



## DESIGN OF CYCLE TRACKS AT BUS STOPS: CASE STUDY AND GUIDELINES

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**Abstract:** With the approval of a new ten year Cycling Network Plan, the cycling infrastructure in the City of Toronto is currently experiencing tremendous growth and investment. This paper identifies and suggests enhancements to existing and proposed bus stops that interact with cycle tracks. In order to accommodate for cycling infrastructure growth in the City of Toronto two designs were developed to be implemented as a standard for both new construction and reconstruction projects. Vehicles are no longer the sole transportation mode of choice; cycling and public transit continue to exceed expectations, soaring in popularity. As a result, city streets must adapt and adjust to these changes in human transportation behaviour: bus-stops being one such example. This report outlines two alternative designs to existing bus-stops on streets with cycle tracks which enhance safety and improve operations while maintaining low costs: A pedestrian safety island; and a sidewalk cutaway design. Reducing conflict zones between cyclists, pedestrians, passengers, public transit vehicles and motorists is of utmost priority, and the creation of a safe urban environment that values all modes of transportation proportionately is critically important. A qualitative and quantitative evaluation was used to determine the best alternatives based on the four preliminary designs. This will allow for a standardized approach which the City of Toronto can use when adding new bus-stops or upgrading existing facilities.

### 1 INTRODUCTION

Cycle tracks are becoming a popular addition to urban road design as cycling continues to gain traction in growing cities like Toronto. The implementation of cycle tracks create additional conflict zones, safety issues, and design flaws at locations where they meet with public transit stops. Bus stops require a large area for level boarding, and typically, cycle lanes run alongside the curb, forcing the bus to stop within the cycle lane. The goal of this project is to create a standardized bus stop that the City of Toronto can adhere to while creating and expanding their network of cycle tracks in the future. This new design standard must prioritize safety of all stakeholders and be an efficient and effective use of space since urban centres are typically very dense. If a creative and dynamic solution can be reached, cycling as a primary mode of transportation may be encouraged in urban centres. Moreover, shifting the focus from vehicular based transportation designs to more sustainable and environmentally conscious cycling and pedestrian designs is an important step in modernizing our urban communities.

The activities of the project conducted by the authors are shown in Fig. 1. As a component the report, the authors have completed a literature review to better understand the interaction between protected bicycle

lanes and transit. Specifically, members studied Vision Zero, Toronto’s road safety plan from 2017 to 2021 (City of Toronto n.d.A), as well as a study conducted by the City of Toronto on collisions involving both bicycle and motor-vehicles (City of Toronto, 2003). A member focused specifically on cycling in the City of Toronto, this consisted of the city’s Ten Year Cycling Network Plan as well as a cycling study from 2001 to 2011 (City of Toronto n.d.B, Toronto 2011). Members also examined case studies in European locations which are known as global leaders in the area of sustainable transportation: Denmark, specifically Copenhagen (City of Copenhagen 2015); and The Netherlands, specifically Amsterdam (Pucher and Buehler 2007A & B). Case studies regarding the interaction between transit and cyclists were also considered, a member consulted Reports from the City of Winnipeg, State of Massachusetts and the Australian Road Authority (Suderman and Redmond n.d., Massachusetts 2011, Ker,Yapp and ,Moore,2005 ). Existing conditions were observed at a standard bus stop on Toronto near Sherbourne St. and Wellesley St. (D’Andrea 2016). Finally, a member studied the methodology behind protected bike lanes, this involved a thesis written in 2014 at Portland State University on models predicting Bicyclist Comfort in Protected Bike Lanes (Foster 2014, Burchfield 2009). Following these reviews a proposal illustrating multiple designs of a bus stop involving a protected cycling lane in the City of Toronto was drafted.

