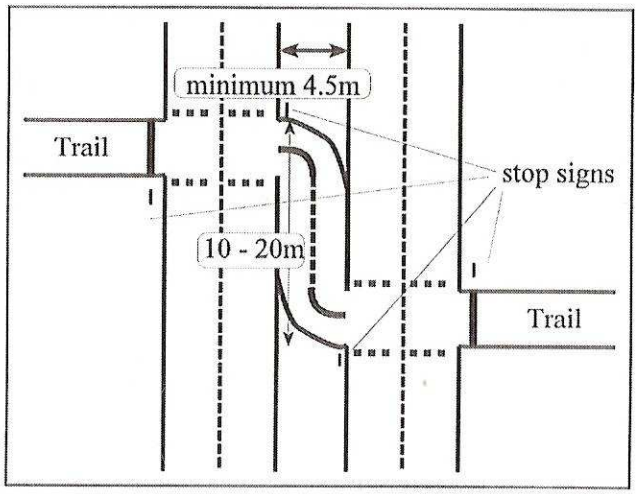

FIGURE 1 Median Refuge Area (*3, pg*)

The Florida manual also includes information regarding offset intersections with respect to trail crossings. The manual specifies a maximum of a 75-degree angle for a median cut-through. To determine whether an angled crossing may be acceptable, the author derived the following equation based on a maximum 75-degree angle. It is assumed that bicyclists will be traveling in the center of the travel way and that the side streets intersect the main roadway at right angles.

$$\text{Maximum Offset} = 0.268*W_{ML}+0.25*W_1-0.25*W_2$$

Where: W_{ML} = Width of the street being crossed
W_1, W_2 = Width of respective side street approaches

Depending on the distance between the offset intersections and the roadway width, this may be acceptable for some locations.

EXISTING TREATMENTS

Three treatments were observed to determine the overall effectiveness of and safety of each design. . These treatments included a side path installation between two intersections, a striped left turn lane in the middle of the major street, and a bicycle left turn pocket in a raised median. A description of the treatment and location is described for each site below.

Description of Existing Treatments

Alvernon Way at 3rd Street, Tucson, AZ. 3rd Street is an east-west residential roadway classified as a bicycle route with a 25 mph posted speed limit. Alvernon Way is a north-south 4-lane divided roadway with a 35 mph posted speed limit. This section of Alvernon Way has an ADT of 33,800 vehicles per day. At this location 3rd Street is offset by 340 feet. A traffic signal in conjunction with a bicycle path on the west side of Alvernon Way was completed in February 2005. Bicyclists traveling eastbound are expected to turn right on to the bike path towards the signalized intersection at the south leg of 3rd Street. Westbound bicyclists first cross at the signal and then turn right and travel along the bicycle path meeting the north leg of 3rd Street. See Figure 2.

FIGURE 2 Alvernon Way at 3rd St, Tucson, AZ.

SE Stark Street at SE 41st Avenue, Portland, OR. SE 41st Street is a north-south residential roadway classified as a bicycle boulevard with a 25 mph posted speed limit. SE Stark Street is an east-west two-lane roadway with a 30 mph posted speed limit. This section of SE Stark Street has an ADT of 10,200 vehicles per day. At this location SE 41st Street is offset by 120 feet. Five-foot wide bicycle left turn lanes are striped in the middle of SE Stark Street between both legs of SE 41st Avenue. This is done by eliminating parking on both sides. This treatment was installed in 2000. In addition to the markings on SE Stark Street, smaller guide markings on SE 41st Avenue direct bicyclists to use the bicycle left turn lanes. Note that left turns from SE Stark Street on to SE 41st Avenue are not prohibited for motor vehicles. See Figure 3.

FIGURE 3 SE Stark St at SE 41ST St, Portland, OR.

8th Avenue NW at NW 77th Street, Seattle, WA. NW 77th St is an east-west residential roadway which is commonly used by bicyclists with a statutory 25 mph speed limit. 8th Avenue NW is a north-south 2-lane divided roadway with a posted 30 mph speed limit. This section of 8th Avenue NW has an ADT of 12,700 vehicles per day. At this location, NW 77th Street is offset by 140 feet. A left turn pocket designed for southbound to eastbound bicyclists was installed in the late 1980's. There is no special striping or signing to indicate a bicycle specific crossing. See Figure 4.

