Transportation
Land Development
Environmental
Services

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Memorandum

To: Jen Francis, Park Planner
Burlington Department of Parks and Recreation

Date: June 4, 2013

Project No.: 57614.00

From: Greg Bakos, P.E.
Project Manager

Erin Parizo, EI
Project Engineer

Re: Burlington Bike Path Crossings Study
Burlington, VT

Vanasse Hangen Brustlin, Inc. (VHB) has completed the yield control analysis of the ten (10) Bike Path crossings as directed by the City of Burlington Department of Parks and Recreation (DPR) and the Chittenden County Regional Planning Commission (CCPRC). These crossings have been identified by the City as candidates for conversion to yield control from the existing stop control on the path due to minimal vehicular traffic and/or slow traffic speeds in conjunction with high volumes on the bike path. The crossing locations are as follows:

1. Harrison Avenue (West)
2. Harrison Avenue (East)
3. College Street
4. Lake Street
5. Little Eagle Bay Road
6. Beachcrest Drive
7. Leddy Beach (South Access)
8. Leddy Beach (North Access)
9. Shore Road
10. North Avenue Extension

This memorandum provides the following:

- Existing state laws and guidance pertaining to path yield control;
- A description of the methodology used to determine each crossing's eligibility for yield control;
- Decision sight distance and findings; and
- Conclusions and recommendations to move forward.

EXISTING STATE LAWS AND GUIDANCE

Existing state laws regarding the right of way between bicyclists in a road crossed by a shared use path and vehicles on the roadway are somewhat vague. The Vermont Bicycling Laws 23 VSA §1051(a) state that "…the driver of a vehicle shall yield the right of way, slowing down or stopping if necessary, to a pedestrian crossing the roadway within a crosswalk." A pedestrian using the shared use path would have the right-of-way, by law, once in the crosswalk due to vehicles being required to yield the right of way. In addition, 23 VSA §1051(b) states that "No pedestrian may suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close that it is impossible for a driver to yield." It is both the pedestrian's responsibility to ensure they have sufficient crossing time, and the vehicle's responsibility to stop to allow the pedestrian in the crosswalk to cross if they can do so safely. The laws are different for cyclists however. The Vermont Bicycle and Pedestrian Coalition compiled the Vermont Bicycling Laws and within their summary they state that "Bicyclists do not have the right-of-way in crosswalks under state law unless they dismount and walk." This would mean unless a cyclist were to dismount at a road crossing and act as a pedestrian, they would be responsible for yielding the right of way to vehicles. This would be accomplished by enforcing a stop or yield control on the shared use path.

The Manual on Uniform Traffic Control Devices (MUTCD) Section 9B.03 provides the following guidance for placement of stop vs. yield signs on shared-use paths:

"Guidance:

Where conditions require path users, but not roadway users, to stop or yield, the STOP or YIELD sign should be placed or shielded so that it is not readily visible to road users.

When placement of STOP or YIELD signs is considered, priority at a shared-use path/roadway intersection should be assigned with consideration of the following:

A. Relative speeds of shared-use path and roadway users,
B. Relative volumes of shared-use path and roadway traffic, and
C. Relative importance of shared-use path and roadway.

Speed should not be the sole factor used to determine priority, as it is sometimes appropriate to give priority to a high-volume shared-use path crossing a low-volume street, or to a regional shared-use path crossing a minor collector street.

When priority is assigned, the least restrictive control that is appropriate should be placed on the lower priority approaches. STOP signs should not be used where YIELD signs would be acceptable."

DECISION SIGHT DISTANCE METHODOLOGY

VHB first referred to the Vermont Pedestrian and Bicycle Facility Planning and Design Manual and the MUTCD for regulations on the appropriate use of stop vs. yield signs on shared use paths at roadway crossings. These offered little direction on the subject aside from general guidance which is detailed in the previous section. The AASHTO Geometric Design of Highways and Streets Book (Green Book) includes guidance pertaining to the Decision Sight Distance as traditionally applied to motorists. This is defined as "the distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or hazard in the roadway environment that may be visually cluttered, recognize the hazard or its threat potential, select the appropriate speed and path, and initiate and complete the required safety maneuver safely and efficiently". The motor vehicle decision sight distances for each intersection were calculated using equation 3-4 in the Green Book and the results are presented in the next section. The equation is as follows:

$$d = 1.47 * V * t + 1.075 (V^2 / a)$$

Where t = pre-maneuver time, s (Assumed to be 3.0s from Green Book guidance)
V = design speed, mph (Field verified at each crossing)
A = driver deceleration, ft/s^2 (Assumed to be 11.2 ft/s^2)

Next, VHB utilized the 2012 AASHTO Guide for the Development of Bicycle Facilities. This provides guidance for calculating the required sight distance for path users to safely cross an intersection with a roadway under a yield control scenario. Tables 5-7, 5-8, and Figure 5-15 from the AASHTO Bike Guide are shown below to demonstrate the necessary sight distance. Figure 5-15 illustrates the appropriate concepts and dimensions that would be needed for a bicyclist on the path to see a motor vehicle at a crossing and decide whether there is sufficient time to cross the intersection or if they must slow down and proceed when safe (i.e. the action required by a yield sign).

