Transitway Station Design Safety Audit – Analysis of Findings

Final Report

Prepared for:

OC Transpo
City of Ottawa

[09.28.21] : Intus Road Safety Engineering Incorporated

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Ottawa, Ontario, Canada

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1.0 INTRODUCTION

1.1 Background

1.1.1 In 2020, OC Transpo commissioned an independent station design safety study of five stations on the OC Transpo Transitway. The study was conducted by Parsons Inc. and generated a road safety audit report titled ***OC Transpo Transitway Station Design Safety Study – Independent Road Safety Study***, dated September 2021. The audit was conducted in general compliance with the procedures described in the ***Canadian Road Safety Audit Guide*** produced by the Transportation Association of Canada in 2001

1.1.2 The stations included in the audit were: Pleasant Park, Westboro, Fallowfield, Longfields, and Hurdman. The audit identified 37 safety issues broken down as follows.

Station	No. of Issues
Pleasant Park	7
Westboro	15
Fallowfield	4
Longfields	5
Hurdman	6
All	37

1.1.3 In addition to the above, the auditors also made five suggestions as a result of benchmarking the current design of the Ottawa Transitway with Bus Rapid Transit guidelines from the City of Winnipeg (MB) and the City of Calgary (AB).

1.1.4 An integral part of any road safety audit is the preparation of a response report.

1.1.5 OC Transpo has retained ***Intus Road Safety Engineering Incorporated*** (Intus) to conduct a review of the audit findings, form independent responses to the audit findings, and present the recommendations (along with the rationale) for OC Transpo to consider implementing.

1.1.6 Intus has had no involvement in the safety audit or the design of the Transitway stations under study.

1.1.7 The purpose of Intus' assignment was to review the audit team suggestions for the five transitway stations, conduct whatever analysis deemed appropriate, and provide a professional engineering opinion outlining a proposed response for each suggestion along with supporting rationale.

1.1.8 To be clear, this report is for the information of OC Transpo and does not constitute a response report. OC Transpo will prepare a separate response report to the audit findings.

1.2 Road Safety Audit Response Reports

1.2.1 A road safety audit response report is a key document in the road safety auditing process. The response report outlines the actions to be taken (if any) for each of the identified safety issues. There are four categories of responses:

1. Agree and implement: The Owner agrees with the identified safety issue and will implement the audit team suggestion to mitigate the risk.
2. Agree and adapt: The Owner agrees with the identified safety issue and will implement a solution to mitigate the risk that was not suggested by the audit team.
3. Agree and take no action: The Owner agrees with the identified safety issue but will not implement a solution to mitigate the risk because of budget, land use, or other valid constraints or competing objectives.
4. Disagree: The Owner does not agree that the identified safety issue is a valid concern.

1.2.2 In the instance that a response from category 3 or 4 is appropriate, then the reasons for not taking actions must be explicitly and fully described in the response report.

1.2.3 In the end, the responsibility for the final design and operation of the Transitway rests with the Owner and not with the road safety auditor.

2.0 ROAD SAFETY AUDIT FINDINGS/SUGGESTIONS AND PROPOSED RESPONSES

2.1 PLEASANT PARK STATION

Issue 1: No speed transition zones
Auditor's Suggestion: Install appropriate speed zoning in terms of sign spacing. Sign spacing should be 100-150m to allow bus drivers to slow at an appropriate deceleration rate for passenger comfort and safety.

Analysis
According to the audit report, the speed transition zone is meant to address an elevated rear-end crash risk resulting from speed differentials proximate to the 80 km/h to 50 km/h speed threshold, and an increase in the general crash risk presented by vehicles operating at too high of an operating speed at the entrance to the station.

Intus respectfully disagrees that the current speed zoning, which includes a transition to/from an 80 km/h speed limit to/from a 50 km/h speed limit at the entrance/exit to the Pleasant Park station is a material safety issue. The 50 km/h speed zone starts a suitable distance upstream of the station platform, and there is no information to suggest that operators are ignoring the 50 km/h speed limit and operating at too high of a speed. Similarly, there is no evidence of different operator's reacting differently to changes in

the speed limit. The Transitway is a private road where there is generally a substantial headway between vehicles operating in the same direction, operators are well-trained, and operators are subject to discipline for not following the rules-of-the-road. Based on OC Transpo records, there have been only two crashes at the Pleasant Park station in the last five years. Inappropriate operating speed was not a contributing factor in either crash.

At any rate, it is not common practice for speed transition zones (i.e., intermediate speed limits) to be used on the Transitway[1]. Most importantly, the best available evidence on transitional speed zones indicates that they are ineffective in achieving any significant reduction in operating speeds.[2]

The typical and accepted practice for demarcating a speed transition from 80 km/h to 50 km/h is the posting of a MAXIMUM SPEED AHEAD sign (Rb-5) a suitable distance upstream of the start of the 50 km/h speed limit.

Recommendation for OC Transpo
OC Transpo should review the northbound approach to the Pleasant Park station and ensure that the MAXIMUM SPEED AHEAD sign (Rb-5) is in place and visible to operators.

Issue 2: Advisory speed signing for the reverse curve is in one direction only
Auditor's Suggestion: Install an advisory speed sign Tab of 40 km/h with the curve sign in the southbound direction.

Analysis
Curve warning signs on the Transitway are an important safety feature and should comply with the recommendations contained in *Ontario Traffic Manual Book 6 – Warning Signs* (MTO, 2001). Based on OTM Book 6 criteria[3], SHARP CURVE or REVERESE SHARP CURVE sign should be erected in advance of curves with a 40 km/h advisory curve speed.

Recommendation for OC Transpo
OC Transpo should implement the auditor's suggestion and ensure that the new sign complies with OTM Book 6 – Warning Signs, with respect to sign size, colour, and placement.

Issue 3: Northbound reverse curve warning sign is located south of the station
Auditor's Suggestion: Relocate the reverse curve sign north (downstream) of the Pleasant Park Station for northbound operations and for southbound operations locate the reverse curve sign south of the Riverside Station.

[1] While there are select instances where a speed limit other than 50 km/h or 80 km/h is used on the Transitway, this is the exception rather than the rule.
[2] Hildebrand ED, Ross A, Robichaud K "The Effectiveness of Transitional Speed Zones", ITE Journal, October 2004, 30-38.
[3] See Table 5 of OTM Book 6 – Warning Signs (MTO, 2001)

Analysis

While Intus agrees that the northbound REVERSE CURVE sign positioned upstream of the Pleasant Park station is located in an area of high driver workload, Intus respectfully disagrees with the auditor's suggestion of relocating the sign to a point downstream of the station.

Positioning the REVERSE CURVE sign downstream of the Pleasant Park station would locate the sign 30 metres of less from the start of the curve. *OTM Book 6 – Warning Signs*, which is the prevailing guideline concerning the longitudinal placement of warning signs on Ontario roadways, specifies that the minimum distance upstream of the start of the curve that a 40 km/h REVERSE CURVE sign should be placed on a facility with a 50 km/h posted speed limit is 95 metres (see Table 1).