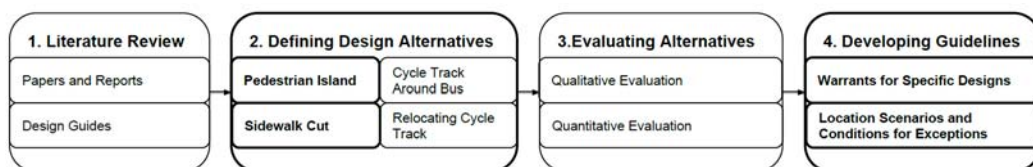


Figure 1: Activities of the project

## 2 DESIGN GUIDELINES

In order to design an effective bus stop, minimum standards across varying agencies must be met. These regulatory values are predetermined for comfort, safety, and accessibility. Some of these regulations fall under the discretion of the City of Toronto, Ministry of Transportation of Ontario (MTO), and City of Toronto Accessibility Guidelines (Toronto 2014 - 2017, MTO 2000, MTO 2013, Toronto Transit Commission 2017, Toronto 2001). Each of the alternative designs outlined in the report will follow these standards and meet each minimum requirement in terms of lane width, cycle track width, grade, and elevation.

Table 1: Design guidelines for bus stops based on critical values from varying standards

Facility	Element	Minimum Design Guideline
Cycle Track	Width	- 1.2 m (channelized) ; 1.5m (typical) ; 2m (desired)
	Taper <sup>a</sup>	- ≥ 3:1 (length to width ratio)
Bus Island <sup>b</sup>	Width	- 2.7 m (2.4 m free of any obstruction)
	Length	- 12 m (free of obstruction) ; 19m (for 18m buses)
	Railing	- 0.9 –1 m (For clear sightlines) ; 0.15-0.3m from curb
	Elevation	- 0.15 m (to match existing curb heights)
Lanes	Width	- 3.3 m (bus lanes) ; 3.1 m (streetcar lanes)

<sup>a</sup> Tactile material to be used along edge of cycle track and sidewalk.

<sup>b</sup> Tactile Strips must be used at each edge for crossings and boarding. Crossings width should be 1.85 m minimum.

### 3 DESIGN ALTERNATIVES

Four alternatives were developed through studying existing cycling infrastructure around the world and adapting these facilities for Toronto and the prescribed mandates. Note that in all of the design alternatives outlined below, it is assumed that the cycle track is raised to sidewalk elevation through typical road sections without access points or bus stops. All boarding and alighting areas will be marked by a standard accessible tactile strip and the cycle track and curb edge would be lined with a tactile surface for pedestrians who are visually impaired. Where snow removal is difficult heated concrete floors may be considered, such as the loading and waiting area for bus passengers. In considering the pavement structure, special consideration should be taken as buses are heavy slow moving vehicles and rutting can occur at bus stops. It is recommended to consider rigid pavement at the bus stop.

#### 3.1 Alternative 1: Pedestrian Island

The first design alternative, a pedestrian island within the right of way between the cycle track and the right traffic lane, focuses on optimizing pedestrian and cyclist safety by minimizing conflict areas. The focal point of this design is the safety island that keeps waiting pedestrians separate from the cycle traffic, while keeping the cycle track and sidewalk elevations separate from the road. The cycle track detours around the pedestrian island so that cyclists remain largely unimpeded by public transit stops. The design also features street furniture which serve as a physical barrier between the cycle lane and waiting pedestrians. Furthermore, a level boarding experience can be achieved for public transit passengers without having to interfere with cyclist traffic. Pavement markings will further delineate the space, making it clear for all stakeholders which portion of the space is reserved for their use. This will be done using a combination of coloured paint and patterns.