FIGURE 4 8TH Ave NW at NW 77TH St, Seattle, WA.

Effectiveness of Existing Treatments

To determine how effective each treatment was, observations of bicyclists using the crossing were conducted. These were carried out for a minimum of four hours at each location on a weekday to observe as many bicyclists as possible. It was assumed that the treatment was effective if a majority of bicyclists followed the intent of the design. From observations conducted at each site, the majority of bicyclists followed the intent of the design. A small portion of bicyclists conducted a hybrid maneuver at each site. These users appeared to do so in response to traffic volumes. At all three sites, these bicyclists typically made a rolling stop and turned onto the right side of the through street (or side path) until there was an acceptable gap. At the Tucson, AZ location, those users who ignored the design conducted their turn like a motor vehicle would.

TABLE 1 OBSERVATIONS OF EXISTING TREATMENTS.

Treatment	Location	Users following the design	Users ignoring the design	Users doing a hybrid maneuver	Total Users
Side Bike Path	Tucson, AZ	100	7	3	110
Striped Bike Left Turn Lane	Portland, OR	20	0	2	22
Median Bike Left Turn Lane	Seattle, WA	3	1	1	5

Considerations of Existing Treatments

Alvernon Way at 3rd Street, Tucson Arizona. This treatment is the most intensive treatment for offset intersections. As shown in the photograph, this treatment includes a traffic signal in addition to the construction of the side bicycle path and traffic islands.

There are a number of advantages to this design including only one intersection for bicyclists to cross (and signalize). Also, the only movement prohibited is the left turn from one of the side streets. During construction of this treatment, there is minimal disruption to traffic since most of the work is conducted on one side of the major roadway.

In most urban situations, side bicycle paths pose additional problems than on street facilities. The AASHTO *Guide for the Development of Bicycle Facilities* (*4*) states nine reasons why these types of bike paths should be discouraged, including vehicles turning across the path to access businesses or residences and at intersections and bicyclists approaching in a direction unexpected by stopped or turning motorists.

SE Stark Street at SE 41st Avenue, Portland, OR. This treatment is a low-cost method to accommodate bicyclists turning left at offset intersections. In addition, this treatment can be accomplished with little impact on the roadway user. In this case, parking was prohibited between intersections which allowed for the striped left turn lanes. This location also does not prohibit any movement.

One concern for this location is the lack of guidance provided to motorists turning left. During the observation period, it was observed that about ½ of left turning motorists did not merge into the bike lane to complete the left turn. While similar to a right turn across a bike lane at a side street, this situation puts bikes to the left of left turning motorists. This alternative, however, does provide bicyclists with a refuge to complete their turn. This treatment, though, encourages bicyclists to turn left from the left lane instead of directly from a bike or shared lane on the right.

8th Avenue NW at NW 77th Street, Seattle, WA. This treatment is the most restrictive of the three treatments observed. Motor vehicle traffic is prohibited from turning left at this location. In addition, side street traffic is reduced to a right-in/right-out condition. Implementation of this treatment where medians or islands already exist would not adversely affect the existing traffic pattern. Similar to the treatment in Portland, OR, this treatment also encourages bicyclists to turn left from the left lane instead of from the bike lane.

ALTERNATIVES ANALYSIS

In addition to the treatments described and observed, three alternative designs were developed to address bicyclists crossing offset intersections. Descriptions and figures of these alternatives are shown below.

Median Left Turn Lane Alternative

One alternative is the combination of treatments from Seattle, WA and Portland, OR. This is shown in Figure 5. Like the Portland and Seattle treatments, this would require bicyclists to turn left from an exclusive bicycle left turn lane. Additionally, it would provide a refuge in case traffic volumes are heavy. This alternative enhances the existing treatment in Portland, by providing a barrier to motor vehicles. This feature enhances the comfort of the bicyclist. One draw back to this alternative is the restriction of movements for motor vehicles. As in the Seattle treatment, side street traffic is reduced to a right-in/right-out condition.