TABLE 1: Minimum Distance from Hazard to Warning Sign
[Source:OTM Book 6]

(km/h)	Final Speed	90	80	70	60	50	40	30	20	10	0
Posted (Initial) Speed	Minimum Advance Distance (m)										
100		250	295	335	370	400	420	440	455	460	465
90			230	270	300	330	355	370	385	395	395
80				205	240	270	290	310	325	330	335
70					185	210	235	255	265	275	275
60						160	185	200	215	225	225
50							95	115	130	135	140
40								80	90	100	100
30									60	70	70

* Based on 2.5 seconds brake reaction time (source: *Ontario Geometric Design Manual*) and 5.3 km/hr/s deceleration time (source: *ITE Transportation and Traffic Engineering Handbook*).

While relocating the REVERSE CURVE sign from its current location to one downstream of the station will place the sign in a lower workload environment, it creates a new safety issue for operators who are not stopping at the Pleasant Park station. Specifically, operators who are moving through the station at the 50 km/h posted speed limit require the information concerning the advisory curve speed before passing through the station in order to perceive and react to the sign (i.e., see the sign, remove the foot from the accelerator, and adjust speed accordingly).

Operators who stop at the Pleasant Park station will be accelerating from a stopped position about 40-50 metres in advance of the start of the curve.[4] At a moderate acceleration rate of 1.0 m/s^2, these stopped buses will only achieve a speed of 36 km/h at the start of the curve. In brief, bus operators that stop at the Pleasant Park station do not need to be warned of the 40 km/h advisory speed at the reverse curve, because they are unlikely to achieve an operating speed that is significantly higher than the advisory speed. The REVERSE CURVE sign and the associated 40 km/h advisory speed tab are intended

[4] As measured from aerial photography and estimating the start of the reverse curve.

to provide important information concerning speed and path to operators who do *not* stop at the Pleasant Park station (i.e., through buses). While through bus operators are attentive to activity and vehicle movements within the station, the curve warning information is salient to their particular task and this information is needed sufficiently far upstream of the curve. This being the case, the best location for the northbound REVERSE CURVE signs is the current location.

Having stated the above, the safety issue of having a station between the reverse curve and the REVERSE CURVE sign can be mitigated by providing better curve delineation. In addition, to providing advance warning of the curve, post-mounted delineators or CHEVRON ALIGNMENT signs should be erected to provide additional guidance to bus operators who do not notice, remember, or attend to the REVERSE CURVE sign. These aforementioned traffic control devices highlight the actual curve in the Transitway downstream of the subject station, and will deliver important visual information to operators concerning the horizontal alignment of the Transitway.

Recommendation for OC Transpo
It is recommended that OC Transpo supplant the auditor's recommendation to relocate the advance warning sign with the implementation of post-mounted delineators or CHEVRON ALIGNMENT signs on the subject curve. All traffic control devices should be erected in accordance with OTM guidelines.

Issue 4: No energy attenuation at the median barrier ends
Auditor's Suggestion: Install an appropriate TL-3 crash cushion attenuator in place of the sloped end. A picture of the TL-3 crash cushion attenuator is shown below.

Analysis
The sloped ends of the concrete median barrier at the Pleasant Park station present an elevated crash severity risk. The prevailing guidelines for traffic barriers in Ontario, do not recommend these types of end treatments for new installations and repairs. Having stated the above, it is recognized that the Pleasant Park installation is not a new installation and is not currently in need of repair. This being the case, the typical approach for deciding on whether to retrofit an out-dated barrier end treatment is to conduct a risk assessment and economic analysis (e.g., benefit-cost ratio).

The crash risk proposed by the exposed median end was estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Pleasant Park station: 540 vehicles per day per direction [Source: OC Transpo]

- Design speed[5]: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Median shoulder width: 1.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of exposed end of barrier: 7.25 m [OPSD 923.383]
- Width of exposed end of barrier: 0.8 m [Figure 4.2.3a of Transitway and Station Design Guidelines]

Based on the above parameters, the expected number of crashes with each exposed barrier end is 0.00351 crashes per year, or one crash every 285 years. Within a typical crash risk profile (see Table 1), this is considered a low risk.

Table 1: Road Crash Risk Matrix

		Crash Frequency				
		More than one per year	One every 1-4 years	One every 5-10 years	One every 10-100 years	Less than on every 100 years
Crash Severity	Fatal	**Very High**	High	High	Medium	Low
	Injury	High	High	Medium	Low	Low
	Property Damage Only	Medium	Medium	Low	Low	Low

Due to the relatively low crash risk there is no urgency to this safety issue. The recommended action is to leave the current end treatment in-service, and to replace the end treatment with a TL-3 crash cushion when this section of the Transitway is reconstructed or when the barrier needs to be replaced. However, it is acknowledged that the current end treatment is technically a hazard, and it should be delineated accordingly with proper signing.

Recommendation for OC Transpo

It is recommended that OC Transpo install TL-3 crash cushion attenuators at each end of the median barrier when the Transitway at this location is due to be reconstructed, or the

[5] ***Design speed*** is a theoretical value selected by the facility owner/designer that is used as a basis to establish appropriate geometric design elements and dimensions for a section of road. The design speed allows a designer to coordinate and harmonize the different elements of design to provide safe and efficient movement of traffic. The prevailing standards for the Transitway (i.e., the OC Transpo Transitway and Station Design Guidelines, June 2013) indicate that the minimum design speed shall be 90 km/h for the transitway outside of station areas and 60 km/h for the transitway through station areas. The limits of the station area are between the upstream ends of the tapers used to introduce the deceleration lanes for both directions of travel at the station (see Figure 3.6.1 in the Transitway and Station Design Guidelines).

median barrier is due to be replaced. In the interim, OC Transpo should review the traffic signs and ensure that a KEEP RIGHT sign (Rb-25) and an OBJECT MARKER (Wa-33L) are properly posted at each median end, per the guidance of Ontario Traffic Manual Book 6 – Warning Signs.

Issue 5: Service vehicle access curb letdown located at the nearside of station
Auditor's Suggestion: Replace the letdown curb on the approach end of the station platform with a 150mm high barrier curb. The letdown curb on the departure end of the station platform can remain. Note potential design guideline implication - locate curb letdown far side of station and curb height should be higher at BRT Stations, namely a raised platform 200mm (8") to 250mm (10") (reference to APTA BRT Stations and Stops Recommended Practice).

Analysis
Whether a roadside curb is likely to redirect an errant vehicle, is dependent on many factors, including but not limited to, the curb height and shape, the angle of departure from the roadway, the vehicle speed at impact with the curb, and the vehicle specifications (mass, tire size, etc.). Full-scale tests on the redirection capabilities of 150 mm high barrier-type curbs indicates that these elements of the roadside have almost no ability to redirect errant vehicles at speeds above 26 km/h, regardless of the angle of departure (see Figure 2).[6] Therefore, while the idea of replacing the depressed curb with a 150 mm barrier curb is intuitively appealing, the research indicates that this action is not likely to mitigate the identified safety issue.