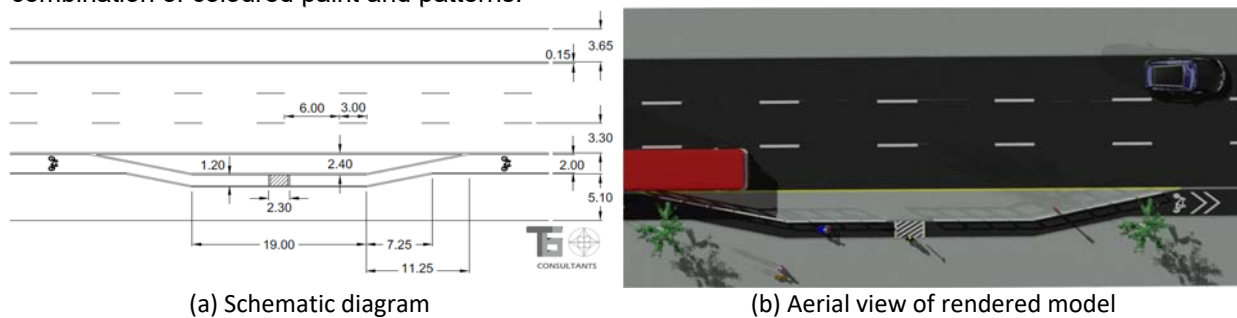


Figure 2: Design alternative 1

#### 3.2 Alternative 2: Cycle Track Around Bus

The second design alternative, altering the path of the cycle track to pass the stopped bus on the left side, focuses on minimizing delays for all road users. This design is based on observed behaviour of current cyclists interacting with transit vehicles at bus stops. The cycle track will ramp down to street level as it approaches the location of the stopped bus at a public transit stop. Painted lines would delineate a tapered path for cyclists that would direct them around the bus loading zone and realign back on the other side, where the track would ramp back up to sidewalk level. Segments of dashed lines will instruct bus operators where to merge or diverge through the track. During the tapering of the cycle path, the track would also narrow to enforce a more cautious approach from cyclists. Additionally, warning signs and coloured zones would be implemented to direct all users to proceed with caution.

#### 3.3 Alternative 3: Sidewalk Cut

The third design alternative, putting the bus stop entirely within the cycle track, builds upon the most common operations on existing cycle tracks such as Richmond/Adelaide. This design attempts to address the safety and operational issues that were found in the current bus stop configurations while reducing the change to existing services and surrounding facilities. On the sidewalk the furniture is reconfigured to

open up the full sidewalk width in order to reallocate the right of way. Where the total cycling facility (including buffers) is not wide enough to accommodate a stopped bus a sidewalk or boulevard cut is made to ensure that when the bus is stopped it is clear of the adjacent traffic lane. A yield line and accompanying signage will be placed at the entrance to the bus stop, as well as coloured zones indicating any conflicts as an additional warning. Following the yield line the cycle track will lower down to street level, and a pavement marking will highlight the grade change. Diamonds or equivalent pavement markings will indicate that the lane is only for cyclists and buses.

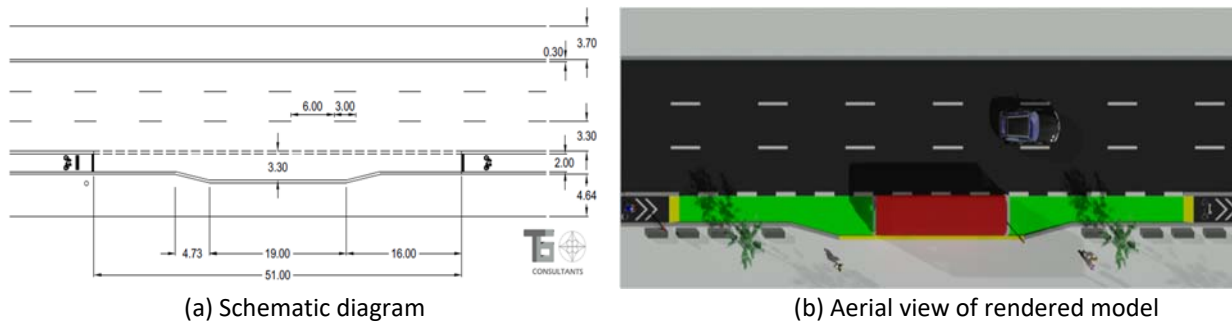


Figure 3: Design alternative 3

### 3.4 Alternative 4: Relocating the Cycle Track

Our fourth and final design, relocating the cycle track to the left side of the street, completely eliminates the bus-bicycle conflict at bus stops. This design is only applicable on one way streets with cycle tracks, such as the Richmond/Adelaide corridor. It would be recommended that sidewalk furnishings and the concrete sidewalk be upgraded to meet the Accessibility for Ontarians Act as well as various City of Toronto and TTC standards (TTC 2005). A partial shelter and benches would greatly improve the waiting conditions for passengers, and a furniture reorganization would allow for clear access and egress to and from the buses. Planters or a separated curb, similar to Sherbourne St. and Wellesley St. W., could be utilized here in place of the elevated track. Right turn boxes could be implemented where necessary and most cyclist left turns will be uninhibited by this design. Bus operations and motor operations would remain the same, however an advanced left may be required to maintain sufficient LOS levels.