Chapter 5: Design of Shared Use Paths

Guide to Bicycle Facilities, 4th Edition

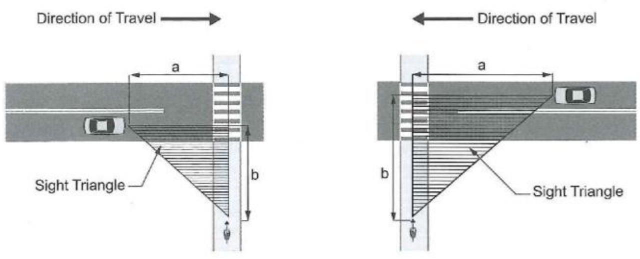

Figure 5-15. Yield Sight Triangles

Table 5-7. Length of Roadway Leg of Sight Triangle

U.S. Customary			Metric		
$t_a = \frac{S}{1.47V_{path}}$ $t_g = t_a + \frac{w+L_a}{1.47V_{path}}$ $a = 1.47V_{road}t_g$			$t_a = \frac{S}{0.278V_{path}}$ $t_g = t_a + \frac{w+L_a}{0.278V_{path}}$ $a = 0.278V_{road}t_g$		
where:			where:		
t_g	=	travel time to reach and clear the road (s)	t_g	=	travel time to reach and clear the road (s)
a	=	length of leg sight triangle along the roadway approach (ft)	a	=	length of leg sight triangle along the roadway approach (m)
t_a	=	travel time to reach the road from the decision point for a path user that doesn't stop (s)	t_a	=	travel time to reach the road from the decision point for a path user that doesn't stop (s)
w	=	width of the intersection to be crossed (ft)	w	=	width of the intersection to be crossed (m)
L_a	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)	L_a	=	typical bicycle length = 1.8 m (see Chapter 3 for other design users)
V_{path}	=	design speed of the path (mph)	V_{path}	=	design speed of the path (km/h)
V_{road}	=	design speed of the road (mph)	V_{road}	=	design speed of the road (km/h)
S	=	stopping sight distance for the path user traveling at design speed (ft)	S	=	stopping sight distance for the path user traveling at design speed (m)

Table 5-8. Length of Path Leg of Sight Triangle

U.S. Customary			Metric		
$t_a = \frac{1.47V_e - 1.47V_b}{a_i}$ $t_g = t_a + \frac{w+L_a}{0.88V_{road}}$ $b = 1.47V_{path}t_g$			$t_a = \frac{0.278V_e - 0.278V_b}{a_i}$ $t_g = t_a + \frac{w+L_a}{0.167V_{road}}$ $b = 0.278V_{path}t_g$		
where:			where:		
t_g	=	travel time to reach and clear the path (s)	t_g	=	travel time to reach and clear the path (s)
b	=	length of leg sight triangle along the path approach (ft)	b	=	length of leg sight triangle along the path approach (m)
t_a	=	travel time to reach the path from the decision point for a motorist that doesn't stop (s). For road approach grades that exceed 3 percent, value should be adjusted in accordance with AASHTO's *A Policy on Geometric Design of Highways and Streets* (5)	t_a	=	travel time to reach the path from the decision point for a motorist that doesn't stop (s). For road approach grades that exceed 3 percent, value should be adjusted in accordance with AASHTO's *A Policy on Geometric Design of Highways and Streets* (5)
V_e	=	speed at which the motorist would enter the intersection after decelerating (mph) (assumed 0.60 × road design speed)	V_e	=	speed at which the motorist would enter the intersection after decelerating (km/h) (assumed 0.60 × road design speed)
V_b	=	speed at which braking by the motorist begins (mph) (same as road design speed)	V_b	=	speed at which braking by the motorist begins (km/h) (same as road design speed)
a_i	=	motorist deceleration rate (ft/s^2) on intersection approach when braking to a stop not initiated (assume −5.0 ft/s^2)	a_i	=	motorist deceleration rate (m/s^2) on intersection approach when braking to a stop not initiated (assume −1.5 m/s^2)
w	=	width of the intersection to be crossed (ft)	w	=	width of the intersection to be crossed (m)
L_a	=	length of the design vehicle (ft)	L_a	=	length of the design vehicle (m)
V_{path}	=	design speed of the path (mph)	V_{path}	=	design speed of the path km/h)
V_{road}	=	design speed of the road (mph)	V_{road}	=	design speed of the road km/h)

Note: This table accounts for reduced motor vehicle speeds per standard practice in AASHTO's *A Policy on Geometric Design of Highways and Streets* (5).