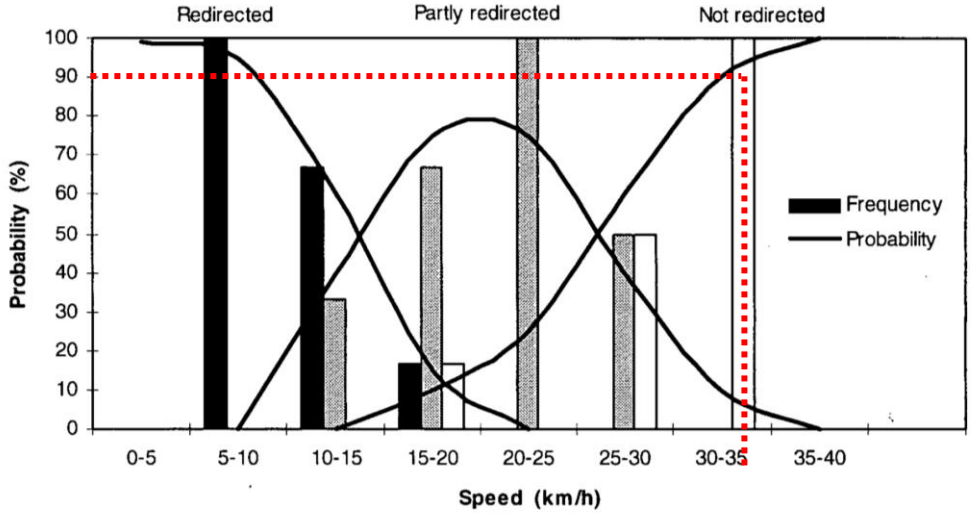

FIGURE 2: Probability of Redirection When Striking a 150 mm Barrier Curb at an Approach Angle of 5°

[6] Lafond N "Redirection Effectiveness of Roadside Curbs", Thesis, University of British Columbia, Faculty of Graduate Studies, Department of Civil Engineering, September 1997

The above assertion is also supported by the prevailing guidelines on roadside safety in Ontario[7]. These guidelines state that curbs are commonly used to control drainage, reduce maintenance operations, and delineate the travelled way, and that curbs do not have significant redirectional capability. Moreover, the guidelines state, if an errant vehicle is spinning or slipping sideways an impact with a curb may cause the vehicle to become airborne or cause the vehicle to trip and rollover. In brief, the purpose of a curb is drainage and delineation – not redirection of errant vehicles. The guidelines also note that curbs are often used in low-speed urban environments to discourage drivers from *deliberately* departing a roadway. This is not an issue on the Transitway, which is closed to the general driving population.

While current good practice in Transitway design is to locate the access to the service bay downstream of the platform, the Pleasant Park station was designed and built many years ago and was built in compliance with the standards of the day.

Recommendation for OC Transpo
It is recommended that OC Transpo take no action on relocating the service bay to downstream of the station due to the limited effectiveness of barrier curbs in redirecting errant vehicles. It is also recommended that, when the station is reconstructed, the guidelines for service bay placement and design conform to the prevailing best practices.

Issue 6: No protection for transit patrons on platform from an errant vehicle
Auditor's Suggestion: An 810mm high TL-3 concrete barrier with an appropriate length of need and taper is suggested to shield waiting passengers from an errant bus mounting the curb on the approach end of the station platform.

Analysis
With respect, Intus does not agree that the lack of a roadside barrier at the Pleasant Park station presents an undue crash risk for transit patrons on the platform.

This is not a high-speed facility, has a relatively low volume of traffic, and is only used by professional drivers. Furthermore, the MTO Roadside Design Guide (2017), which is the prevailing guideline, states that "[u]nder certain conditions on certain facilities, barriers may also be used to separate high speed vehicular traffic from other facilities such as pedestrian sidewalks, active transportation paths, and snowmobile trails." The guidance indicates that barriers are permitted and not recommended or required.

The use of traffic barriers to protect pedestrians at the roadside is generally reserved for schools, playgrounds, and parks located on the outside of sharp curves or across from T-intersections. In other words, barriers are reserved for locations with intense pedestrian activity where there is also an elevated probability of a vehicle leaving the roadway and striking a person or persons. The Pleasant Park station is on a tangent section of the Transitway, has a 50 km/h posted speed limit, and there is no reason to expect that the

[7] Roadside Design Manual, Ontario Ministry of Transportation, Highway Standards Branch, Design & Contract Standards Office, December 2017

risk of a vehicle leaving the travelled way is any different/greater at the Pleasant Park Station than the risk presented along a typical arterial street in the Ottawa area.

The crash risk to pedestrians resulting from errant vehicles was estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Pleasant Park station: 540 vehicles per day per direction [Source: OC Transpo]
- Design speed: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Shoulder width: 0.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of platform: 55 m [OC Transpo Transitway Design Guidelines]
- Width of the platform: 6 m [OC Transpo Transitway Design Guidelines]

Based on the above parameters, even if pedestrians were standing shoulder-to-shoulder at the edge of the platform, along the entire length of the platform, at all times of the day, the expected number of crashes is expected to be 0.01108 crashes per year, or one crash every 90 years. Given that pedestrians do not generally stand at the edge of the platform, they are not always present, and do not line the platform, this is a relatively low crash risk.

Given the relatively low vehicular traffic volume and the 50 km/h posted speed limit, the potential for vehicles encroaching on the platform is very low.

Recommendation for OC Transpo
It is recommended that OC Transpo take no action on this audit findings as there is no undue risk presented by providing an unshielded station platform.

Issue 7: Concrete abutment end located in clear zone
Auditor's Suggestion: Remove the concrete abutment or shield it with an appropriate length of need and taper of a TL-3 concrete barrier.

Analysis
The subject "abutment" is actually a concrete wall that located within the clear zone of the Transitway. City staff have determined that this concrete wall is integral to the structure of the station and cannot be removed. With respect to shielding the wall, the minimum clear zone for a facility with a 60 km/h design speed and a barrier curb *at the time the Pleasant Park station was designed and constructed* was only 0.5 metres.[8] This is an instance of a facility that was constructed in accordance with the standards-of-the-day, that became "substandard" because the clear zone requirement was revised post-

[8] See Table 2.2.1 in the Roadside Safety Manual, Ontario Ministry of Transportation, Quality & Standards Division, 1993.

construction. As with the now "substandard" median end treatments at the Pleasant Park station, the need and/or urgency to correct this substandard condition is typically determined using a risk analysis.

The crash risk proposed by the unprotected concrete wall was estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Pleasant Park station: 540 vehicles per day per direction [Source: OC Transpo]
- Design speed: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Shoulder width: 0.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of exposed end of barrier: 7.25 m [standard length of a TL-3 energy attenuator, per OPSD 923.383]
- Width of exposed end of barrier: 0.35 m [measured on site]
- Offset from travelled way to concrete wall: 1.2 m [measured on site]

Based on the above parameters, the expected number of crashes with the exposed end of the concrete wall is about 0.00159 crashes per year, or one crash every 629 years. Within a typical crash risk profile (see Table 1), this is considered a low risk.
Given the above, the recommended action is to leave the concrete wall, and to provide a more suitable clear zone when this Transitway station is scheduled for reconstruction. Nonetheless, it is acknowledged that the current exposed end of the concrete wall is a hazard within the clear zone and it should be delineated accordingly with proper signing.

Recommendation for OC Transpo
It is recommended that OC Transpo ensure proper clear zones are provided at this station when the station is due to be reconstructed. It is further recommended that OC Transpo erect an OBJECT MARKER (Wa-33R) on or directly in front of the upstream end of the concrete wall in accordance with the guidance of Ontario Traffic Manual Book 6 – Warning Signs.