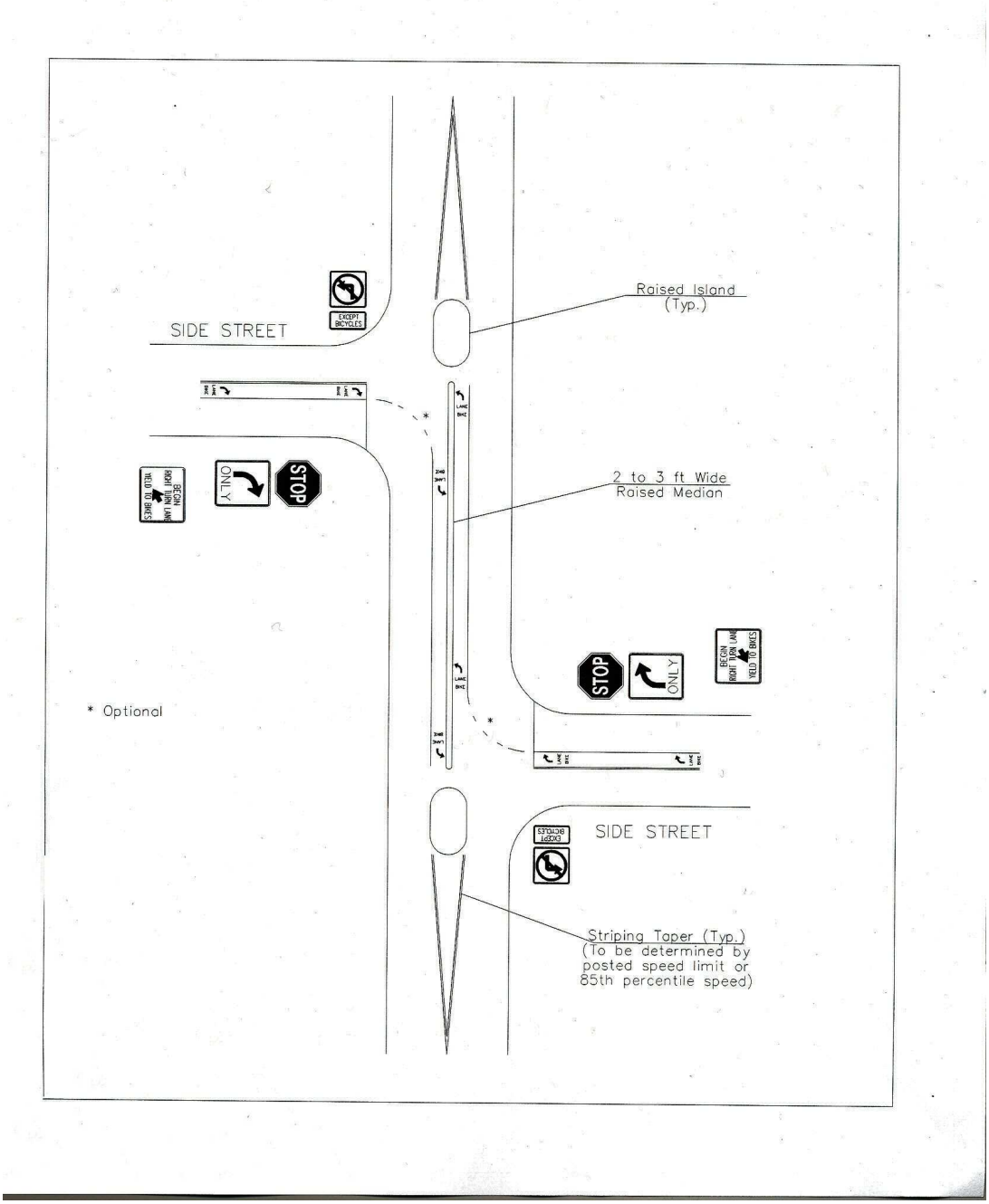

FIGURE 5 Median Left Turn Lane Alternative

One concern of this alternative which is true of both treatments in Seattle, WA and Portland, OR, is the placement of a bicycle lane to the left of traffic. Although, there is no prohibition against bike lanes to the left of traffic, (*4*) states:

> "Bike lanes on the left side are unfamiliar and unexpected for most motorists. This should only be considered when a bike lane on the left will substantially decrease the

> number of conflicts such as those caused by heavy bus traffic or unusually heavy turning movements to the right, or if there are a *significant number of left-turning bicyclists*.[emphasis by author]"

The high number of left turning bicyclists in addition to the short distance traveled should minimize the risk posed by installing a bike lane to the left of traffic. It should be noted that if a bicycle lane is already on the major roadway to the right of motorized traffic, the left bike lane should not "replace" the existing bike lane. Doing so would cause a hazard to the existing bicycle traffic. An additional concern about a left side bicycle lane is that of the users. While some bicyclists using a bike route along low-volume residential roadways are experienced riders who are also comfortable riding on major roadways, a substantial number of these cyclists may be novice bicyclists either learning how to ride in traffic or preferring to avoid major roads for a perceived safety benefit. A bike lane to the left of high-speed traffic will be a high-stress environment for this type of rider. If this alternative is chosen, the overall length of the bike lane to the left of traffic should be minimized.