The length of the roadway leg (a) is comparable with the vehicle decision sight distance which was calculated based on the above equations in the AASHTO Green Book. The length of the path leg (b) is also necessary to complete the sight triangle and has been calculated using the equations in Table 5-8 above. Additional guidance from the AASHTO Bike Guide indicates that "20 miles per hour is the minimum design speed to use when designing a trail". This value is specific to a paved multi-use path. For this reason VHB used a speed of 20 mph for a cyclist approaching an intersection in the design calculations where existing bicyclist speed data was not able to be acquired. The CCRPC gathered bicyclist speed and volume data on the days of Saturday, May 18th 2013, through Tuesday, May 21st 2013 at two locations along the bike path. The first location was between the crossings of College Street and Lake Street and the second location was between the two Leddy Park Access Roads. These locations were chosen due to the existing sight distance and because they were the four crossings (College, Lake, and two Leddy Roads) with the greatest sight distances that might most feasibly entertain a yield path control. The four day average of the 85th percentile cyclist speeds collected at the Waterfront location was 13.3 mph and at the Leddy Park location was 15.1 mph so these speeds were used for calculations at those crossings. The approach speed of the motor vehicles is dependent upon the posted speed limit for each roadway that crosses the path, so this value varies from intersection to intersection. The width of each crossing was verified in the field and also varies among crossings.

Using these variables, each of the equations from Table 5-8 above were calculated and the results are shown in the next section.

VEHICLE DECISION SIGHT DISTANCE AND PATH SIGHT DISTANCE CALCULATIONS

The decision sight distance for motor vehicles and the sight distance for bicyclists at a crossing were calculated per the methodologies described above. Crossings such as College Street, Beachcrest Drive, and North Avenue Extension include two rows since one is the posted speed limit and the other is the apparent speed in which vehicles are able to travel in these areas. Results from the calculations are shown in Table 1:

TABLE 1

DECISION SIGHT DISTANCE

Crossing	Driver Decision Sight Distance (ft)	Calculated Bike Path Leg (ft)
Harrison (West)	130	125
Harrison (East)	130	125
College Street – 10 mph	55	95
College Street – 25 mph	175	90
Lake Street	130	85
Little Eagle Bay Road	55	140
Beachcrest Drive – 10 mph	55	140
Beachcrest Drive – 25 mph	175	130
Leddy Beach (South)	90	95
Leddy Beach (North)	90	95
Shore Road	175	130
North Avenue Extension – 10 mph	55	140
North Avenue Extension – 25 mph	175	130

The driver decision sight distance was calculated at each crossing to provide a factor of safety on the chance a cyclist does not stop or yield at the crossing and a vehicle is forced to stop to avoid a collision. VHB verified that each of the ten crossings have sufficient decision sight distance for a vehicle to make a complete stop or avoidance maneuver before conflicting with a user of the bike path who has already entered the crossing.

The crossings of the path with College Street, Beachcrest Drive, and North Avenue Extension all have either un-posted speed limits (which in Burlington implies that the speed limit is 25 mph), or are posted at 25 mph. They were all observed to have slower moving vehicles than the posted speed limit due to the design, population, use, or context of the surrounding area. Beachcrest Drive and North Avenue Extension both lead to private homes or developments and vehicles were observed traveling approximately 10 mph due to the horizontal alignments of the road. Based on an analysis of the crossings using the posted speed limit, yield signs on the path would not be recommended. Even if vehicles only travel 10 mph in these locations, a yield sign would still not be recommended for replacing the stop control due to limited sight distance from the path user's point of view.