2.2 Westboro Station

Issue 8: Jagged rock face and wall surface protrusions
Auditor's Suggestion: Install an appropriate length of need and taper of an anchored TL-3 F-Shape concrete barrier or a Cast-In-Place TL-4 F-shape concrete barrier. The barrier should be installed 1m offset from the edge line.
(Note: An unanchored concrete barrier could shift or deflect by a maximum 1.8 metres if hit by a heavy vehicle but bus would be less [sic]. Any barrier used on the Transitway must have a FHWA acceptance letter specifying the Test Level (TL).)

Analysis

A jagged rock face increases the potential for higher severity crash in the event that an errant vehicle makes contact with the rock face. However, it is not axiomatic that an exposed rock face is a more severe hazard than a concrete barrier located 1.0 metres from the travelled way. According to the Roadside Design Guide the severity indices for rock cuts and concrete barriers are as shown in Figure 3.[9]

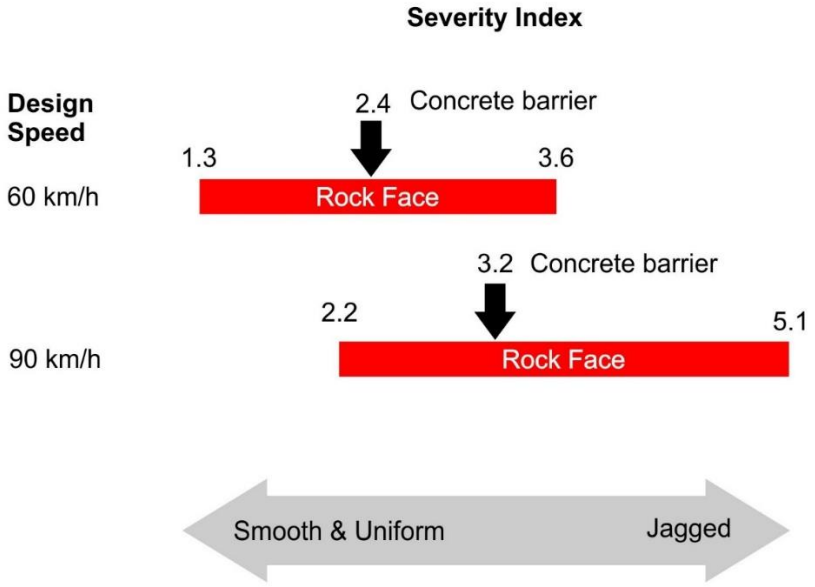

FIGURE 3: Severity Indices for Rock Cuts and Concrete Barriers

Whether the concrete barrier is a less severe hazard than the rock face is very much dependent on the smoothness of the rock face. The difference between smooth and jagged is not defined in the Roadside Design Guide. Moreover, because the proposed concrete barrier would be located closer to the Transitway, the barrier would result in a higher frequency of crashes than the exposed rock face. Hence, installing a traffic barrier may be detrimental to safety if crashes with the rock face are infrequent.

What can be concluded from the above information is that ensuring the rock cut is smooth and uniform is preferable to erecting a concrete barrier, from a crash severity and crash frequency perspective. The smooth and uniform rock cut has a lower severity index then a concrete barrier and would be located further from the Transitway.

A risk analysis and economic evaluation of the exposed rock face versus installing a TL-3 precast concrete barrier or scaling the rock face to provide a smooth rock face was

[9] A severity index is a number from zero to ten used to categorize the potential severity of an encroachment or impact by an errant vehicle for a range of design speeds over a variety of surfaces and slopes, fixed objects and natural features within the roadside environment. The number is used for evaluating alternative safety treatments. A severity index of 10 indicates that impact with the roadside object will almost certainly result in a fatal crash; a severity index of 0 suggests the likely outcome of any crash will be property damage only.

estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Westboro station: 1500 vehicles per day [Source: OC Transpo]
- Design speed: 90 km/h design speed [OC Transpo Transitway Design Guidelines][10]
- Two-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Shoulder width: 0.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Unit cost of a precast TL-3 barrier: $204/m[11]
- Assumed cost for rock scaling 100 linear metres of rock face: $50,000

The initial condition was assumed to have a jagged rock face with a severity index of 5.1, while the scaled rock face was assumed to be smooth, with a severity index of 2.2. Based on the above parameters, the crash frequency is (as expected) greatest when a concrete barrier is placed adjacent to the Transitway to shield the rock face. Furthermore, while the severity of the crashes decreases when compared to the existing condition, the cost of installing the barrier, and the limited service life of the Transitway at this location (less than one year, according to City staff), makes the installation of the barrier economical unattractive (i.e., the benefit-cost ratio is less than 1.0). Similarly, the cost of scaling the rock has to be less than $77.50/linear metre of rock face in order for the benefit-cost ratio to be favourable. This unit price seems highly unlikely.

Recommendation for OC Transpo
It is recommended that OC Transpo review the rock cut at this location and conduct rock scaling and other maintenance to the rock face to provide as smooth a rock face as practicable. The cost and effort expended on this initiative should be commensurate with the fact that the Westboro station is to be decommissioned in the second quarter of 2022.

Issue 9: Light areas and shadows due to sun angle
Auditor's Suggestion: Low sun angles cannot be easily mitigated. Driver training, reduced speed and a higher level of winter maintenance are suggested for the short term. In the longer-term better drainage and a flashing beacon activated by a road surface sensor monitoring conditions such as ice and temperature are suggested.

Analysis
The actual safety issue identified by the auditor is patches of ice (and inconsistent road surface friction) that may appear when pavement temperatures drop below the freezing

[10] This calculation is for the rock face is outside of the station area, which is a more safety-critical situation than the rock face within the station area where the design speed is 60 km/h.
[11] This cost is the unit price for a concrete barrier from the Mississauga Bus Rapid Transit Construction Tender – Segment 1 from Hurontario Street to Fieldgate Drive in 2014 ($182) and adjusted for inflation to 2021 cost using the Bank of Canada Inflation Calculator (https://www.bankofcanada.ca/rates/related/inflation-calculator/).

point due to shade on the Transitway caused by the rock cuts on both approaches to the station.

It is acknowledged the there is the potential for ice and snow to accumulate on the Transitway in areas that are shaded from the sun, and that these situations are not easily mitigated. Roadside objects (e.g., high rock cuts, buildings, noise fencing) that are proximate to the Transitway commonly create shade on the travelled way.

In the past five years, there have been a total of 11 crashes at the Westboro station. None of these crashes had ice or snow on the road surface as a contributing factor.

Reducing the speed limit in response to Transitway icing that may occur in the shadows should not be implemented because it will be an ineffective solution. Icy conditions are temporary and sporadic, whereas a speed limit reduction is a full-time measure. In the absence of a proven crash history resulting from icy conditions, it is inappropriate to reduce the full-time speed limit. During times of good weather, the speed limit will be considered "too low" by operators, and the inappropriate speed limit for the conditions will breed disrespect for speed limits in general.

The Westboro station is scheduled to be decommissioned in the second quarter of 2022. Longer-term solutions are inappropriate and should not be considered as the cost of implementation are throw-away and will not provide a favourable benefit-cost ratio.

Recommendation for OC Transpo
OC Transpo should continue to provide appropriate driving training concerning driving during inclement weather, and should continue to provide winter maintenance of the Transitway that meets or exceeds the minimum maintenance standards.