Right Bicycle Lane and Refuge Area Alternative

A second alternative is the use of a bicycle lane on the right with a refuge area for bicyclists to wait to cross at the next intersection. This alternative is shown in Figure 6. Since the location of offset intersections at major streets is often limited to residential streets, there is a high probability that a number of bicyclists are novice riders with hesitation to interact with traffic. As such, these riders may avoid using treatments which would involve waiting between two directions of motor vehicles. This treatment provides a bicycle lane on the right of the main street. At the intersection with the next leg of the offset intersection, there is a waiting area for the bicyclist to use until an adequate gap is available.

This alternative is able to be installed on roadways with width available for a bicycle lane. In particular, on roadways with on street parking, the parking can be removed for the short distance between offset intersections, as was done at the Portland, OR location. Additionally, if room allows for a both a parking lane and a bicycle lane, parking can be prohibited on the top of the tee intersection to provide an area for waiting bicyclists.

One concern of this alternative is the overall crossing distance. Unlike the bicycle left turn lane alternatives, this alternative requires a bicyclist to make a crossing in one stage. This may be possible at some locations but at high volume locations, this may not be possible and could require the installation of a traffic signal. Due to the proximity of the intersections, any signalization would pose challenges in regards to both phasing and timing. Consideration should be given to the installation of median refuges with this alternative to negate the need for a signal.

Median Bicycle Path Alternative

The third alternative is an enhancement of the median crossing alternative shown in Figure 1 and adapted for use at intersections with shared roadways. This alternative is shown in Figure 7. A full median island is installed between the two offset intersections. To accommodate bicyclists, a pathway is installed in the middle. Under this alternative, a minimum width of 8 feet is required although 10 feet is preferable.

This alternative allows for a two-stage crossing and would likely be used by both novice and experienced bicyclists.