## 4 EVALUATION OF ALTERNATIVES

To gain a comprehensive understanding of all the alternatives, a qualitative and quantitative assessment was conducted deriving from the triple-bottom line: society; environment; and economy. As such, design parameters of safety, design utility, cost, and the environmental impacts were examined. The quantitative approach enabled the evaluation of criteria through the assignment of weighting factors, while the qualitative approach addressed the various impacts of an alternative on stakeholders with respect to the status quo conditions. These stakeholders include transit users, cyclists, pedestrians, motorists and the City of Toronto. One recurring assumption used for both evaluations was that all stakeholders act rationally, which was done to simplify the process and generate accurate ratings. Due to limitations in available software the design models can not be modelled, and our evaluation will rely on the previously mentioned methods. These methods enabled us to better serve our clients by allowing us to develop solutions that are both pragmatic and inclusive.

### 4.1 Quantitative Methodology

The classical quantitative method for scoring alternatives was conducted by using a set of 19 evaluation criteria based on safety, design utility, cost, and environmental factors, as seen in Table 1. Weightings were strategically assigned to each of the 4 factors in order to create an optimal design tailored for our stakeholders from a value from 1-5 which was utilized in Equation 1.

$$[1] S_i = W_j R_{ij}$$

Where:  $S_i$  = score of alternative  $i$  ranging from 1-10 with 1 being the lowest and 10 the highest;  $W_j$  = weight of factor  $j$ ; and  $R_{ij}$  = rating of alternative  $i$  with respect to factor  $j$ .

Scores were assigned based on their importance, since safety has the potential to be a hazard and create risk is a top priority for engineering alternatives, so this criteria was adjusted by a factor of five, whereas design utility criteria was adjusted by four since it can create significant problems for a governing agency due to items such as snow and ice control. Although cost factors were not emphasized for this project, a multiplier of two was assigned. The environmental factors were taken as a singular unit given that the nature of the project carried minimal environmental implications with respect to the status quo. For efficiency, all members scored the selected criteria as a team and discussions were kept as objective as possible. The scores for the quantitative analysis can be seen in Table 2.

Table 2: Results of quantitative evaluation

	Alternatives					Alternatives					
	1	2	3	4		1	2	3	4		
Design Utility	Traffic Impacts	7	4	6	8	Safety	Perceived Safety	8	3	7	9
	Transit Integration	9	3	7	9		Cycle-Ped Conflict	8	10	10	10
	User Concern	9	3	5	9		Cycle-Bus Conflict	10	5	8	10
	Attractiveness	8	4	9	7		Cycle-Vehicle Conflict	10	9	10	10
	Accessibility	9	6	9	9		Bus-Vehicle Conflict	9	8	7	9
	Street Furniture	9	6	7	8		Total	225	175	210	240
	Operations & Maintenance	8	8	9	9		Material & Construction	3	7	7	4
Constructability	4	9	6	9	External Infra. Upgrades	8	4	4	7		
	Total	252	172	232	272	Constructability	4	5	6	4	
Environment	Construction Waste	6	9	8	9	Cost	Operations & Maintenance	8	8	9	9
	Green Space Potential	7	6	7	8		Total	46	48	52	48
	Total	13	15	15	17		Net Score	536	410	509	577

The first theme evaluated was safety which prioritized vulnerable road users. The highest scores were given to alternatives 1 and 4, followed by 3 and finally 2. Conflicts were distinguished between modes, with each alternative scoring similarly, less alternative 2, due to its inherently conflicting nature. In regard to Design Utility, specifically traffic impacts, all categories scored well except alternative 2 due to motorists' flow being disturbed by moving cyclists. Transit integration showed to be polarizing as alternatives 1 and 4 scored very well, while alternatives 2 and 3, received lower scores due to the need for transit to merge through traffic. Accessibility showed exemplary results in all alternatives except 2. Operations and maintenance was a strong suit of all alternatives since the current maintenance practices were adopted and improved. Finally, constructability received scores ranging from 4 to 9. Alternatives 2 and 4 received the highest, due to their simplicity, while alternative 1 being more complicated scored the lowest. Cost was distinguished between materials and construction cost, as well as the need for external infrastructure upgrades. Initial costs ranged significantly, with Alternatives 1 and 4 scoring lowest, due to their complexity and need for concrete work. Alternatives 2 and 3 scored significantly higher as much of their work involved primarily line painting. External infrastructure upgrades followed this trend, with alternatives 1 and 4 being more expensive. The alternative with the most waste generated was alternative 1, while the other alternatives scored relatively low due to their simplicity. Green space potential scored similarly across the board, as all alternatives make good use of street furniture and available space.