Issue 10: Water and ice on transitway surface cause glare
Auditor's Suggestion: During the site visit it was noticed that snow which had accumulated on the curved roof resulted in snow and water from melting snow falling on the roadway. Eavestrough along the canopy edge is suggested to drain water away from falling on the Transitway.

Analysis
The edge of the canopy is actually set back about 0.5 metres from the face of the Transitway curb and rain/snow is deposited onto the station platform (and not directly onto the Transitway). The drainage system of the station is purposely designed so that surface water from the platform is drained onto the Transitway towards the median (see Figure 4). Unless the proposed eavestrough is directed to an underground pipe that is connected to a subdrain, the eavestrough would simply concentrate the roof runoff at a single point, creating a potentially more dangerous condition.

Recommendation for OC Transpo
OC Transpo should continue to provide winter maintenance of the subject area that meets or exceeds the minimum maintenance standards prescribed by legislation.

Issue 11: Limited intersection sight distance at T-intersection
Auditor's Suggestion: Install a flashing beacon activated by buses at the stop bar to warn westbound buses of the potential turning movement conflict would help reduce the potential for collisions. Install "No Stopping" signs along the north side of the transitway for the extent of the hatched area.

Analysis
Transit vehicles parked or stopped in the subject hatched area do limit visibility for operators entering the Transitway from the access road. As visibility is a primary safety consideration, and the audit recommendation is a low-cost and effective option to address the visibility concern, it is preferable to proceed with the auditor recommendation for NO STOPPING signs.

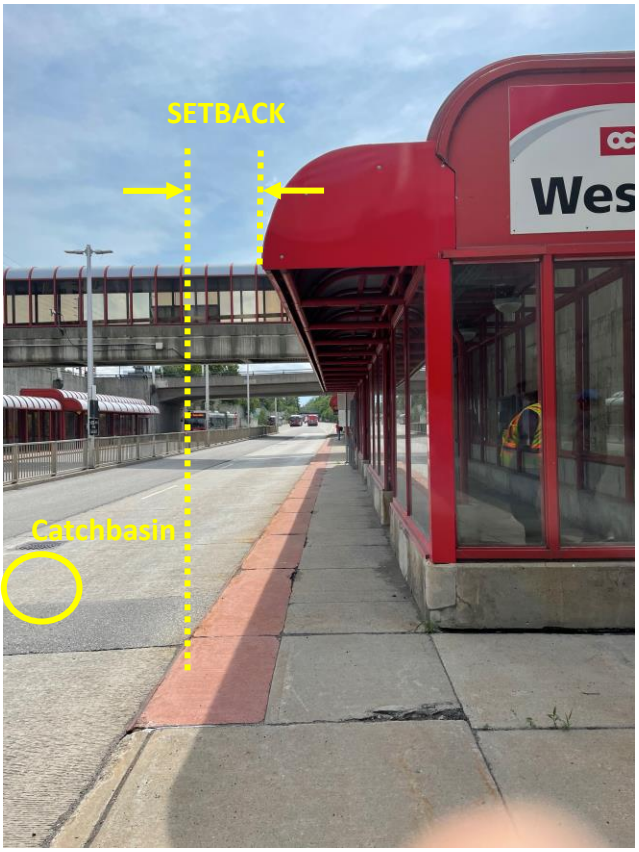

FIGURE 4: Westboro Station Canopy

A bus-activated flashing beacon is a level of traffic control that is generally reserved for locations with fixed objects that severely restrict visibility and/or locations with a record of crashes between conflicting vehicles. Neither of these conditions exist at the subject site, and, in Intus' opinion, it is not prudent to proceed with this auditor recommendation at this time.

Recommendation for OC Transpo
Replace the NO PARKING signs with NO STOPPING signs along the north side of the Transitway for the extent of the hatched area. A traffic-actuated, flashing beacon should only be implemented if the NO STOPPING signs prove to be ineffective, and a record of conflicts/crashes due to limited visibility becomes evident.

Issue 12: Retro reflectivity of traffic signs rated as fair
Auditor's Suggestion: The RSA Team suggests that OC Transpo consider a formalized sign asset management program to ensure traffic signs are replaced before they reach the end of their effective life. The reflective sheeting on the face of traffic signs usually has an effective life of about seven years.

Analysis
Traffic signs that have become less retroreflective since being placed in service present an increased risk of night-time crashes. It is our understanding that OC Transpo is currently developing a retroreflectivity monitoring program and will implement it as soon as practicable. In the interim, the Transitway signs are maintained in accordance with the City of Ottawa Maintenance Quality Standards, and OC Transpo also complies with the provisions of the current version of *Ontario Regulation 239/02 - Minimum Maintenance Standards for Municipal Highways*. These latter maintenance standards prescribe a minimum frequency for inspecting regulatory and warning signs for retroreflectivity of once per calendar year, with each inspection taking place not more than 16 months from the previous inspection.

Recommendations for OC Transpo
OC Transpo should review the Transitway signs at the Westboro station and the approaches to the station and replace any signs that no longer possess the minimum level of retroreflective. Further, OC Transpo should continue to maintain signs in accordance with prevailing standards.

Issue 13: No protection for transit patrons on platform from an errant vehicle
Auditor's Suggestion: An 810mm high TL-3 concrete barrier with an appropriate length of need and taper is suggested to shield waiting passengers from an errant bus mounting the curb on the approach end of the station platform.
Proposed Response:

Analysis
With respect, Intus does not agree that the lack of a roadside barrier at the Westboro station presents an undue crash risk for transit patrons on the platform.

This is not a high-speed facility, has a relatively low volume of traffic, and is only used by professional drivers. Furthermore, the MTO Roadside Design Guide (2017), which is the prevailing guideline, states that "[u]nder certain conditions on certain facilities, barriers may also be used to separate high speed vehicular traffic from other facilities such as pedestrian sidewalks, active transportation paths, and snowmobile trails." The guidance indicates that barriers are permitted and not recommended or required.

The use of traffic barriers to protect pedestrians at the roadside is generally reserved for schools, playgrounds, and parks located on the outside of sharp curves or across from T-intersections. In other words, barriers are reserved for locations with intense pedestrian activity where there is also an elevated probability of a vehicle leaving the roadway and striking a person or persons. The Westboro station is on a tangent section of the Transitway, has a 50 km/h posted speed limit, and there is no reason to expect that the risk of a vehicle leaving the travelled way is any different/greater at the Westboro Station than the risk presented along a typical arterial street in the Ottawa area.

The crash risk to pedestrians resulting from errant vehicles was estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Westboro station: 1500 vehicles per day [Source: OC Transpo]
- Design speed: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Shoulder width: 0.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of platform: 55 m [OC Transpo Transitway Design Guidelines]
- Width of platform: 6 m [OC Transpo Transitway Design Guidelines]

Based on the above parameters, even if pedestrians were standing shoulder-to-shoulder at the edge of the platform, along the entire length of the platform, at all times of the day, the expected number of crashes is expected to be 0.01662 crashes per year, or one crash every 60 years.. Given that pedestrians do not generally stand at the edge of the platform, they are not always present, and do not line the platform, this is a relatively low crash risk.

Given the relatively low vehicular traffic volume and the 50 km/h posted speed limit, the potential for vehicles encroaching on the platform is very low.