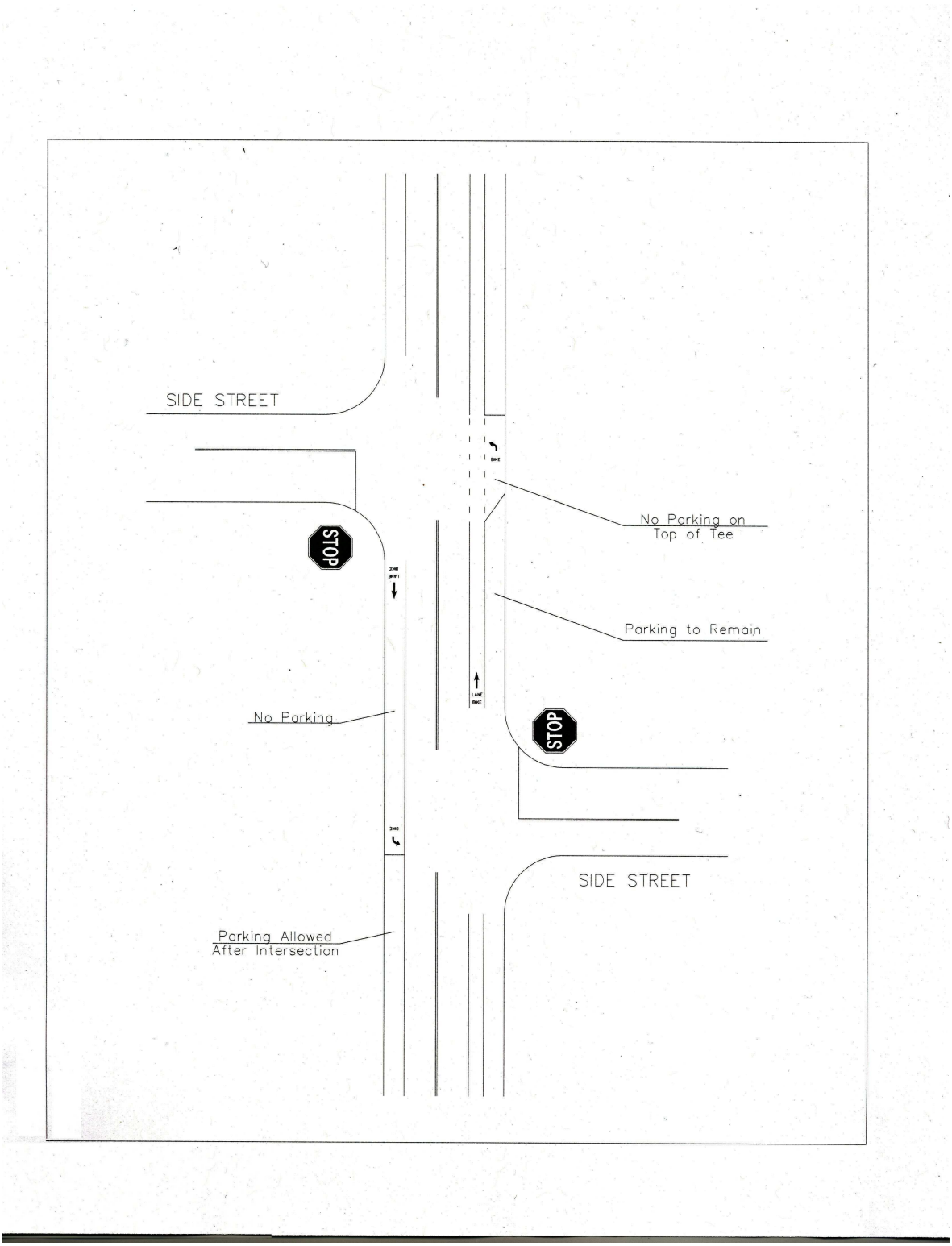

FIGURE 6 Right Bicycle Lane and Refuge Area Alternative. Note that both on-street parking and no parking situations are shown on the figure.