## 4.2 Qualitative Methodology

The advantage of the qualitative method stems from an emphasis on the stakeholders at hand. Stakeholders are identified by C, BD, BP, P, Ci and M; Cyclists, Bus Drivers, Bus Passengers, Pedestrians, the City/Municipality and Motorists. Using the previously defined evaluation criteria for the

quantitative evaluation, this method compares the effectiveness of each alternative to the status quo, with respect to the stakeholders. As seen in Table 2, arbitrary values of 1,0,-1 were assigned corresponding with a colour scheme of green, yellow, and red respectively for ease of visual interpretation and analysis. If a factor belonging to a criteria improved the user experience for a given stakeholder, a value of 1 was assigned. A value of -1 was assigned if a user's experience was worsened and a value of 0 was assigned if there was no change. The culmination of all scores for each stakeholder will aid in identifying the best design. Like the quantitative method, the scores for this method were generated holistically to avoid bias.

Table 3: Results of qualitative evaluation

	Alternative 1						Alternative 2						Alternative 3						Alternative 4					
	C	BD	BP	P	Ci	M	C	BD	BP	P	Ci	M	C	BD	BP	P	Ci	M	C	BD	BP	P	Ci	M
Perceived Safety	1	0	-1	0	0	0	-1	-1	0	0	-1	-1	1	0	0	0	0	0	1	1	0	0	0	1
Safety																								
Cycle-Passenger Conflict	-1			-1			0			0			0			0			0			0		
Cycle-Bus Conflict	1	1					-1	-1					1	1					1	1				
Cycle-Vehicle Conflict	1					1	-1					-1	0					0	1					1
Bus-Vehicle Conflict		1						0						0						1				
Traffic Impacts	1	1		1		-1	-1	-1		0		-1	0	1		0		0	1	1		1		-1
Transit Integration			1	1				-1	1					1	1					1	1			
User Comfort	1	1	-1	1		-1	-1	-1	0	0		-1	1	1	0	0		0	1	1	0	0		-1
Design Utility																								
Attractiveness	1	1	1	1		1	0	0	0	0		0	0	0	0	0		0	0	0	0	0		0
Accessibility	1		1	1			-1		1	1			1		1	1			1		1	1		
Street Furniture Utility	1		1	1			0		1	1			0		1	1			1		1	1		
Operation and Maintenance		1				0		-1				0		1				-1		1				0
Constructability						-1						-1						-1						0
Cost																								
Materials and Const. Cost						-1						-1						-1						0
External Infra. Upgrades						0						0						-1						0
Constructability						-1						-1						-1						-1
Operation and Maintenance						0						0						-1						0
Environment																								
Construction Waste						-1						-1						-1						0
Green Space: Planters						1						1						1						1
Score (%)	78	88	33	57	-38	17	-67	-75	50	29	-38	-67	44	63	50	29	-75	0	78	88	50	43	0	17

### 4.3 Alternative 1: Pedestrian Island

The first alternative, the bus stop island, was evaluated and showed a positive result overall. The culminating colour was green which shows that in comparison to the status quo, the bus stop island showed an overall improvement. Further analyzing the design, safety scored a net benefit, clearly improving the safety of most stakeholders due to the effective use of channelization and the mitigation of bus/vehicle interactions with cyclists. Cyclist-passenger conflicts showed a net decrease as passengers are now required to cross a live cycle track. This conflict is less critical however than conflicts between vehicles and pedestrians/cyclists which have a higher level of KSI collisions. Overall, most conflicts are eliminated by implementing this design, and safety is inherently improved. The analysis of the design utility shows a net benefit result as it proves to be more accessible, and visually appealing to all stakeholders across the board. Constructability also shows a net decrease due to the increased complexity of the design. Traffic impacts are minimal but likely to improve for most stakeholders. The costs of the design is larger due to the requirement for more materials, space, and labour to construct. As a result most categories show a net decrease in this regard. Fortunately for maintenance it is believed that the the costs should be similar to the status quo. The environment is relatively unaffected but the addition of "green" street furniture will certainly benefit the design.