Recommendation for OC Transpo
It is recommended that OC Transpo take no action on this audit findings as there is no undue risk presented by providing an unshielded station platform.

Issue 14: Curb height at station only 75 to 100 mm or 3 ½ to 4 inches
Auditor's Suggestion: Rebuild the low curb with a 150mm high barrier curb in keeping with the current transitway design guidelines. Note potential design guideline implication - Curb height should be higher at BRT Stations namely a raised platform 200mm (8") to 250mm (10") (reference to APTA BRT Stations and Stops Recommended Practice).

Analysis
Rebuilding the curb with a 150 mm height will not significantly change this crash risk, because of the limited effectiveness of barrier curbs in redirecting errant vehicles.

Whether a roadside curb is likely to redirect an errant vehicle, is dependent on many factors, including but not limited to, the curb height and shape, the angle of departure from the roadway, the vehicle speed at impact with the curb, and the vehicle specifications (mass, tire size, etc.). Full-scale tests on the redirection capabilities of 150 mm high barrier-type curbs indicates that these elements of the roadside have almost no ability to redirect errant vehicles at speeds above 26 km/h, regardless of the angle of departure.[12] Therefore, while the idea of replacing the 75 to 100 mm curb with a 150 mm barrier curb is intuitively appealing, the research indicates that this action is not likely to mitigate the identified safety issue.

The above assertion is also supported by the prevailing guidelines on roadside safety in Ontario[13]. These guidelines state that curbs are commonly used to control drainage, reduce maintenance operations, and delineate the travelled way, and that curbs do not have significant redirectional capability. Moreover, if an errant vehicle is spinning or slipping sideways an impact with a curb may cause the vehicle to become airborne or cause the vehicle to trip and rollover. In brief, the purpose of a curb is drainage and delineation – not redirection of errant vehicles. The guidelines also note that curbs are often used in low-speed urban environments to discourage drivers from *deliberately* departing a roadway. This is not an issue on the Transitway, which is closed to the general driving population.

While good practice is to provide 150 mm barrier curbs, it is not uncommon for resurfacing projects to result in curb heights that are less than 150 mm. Given that the Westboro station is scheduled to be decommissioned in the second quarter of 2022, the ineffectiveness of barrier curbs in redirecting errant vehicles, and the low probability of an errant vehicle at the station platform, there is no undue crash risk, no urgency, and no imminent need to undertake remedial measures for the low curb height.

Recommendation for OC Transpo
It is recommended that OC Transpo take no action on this audit findings as there is no undue risk presented by the current curb height at the platform.

Issue 15: Service vehicle access letdown at near side of station
Auditor's Suggestion: Replace the letdown curb on the approach end of the station platform with a 150mm high barrier curb. The letdown curb on the departure end of the station platform can remain.

[12] Lafond N "Redirection Effectiveness of Roadside Curbs", Thesis, University of British Columbia, Faculty of Graduate Studies, Department of Civil Engineering, September 1997
[13] Roadside Design Manual, Ontario Ministry of Transportation, Highway Standards Branch, Design & Contract Standards Office, December 2017

Analysis

Whether a roadside curb is likely to redirect an errant vehicle, is dependent on many factors, including but not limited to, the curb height and shape, the angle of departure from the roadway, the vehicle speed at impact with the curb, and the vehicle specifications (mass, tire size, etc.). Full-scale tests on the redirection capabilities of 150 mm high barrier-type curbs indicates that these elements of the roadside have almost no ability to redirect errant vehicles at speeds above 26 km/h, regardless of the angle of departure (see Figure 2).[14] Therefore, while the idea of replacing the depressed curb with a 150 mm barrier curb is intuitively appealing, the research indicates that this action is not likely to mitigate the identified safety issue.

The above assertion is also supported by the prevailing guidelines on roadside safety in Ontario[15]. These guidelines state that curbs are commonly used to control drainage, reduce maintenance operations, and delineate the travelled way, and that curbs do not have significant redirectional capability. Moreover, the guidelines state, if an errant vehicle is spinning or slipping sideways an impact with a curb may cause the vehicle to become airborne or cause the vehicle to trip and rollover. In brief, the purpose of a curb is drainage and delineation – not redirection of errant vehicles. The guidelines also note that curbs are often used in low-speed urban environments to discourage drivers from *deliberately* departing a roadway. This is not an issue on the Transitway, which is closed to the general driving population.

While current good practice in Transitway design is to locate the access to the service bay downstream of the platform, the Westboro station was designed and built many years ago and was built in compliance with the standards of the day.

Recommendation for OC Transpo

It is recommended that OC Transpo take no action on relocating the service bay to downstream of the station due to the limited effectiveness of barrier curbs in redirecting errant vehicles.

Issue 16: Overhead canopy located within the desired Clear Zone

Auditor's Suggestion: Either reduce operating speed of buses to 20 km/h within the limits of the station to mitigate severity of possible collision with canopy or alternatively remove the canopy.

Possible steps for removing the canopy are also suggested:

- *Extend the temporary concrete barrier (six components) with an appropriate taper (while gravity unanchored concrete barriers are TL-3 rated temporary concrete barrier systems can have a dynamic deflection of 1.8m. Consider anchoring the barriers with 25mm rebar this reduces deflection to 75mm up to 900mm). The existing barrier system should be anchored as well and the extension tied to the existing temporary barrier system along the curb.*

[14] Lafond N "Redirection Effectiveness of Roadside Curbs", Thesis, University of British Columbia, Faculty of Graduate Studies, Department of Civil Engineering, September 1997

[15] Roadside Design Manual, Ontario Ministry of Transportation, Highway Standards Branch, Design & Contract Standards Office, December 2017

- *With the barrier in place remove the canopy and install eaves troughing on the station roof.*
- *Before beginning any work reduce approach speeds to 30 km/h or stopping buses at the approach end of the platform and moving ahead slowly*

Note potential design guideline implications regarding clear zone considerations

Analysis

At the time that the Westboro station was constructed, the minimum clear zone for a facility with a 60 km/h design speed and a barrier curb was only 0.5 metres.[16] Therefore, the facility was designed and constructed in compliance with the standards of the day. A relatively recent change in the Ontario roadside design standards (i.e., the introduction of the Roadside Design Manual by the Ontario Ministry of Transportation in December 2017), widened the clear zone from 0.5 metres to approximately 3.0 metres – rendering the canopy non-compliant or "substandard".

Removing the canopy to provide a wider clear zone is a viable solution and does not appear to introduce any new or unexpected hazards. Nonetheless, canopy removal is not a cost-efficient use of OC Transpo resources. Specifically, the crash risk presented by the canopy is too low to warrant removal of the canopy. Using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018), the crash risk of the canopy can be estimated. The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Westboro station: 1500 vehicles per day per direction [Source: OC Transpo]
- Percentage of volume that are double-decker buses: 50% [assumed]
- Design speed: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Shoulder width: 0.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of canopy: 36 m [measured from aerial photography]
- Width of canopy: 1.5 m
- Offset from travelled way to canopy: 0.5 m

Based on the above parameters, the expected number of crashes with the canopy is about 0.0040 crashes per year, or one crash every 250 years. Within a typical crash risk profile (see Table 1), this is considered a low risk. Implementation of a barrier for such a low risk does not yield a favourable benefit-cost ratio.