CONCLUSIONS AND RECOMMENDATIONS

The findings of the Yield Control Analysis indicate that providing yield signs for path users at the proposed crossings are not supported based on the existing available decision sight distance for cyclists using the path except at the crossing of Lake Street. The table below displays a summary of findings for each of the crossings. The Calculated Bike Path Leg column matches the one in Table 1 above as these distances are what would be required for the bike path leg in the field. From the vantage point of a potential driver, the bike path leg was measured and these numbers are shown in the Observed Bike Path Leg column. As an example, a vehicle near the intersection at Harrison Ave (West) would need to be able to see 125 ft down the bike path in either direction in order for a yield sign to be applied to the path. This would provide sufficient sight distance for the cyclist to see on coming vehicles and slow or stop as needed before crossing. The field verification revealed that a vehicle was not able to see any length of the bike path due to fencing and shrubs and thus this column shows 0 ft. The fourth column summarizes whether or not the sight distances will allow for a yield control on the path based on the limiting sight distance, and the last column provides notes on what physical constraints at the intersection limit the existing sight distance.

TABLE 2

EXISTING SIGHT DISTANCE SUMMARY

Crossing	Calculated Bike Path Leg (ft)	Observed Bike Path Leg (ft)	Acceptable for Yield?	Notes
Harrison (West)	125	0	No	Fence and shrubs on the southwest corner block all visibility to the path for eastbound vehicles.
Harrison (East)	125	0	Yes	Entrance to Harrison Ave. rather than a crossing, so a yield path control here would be acceptable.
College Street – 10 mph	95	100	Yes	If it can be proven that vehicles only travel 10 mph through this crossing, this would be acceptable.
College Street – 25 mph	90	65	No	
Lake Street	85	85	Yes	
Little Eagle Bay Road	140	10	No	Hedges on the west side of path limit sight distance for eastbound vehicles.
Beachcrest Drive – 10 mph	140	15	No	Hedges on northeast corner limit sight distance for westbound vehicles.
Beachcrest Drive – 25 mph	130	5	No	
Leddy Beach (South)	95	20	No	Trees on southwest corner limit sight distance for eastbound vehicles.
Leddy Beach (North)	95	60	No	Trees on the northeast corner limit sight distance for westbound vehicles.
Shore Road	130	10	No	Trees and fencing on various corners limit sight distance.
North Avenue Extension – 10 mph	140	20	No	Trees on various corners limit sight distance.
North Avenue Extension – 25 mph	130	10	No	

The East crossing of Harrison Avenue currently does not have any sort of path control. This is because rather than crossing the road it is more of an entrance into Harrison Avenue. For this reason it could be justified to add a yield sign at that location. It could also be justified to add a yield sign at the crossing of College Street if data can show that vehicles travel 10mph or less through that crossing.

Given the very conservative decision stopping sight distance that AASHTO prescribes along the path it is very difficult to find intersection sight triangles of suitable length along the Burlington Bike path to allow the use of yield control. The desired sight triangles are typically obstructed by vegetation, fences, signs or structures. VHB is therefore unable to support replacing stop signs with yield signs where the site conditions do not provide at least the minimum sight lines required by the accepted design guidelines.

The City may, however, choose to weigh other site conditions such as low side street volumes in combination with lower than posted vehicle speeds and good visibility of an intersection to still consider yield controls. The 2013 ITE Traffic Control Devices Handbook (ITE TCD Handbook) offers guidance on assigning priority at bike path/ roadway crossings in Chapter 14: Bicycle Facilities. This handbook states that “A number of factors should be considered in determining priority, including volume and type of users on the path, volume of traffic on the intersecting roadway, available sight distance, and other factors.” There may be a concern under the current stop controls that the high volume of cyclists is leading to bike-bike crashes as some cyclists stop at every crossing while others perform a “rolling” stop maneuver. This type of cyclist action is also discussed in the ITE TCD Handbook at locations where there are routinely placed stop signs. “Observation has noted that bicyclists often treat STOP signs as YIELD signs at these locations, slowing, scanning for conflicting traffic, and then proceeding if no conflicting traffic is detected…Yield control (either for the roadway or pathway) can be an effective and efficient treatment as it encourages appropriate scanning behavior without unneeded restriction (or routine disobedience).” While we cannot formally endorse yield controls where the required sight lines do not support them, the City may wish to selectively convert to yield control where stop controls are observed to be routinely ignored, as described above.

For locations where yield control is considered, it is important to note that yield control does not remove responsibility on the part of the cyclists to control their approach speed and to stop if motor vehicles are approaching the crossing. Placing Yield Ahead pavement markings and W3-2 signs along the path in advance of the road crossings would help alert cyclists to start slowing down in advance of where they would see approaching vehicles. This speed reduction would reduce the required sight triangle lengths, which would be a favorable modification. The below graphic from the AASHTO Design Guide provides guidance on the suggested yield control signing and striping layout.