The benefits are clear based on the safety and design utilities of this particular model. The negative effect on bus passengers is relatively small, and the overall improvements outweigh the negative factors which were discussed. As a result of this qualitative assessment this design is to be the frontrunner since design alternative 4 will be excluded for the purposes of this study.

### 4.4 Alternative 2: Cycle Track Around Bus

As discussed, this alternative requires the bus to merge at two points, it is largely for this reason that it scored poorly in the evaluation. While this design served well in both the accessibility and street furniture

portions of design utility it scored poorly in nearly every other category. Perceived safety is sorely lacking for all stakeholders and negative scores were assigned. While there is no cycle-passenger conflict, or an impact on bus vehicle conflicts, there is a potential for cycle-bus and cycle-vehicle conflicts, which are some of the most severe.

As the bus has to merge twice the scores for design utility and user comfort are negative. Attractiveness, accessibility and street furniture utility are strengths of this design as they showed positive or neutral scores. Operation and maintenance as well as constructability scored poorly, due to its intricacy. Cost has scored poorly as the additional elements of safety are more expensive than the status quo however, this alternative does not require any external infrastructure upgrades. Environmental scores for this alternative vary depending on the category. While the potential for green space is improved over the status quo, the construction waste is increased. This alternative clearly scores the worst among the four analyzed in this report, largely due to safety as there are more potential conflict points when compared with other alternatives. For this reason, it will not be recommended further.

#### **4.5 Alternative 3: Sidewalk Cut**

In Alternative 3, the sidewalk is cut back to allow adequate space for a bus to safely pull out of the lane of traffic. This alternative scored well in the quantitative evaluation as it is the status quo but with additional safety measures. Safety was enhanced by the additional signage, coloured zones, and grade separation clearly indicating the right-of-way. The design utility of this concept scored higher than the status quo due to the improved use of space, additional greenery, safer delineation, and improved conflict resolution. This alternative improves the existing traffic for motorists by allowing the bus to fully merge out of the lane of traffic. The transit integration is improved due to the less ambiguous right of way between cyclists and buses. The accessibility is improved for cyclists of all ages and abilities and more space is implemented in the design to comply with the Accessibility for Ontarians with Disabilities Act (AODA).

This option is easy to maintain with the use of plows and sweepers. Overall the alternative is a low cost option but requires some additional expenses such as the added pavement markings. Maintenance fees may also be lowered as the existing facility has a high cost to replace damaged bollards and faded pavement markings. The sidewalk cutaway design allows for a properly planned urban landscape and had a positive score in the category of street furniture. The design can be easily integrated into many reconstruction projects and requires minimal disruption of existing traffic networks. It is recommended to be further analyzed for future use where inadequate right of ways make it difficult to implement Alternative 1.

#### **4.6 Alternative 4: Relocating the Cycle Track**

The final alternative, relocating the cycle track into the left lane, appeared to show the best result of all the alternatives. In comparison to the status quo it is either better or equivalent in almost all aspects, except for motorist traffic impacts and comfort, and the city's constructability concerns. With regards to safety it scored positively in most categories as the bus-bicycle conflict is completely eliminated for all bus stops, as well as bus-vehicle merging conflicts. The actual conflicts between cyclists and motorists are the same as the status quo, the only difference being a conflict with right turns as opposed to left turns. As for design utility, this design essentially takes the existing design and improves it. This design offers the chance to reorganize sections of roadways and more appropriately place boarding areas, drop-offs, and bus stops. Further traffic analysis will be required to determine if re-timing signals or if protected left phases are warranted. The cost observed no comparable difference under the assumption that any new cycle track will also be raised but may require the installation of new signal heads and signage for the protected left turns.

Overall this alternative appears to be superior. It eliminates the majority of existing conflicts, does not create any additional conflicts between motorists and cyclists, is easy to implement, and the operations and maintenance can be completed using existing equipment and methodologies. However, it is not recommended to pursue this alternative further for this project. The relocated cycle track is only feasible

on the Richmond-Adelaide corridor, and largely cannot be used elsewhere in the cycle track network. The goal of this project is to create a standardized bus stop that the City of Toronto can adhere to while expanding or enhancing their cycle track network. We strongly recommend that this alternative be investigated further and potentially a new standard be created for the Richmond-Adelaide Corridor between Bathurst Street and Parliament Street.