As the canopy is a fixed hazard located within the clear zone, and the risk posed by the hazard is considered low, a typical mitigation measure is to warn users of the hazard by making the hazard conspicuous. This general takes the form of either posting an

[16] See Table 2.2.1 in the Roadside Safety Manual, Ontario Ministry of Transportation, Quality & Standards Division, 1993.

OBJECT MARKER (Wa-33). However, with structures that are located within the clear zone, the OBJECT MARKER is usually replaced with alternating yellow and black diagonal markings placed directly on the structure (see Figure 5). Markings such as those shown in Figure 5 are a reasonable mitigation measure.

With respect to the auditor suggestion to limit operating speeds to 20 km/h, the recommended speed limit is lower than the 30 km/h or 50 km/h speed limits purported by good practice. Based on my experience and training, the 20 km/h is considered an unreasonably low speed with which operators will find it difficult to comply.

Recommendation for OC Transpo
It is recommended that, rather than remove the canopy or reduce the operating speed of buses to 20 km/h, OC Transpo mark the canopy with black and yellow striped markings similar to those used on low clearance structures (see Figure 5).

Issue 17: Curved shape of overhead canopy and station roof dropping snow and water onto transitway lane
Auditor's Suggestion: Remove canopy as it cannot be made frangible or shielded. Alternatively install an eavestrough to capture water dripping on the transitway.

Analysis
The edge of the canopy is actually set back about 0.5 metres from the face of the Transitway curb and rain/snow is deposited onto the station platform (and not directly onto the Transitway). The drainage system of the station is purposely designed so that surface water from the platform is drained onto the Transitway towards the median (see Figure 4). Unless the proposed eavestrough is directed to an underground pipe that is connected to a subdrain, the eavestrough would simply concentrate the roof runoff at a single point, creating a potentially more dangerous condition.

Recommendation for OC Transpo
OC Transpo should continue to provide winter maintenance of the subject area that meets or exceeds the minimum maintenance standards prescribed by legislation.

Issue 18: Position of pedestrian bridge creating shadow area on transitway in advance of station (east end of the station for westbound vehicles)
Auditor's Suggestions: Consider a sunscreen to block out the sunlight on the transitway.

Analysis
While the pedestrian bridge near the Westboro station can create an isolated shaded section of the Transitway on the westbound approach, the subject shadow does not create any actionable safety issues. The auditor states that the shadow cast across the Transitway by the bridge, in bright sunlight near sunset, can cause short-term, visual impairment due to a sudden transition from light-to-dark, and vice versa. Furthermore, the auditors specify it is the visual factors of light adaptation and glare sensitivity that are of concern.

FIGURE 5: Proposed Object Markings

With respect to light adaption, a shadow cast across the Transitway from a pedestrian bridge does not necessarily create a condition that results in visual impairment due to light adaptation. What matters in this regard is the magnitude of the change in the ambient light levels. While the road surface in the bridge's shadow will be markedly darker than the road surface in the bright sunshine, the change in the ambient light level is not as drastic because light from the sun is reflected off nearby surfaces, helping to illuminate the Transitway. More specifically, and in the simplest terms, light adaptation causes short-term visual impairment when an observer transitions rapidly from having to use photopic to scotopic vision (a rapid transition from light to dark) or vice versa (dark

to light). Different photoreceptors are used in light and dark conditions respectively, and a rapid transition can cause periods of temporary visual impairment as the eye switches from one type of photoreceptor to the other type (see Figure 6).

The ambient light in the shadow of the pedestrian bridge, even on the brightest day, is still likely to be in the range of typical indoor lighting. This being the case, operators on the Transitway would still be using photopic vision and visual impairment due to light adaption is not likely.

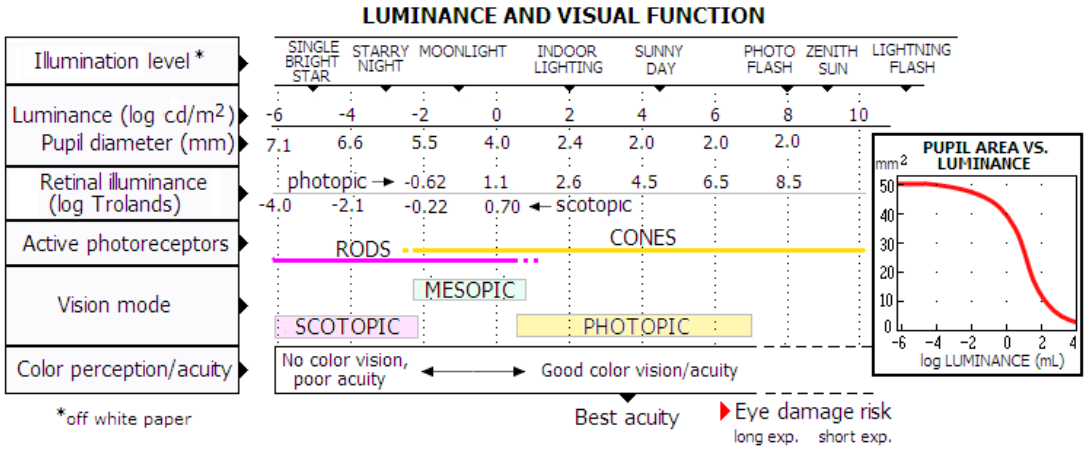

FIGURE 6: Luminance and Visual Function

With respect to glare sensitivity, the impairment is a reduction in visual performance due to the looking towards a bright light. The transition from dark-to-light (i.e., a shadow across the road) has very little impact on glare sensitivity.

At any rate, the auditor suggestion of a sunscreen to block out the sunlight on the Transitway is overly optimistic. A sunscreen would either create a larger shadow on the Transitway or introduce a more gradual transition from light-to-dark (depending on the opacity of the screen). In either case, operators will still need to transition from light-to-dark-to-light over a relatively short time. More importantly, Intus is not aware of any such product on the market today.

Recommendation for OC Transpo
It is recommended that OC Transpo take no action on erecting a sun screen but continue best efforts to ensure that the windscreens of all buses on the Transitway are as clean as possible to reduce the impacts of glare from the sun.

Issue 19: Median barrier is not designed for deflecting an errant vehicle
Auditor's Suggestion: Replace the median fencing with a TL-3 F-Shape 810mm concrete barrier and TL-3 crash cushion end treatments.

Analysis
The purpose of the median fencing at the Westboro station is to discourage transit patrons from crossing the Transitway, and the current median barrier is ***not*** intended to contain errant vehicles from crossing the centreline of the Transitway. Furthermore, current best practices in transitway design do not recommend or require a median barrier at transit stations. Since there is no history of crossover crashes at the station, and given the approach geometry of the Transitway is generally straight, the probability of future crossover crashes is nominal.

Recommendation for OC Transpo
OC Transpo should ensure that the ends of the median fencing are marked with a KEEP RIGHT sign (Rb-25) and OBJECT MARKER (Wa-33L) assembly, as recommended by the Ontario Traffic Manual.

Issue 20: Edge of platform is not conspicuous for transit vehicle operators or mobility challenged pedestrians
Auditor's Suggestion: Install a high tonal tactile strip along the edge of the platform, in accordance with Accessibility for Ontarian with Disability Act (AODA) Guidelines. Noting that the colour is not specified in AODA, the standard high contrast colour for tactile strips in most jurisdictions in North America is yellow.