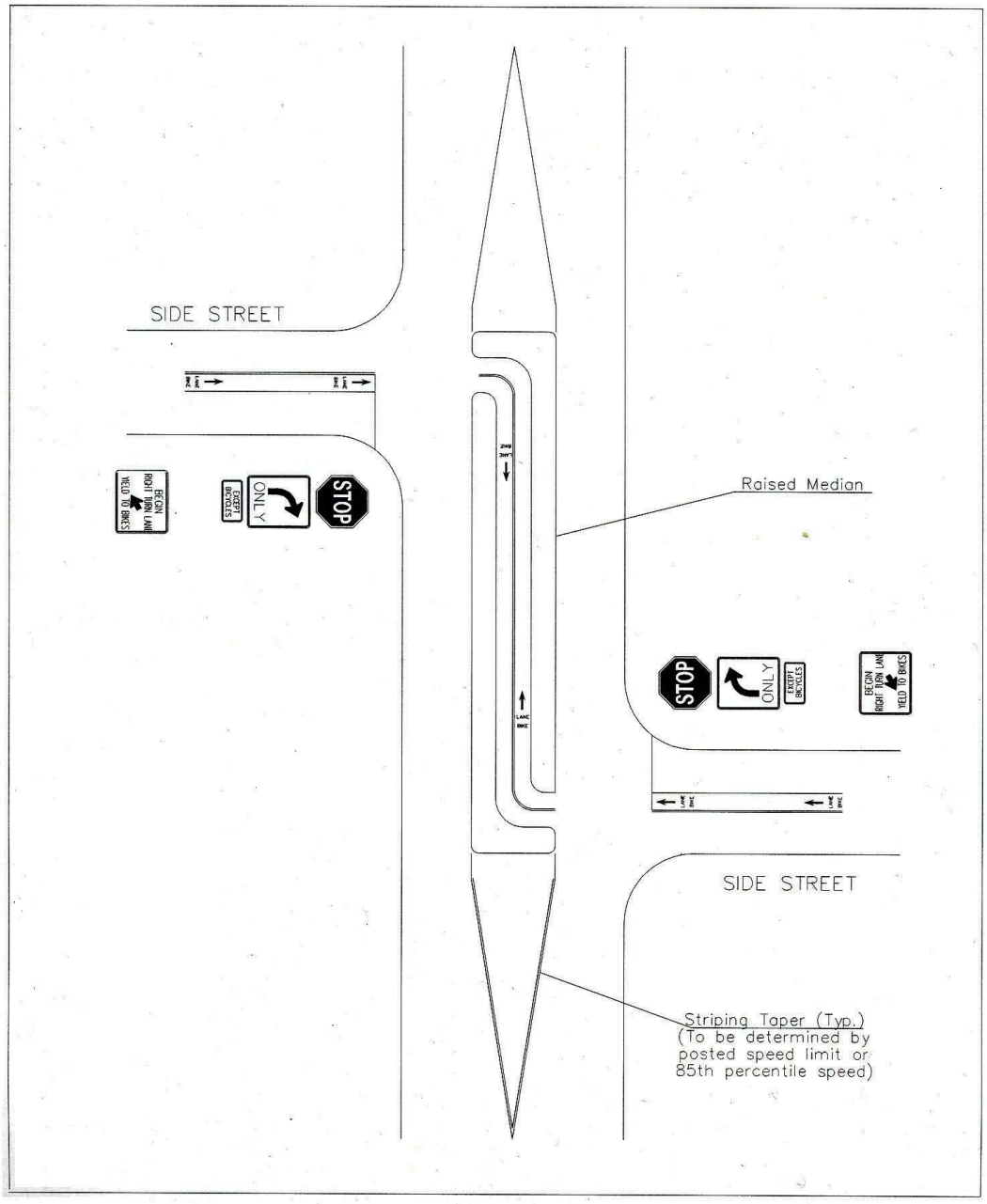

FIGURE 7 Median Bicycle Path Alternative

There are some disadvantages to the median alternative. This alternative would effectively reduce the side streets to a right-in/right-out situation. However, depending on the

volume of traffic on the through street, the side street may already be effectively limited to right turns only during peak hours. Additionally, if signalized, this alternative could result in the creation of a left-turn trap situation. If left turns are permitted before the median (i.e. for U-turns or driveway entrances), standard signal indications could provide a false message to a left turning vehicle.

These disadvantages can be mitigated through the use of innovative signal operations, including the flashing yellow arrow and signing allowed in the 2003 MUTCD (*5*).

General Notes on Alternatives

All of the alternatives mentioned above are acceptable for use with or without traffic signals. While traffic signal warrants could be used to determine whether or not a traffic signal is needed at a certain location, there are no such warrants or guidelines for the general construction of offset crossings and which design may be more appropriate. Some potential factors to be considered when designing offset crossings are the volume of traffic including turning volumes, the speed limit or 85^{th} percentile speed of the main street, and the make up of the bicyclists using the crossing. As mentioned above, novice bicyclists and/or bicyclists riding with children may not be comfortable to the left of high-speed traffic. Likewise, if this group make-up a high percentage of bicyclists using the bicycle route, some of these alternatives may not be appropriate.

This paper proposes alternatives for offset intersections where bicyclists must first turn right and then turn left to continue along the bicycle route. There has been no mention of the mirrored opposite of this intersection where a bicyclists must first turn left and then right to continue along a route. The left side bike lane alternative would not be applicable to this situation at all. However, the median alternative would be able to handle this situation with minor modifications. These modifications may include lengthening the median for a right-in/right-out condition for the side street.

The three proposed alternatives have discussed offset intersections in relationship to bicyclists only. A key consideration in urban design is how to accommodate pedestrians, as well. Only the Tucson, AZ treatment directly addressed the needs of crossing pedestrians with the installation of a crosswalk at the same crossing as bicyclists. The alternatives presented can be adapted to also accommodate pedestrians with median cut-throughs and/or additional signing and striping.

CONCLUSIONS

The observations of the existing treatments conclude that the designs are appropriate for their respective locations. Bicyclists, as other roadway users, will ignore treatments which increase delay or present safety concerns. From the observations of the three existing treatments, the number of bicyclists following the designers' intent validates both the Tucson, AZ and Portland, OR location. More observations are needed for an assessment of the Seattle, WA location.

As bicycle boulevards continue to increase in popularity, more jurisdictions will likely encounter offset intersections at major streets. The existing treatments evaluated show that these treatments are effective. The proposed alternative treatments comply with traffic engineering principles while accommodating the unique needs of bicyclists.

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(4)American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. American Association of State Highway and Transportation Officials, Washington, D.C.:1999

(5)*Manual of Uniform Traffic Control Devices*. FHWA, U.S. Department of Transportation, 2003.