## **5 WARRANTS**

This section aids in simplifying the selection process for designing bus stops at cycle tracks. The designs in question are the sidewalk cutaway, and pedestrian island. The Sidewalk Cutaway design is advantageous in cases where there is a restricted ROW and the island is beneficial in areas of high cycle/bus ratio. A low bus volume may suggest the simple sidewalk cutaway be advantageous. Additional warrants can be found below assuming a cycle track is warranted by surpassing 2000 cyclists/day as follows: If two or more of the following warrants are true, the Sidewalk Cutaway should be used, otherwise the Pedestrian Island is to be used. All warrants should be considered in the peak hour for all transportation modes (# of cyclists, pedestrians, motorists, and busses):

1. The roadway operates at 60% capacity or greater.
2. The volume of Cyclist/Bus ratio is equal to or greater than 2.
3. The volume of Cyclist/Pedestrian ratio is equal to 3 or less.

Special provisions should occur for areas where there is a high number of conflicts between cyclists and buses, cyclists and pedestrians or cyclists and vehicles or the location has a history of collisions.

## **6 CASE STUDY**

A case study was taken at TTC stop #11887 to showcase how the newly developed standards can be implemented during a road reconstruction of Adelaide St. West. This street has an average daily cyclist count of 2564 during an 8hr period for 2016 (City of Toronto 2018) and approximately 62 buses/day at this location between Monday to Friday (Toronto Transit Commission 2018). This is a midblock stop with access points on either side of the stop, one being a private access and the other being Peter St. This creates a unique longitudinal space restriction that may impact the design of the pedestrian island. The large right-of-way has provided an adequate width to implement either alternative 1 or 3, the bus island or sidewalk cutaway, as they were the top scoring. Stop #11887 is host to street furniture that blocks the boarding and alighting of public transit customers. This is another characteristic that will showcase the two design's abilities to adapt to a variety of conditions.. The accessibility of the stop and overall appeal of the area will be improved with either design choice. This has been applied through the use of tactile strips, street furniture and coloured conflict zones. Grading and drainage are major considerations that pose a concern in any design. The extensive underground utilities in this region create a challenge in handling drainage and special attention has been provided to this matter. The island itself will feature a heated concrete pad to minimize maintenance operations whereas the sidewalk cutaway will not require this attribute due to its linear design. Asphalt concrete will be utilized for the stop as there is no concern of rutting due to the low bus volume. A bus shelter is optional for this location due to the minimal rider usage but benches have been provided in designated areas. Right-of-ways have been clearly established with pavement markings, lines, and grade separations. A sample model of the pedestrian island has been provided in Figure 4 below:





Figure 4: Model of the pedestrian island implemented at TTC Stop #11887

## 7 CONCLUSIONS

Four design alternatives have been created in this project as standardized solutions for transit stops that interact with cycle tracks. This report hosted a series of challenges such as, no software being able to analyze the impacts of each alternative and there being no current accepted references for these facilities in Ontario. After undergoing a detailed qualitative and quantitative evaluation of all four alternatives, some conclusions can be drawn about which alternatives show the most promise, and which alternatives to continue forward with. The leading design in both the qualitative and quantitative evaluations was design alternative #4, relocating the cycle track to the opposite side of the road on one-way streets. This design alternative is the simplest, and most effective, but due to the fact that its use is limited to one-way streets, selecting this as a standardized option is not feasible and this option will be intentionally overlooked. This being said, it is recommended that an additional project be opened that focuses on this alternative as the primary option for one-way streets. Design alternatives #1 and #3, the bus-stop island and the sidewalk cutaway respectively, both scored relatively well on the qualitative and quantitative evaluations. Although the bus-stop island scored slightly higher than the sidewalk cutaway, the space limitations that exist on many streets make this space-intensive design difficult to standardize on its own. As a solution, the recommended approach is to combine both the bus-stop island and the sidewalk cutaway alternatives into a single city standard. The bus-stop island will always be the first choice, but on streets where space is limited, the sidewalk cutaway will be implemented as a second option that is almost as effective. The trade-off in efficiency and effectiveness is minimal as shown by the qualitative and quantitative assessments which makes this dual standard approach not only possible, but preferred.

## Acknowledgements

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