Analysis
The current OC Transpo guidelines require a 500 mm wide, red coloured concrete along the full length of the platform.[17] This standard is applied consistently across all Transitway station platforms and offers a similar visual contrast as any curb-faced sidewalk in the Ottawa area. Consistency in the application of accessibility measures is a desirable trait of station design.

At any rate, the *Integrated Accessibility Standards* of the Accessibility for Ontarians with Disabilities Act (AODA) state that elements of high tonal contrast are required at stairs, curb ramps, and depressed curbs within pedestrian walking paths. A high tonal contrast element is not required (or recommended) to demarcate the upper edge of a 150 mm barrier curb.

Recommendations of OC Transpo
OC Transpo should remain committed to providing facilities that are accessible to all Ontarians and comply with all local codes and ordinances respecting accessibility, including the Integrated Accessibility Standards of the Accessibility for Ontarians with Disabilities Act (AODA). The use of a higher contrast strip along the full length of the platform *may* be considered when the OC Transpo design standards are updated.

[17] Page 4.2

Issue 21: Merge warning signs for lane merges on exiting the Westboro station
Auditor's Suggestion: In the westbound direction install the lane ends sign past the departure end of the platform. Similarly in the eastbound direction install a lane ends sign past the departure end of the platform.

Analysis
OTM Book 6 – Warning Signs recommends the LANE ENDS sign (Wa-23) be erected a minimum of 195 metres in advance of the physical lane termination on facilities with a 50 km/h speed limit. This advance placement is required to afford operators with sufficient time to see and react appropriately to the lane termination in a safe and prudent manner. However, in this instance the lane that is terminating is only used by bus operators that are stopping at the Westboro station. Given that buses using the lane that is terminating are not operating continuously at 50 km/h (as assumed by the design guidelines), a shortened advance warning distance is acceptable. Furthermore, the auditor is correct in suggesting that placement of the LANE ENDS sign (Wa-23) downstream of the of the platform will spread driver information load, and assist operators in directing their attention to the right information at the right time.

Recommendation for OC Transpo
It is recommended that OC Transpo implement the auditor suggestion.

Issue 22: Gore area ineffective for prohibiting parking on the transitway
Auditor's Suggestion: In the immediate term install no stopping signs. In the longer term if bus drivers continue to park in the hatched area install drivable delineators 500mm offset from the outside of the edge line to prevent drivers from entering the hatched area.

Analysis
Transit vehicles parked or stopped in the subject hatched area do limit visibility for operators entering the Transitway from the access road. As visibility is a primary safety consideration, and the audit recommendation is a low-cost and effective option to address the visibility concern, it is preferable to proceed with the auditor recommendation for NO STOPPING signs.

The installation of driveable delineators in the event that the NO STOPPING signs are ineffective, is a reasonable approach to managing safety at this location. Typical crash mitigation involves implementing one or more low-cost alternatives to address an identified safety issue, before moving towards more expensive and/or restrictive measures.

Recommendation for OC Transpo
Implement the auditor recommendation, as written.

2.3 FALLOWFIELD STATION

Issue 23: No energy attenuation at median ends
Auditor's Suggestion: Replace the sloped ends with an appropriate TL-3 crash cushion.

Analysis
The sloped ends of the concrete median barrier at the Fallowfield station present an elevated crash severity risk. The prevailing guidelines for traffic barriers in Ontario, do not recommend these types of end treatments for new installations and repairs. Having stated the above, it is recognized that the Fallowfield installation is not a new installation and is not currently in need of repair. This being the case, the typical approach for deciding on whether to retrofit an out-dated barrier end treatment is to conduct a risk assessment and economic analysis (e.g., benefit-cost ratio).

The crash risk proposed by the exposed median end was estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Fallowfield station: 750 vehicles per day [Source: OC Transpo]
- Design speed: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Median shoulder width: 1.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of exposed end of barrier: 7.25 m [OPSD 923.383]
- Width of exposed end of barrier: 0.8 m [Figure 4.2.3a of Transitway and Station Design Guidelines]

Based on the above parameters, the expected number of crashes with each exposed barrier end is 0.00351 crashes per year, or one crash every 285 years. Within a typical crash risk profile (see Table 1), this is considered a low risk.

Due to the relatively low crash risk there is no urgency to this safety issue. The recommended action is to leave the current end treatment in-service, and to replace the end treatment with a TL-3 crash cushion when this section of the Transitway is reconstructed or when the barrier needs to be replaced. However, it is acknowledged that the current end treatment is technically a hazard, and it should be delineated accordingly with proper signing.

Recommendation for OC Transpo
It is recommended that OC Transpo install TL-3 crash cushion attenuators at each end of the median barrier when the Transitway at this location is due to be reconstructed, or the median barrier is due to be replaced. In the interim, OC Transpo should review the traffic

signs and ensure that a KEEP RIGHT sign (Rb-25) and an OBJECT MARKER (Wa-33L) are properly posted at each median end, per the guidance of Ontario Traffic Manual Book 6 – Warning Signs.

Issue 24: No redundant entry prohibition signs for motorist egress from VIA Rail station
Auditor's Suggestion: Install Entry Prohibited (RB-23) signs with a Tab "Except Buses" at the throat of the transitway. Double signing is suggested.

Analysis
Wrong-way movements at the interface between the station access roads and the Transitway have the potential to result in high severity crashes. Low cost mitigation measures, such as traffic signs, are an appropriate risk management strategy.

Recommendation for OC Transpo
OC Transpo should implement the signs, as recommended by the auditor,

Issue 25: STOP sign intrusion into transitway lane
Auditor's Suggestion: Relocate stop sign 500mm from the face of curb.

Analysis
The subject STOP sign does not conform to the recommendations for lateral setback of traffic signs in the OTM. The proximity of the near side of the STOP sign to the travelled way is presenting an increased risk of low severity crashes with buses.

Recommendation for OC Transpo
The subject STOP sign should be repositioned so that it complies with the lateral setbacks recommended in the Ontario Traffic Manual.

Issue 26: Conspicuity of tactile surface
Auditor's Suggestion: Install Accessibility for Ontarian with Disability Act (AODA) approved high tonal tactile surface. Although the colour of the tactile surface is not specified in AODA, the common high contract colour standard for most jurisdictions in North America is yellow.

Analysis
Based on the conditions observed during the site visit, it is our opinion that the current tactile surface offers a sufficient contrast with the surrounding concrete sidewalk. Furthermore, the auditor suggestion of providing a yellow surface at the curb ramp, while compliant with typical industry, would decrease the visual contrast between the concrete and the tactile surface.

The metal of the current tactile surface is quite dark and contrasts well with the light-coloured concrete of the sidewalk. The RGB values of the metal surface and the adjacent concrete are approximately R:235, G:236, and B:241 and R:160, G:115, and B:100,

respectively[18]. This offers a contrast ratio of 3.46:1. A chrome yellow tactile strip has RGB values of R:255, G:167, and B:0 and offers a contrast ratio of 1.65:1 against the adjacent concrete.[19]

While the industry practice may be to install a yellow tactile surface at the curb ramp, the current metal surface provides a similar or better contrast with the surrounding concrete, and satisfies the AODA requirement.

Recommendation for OC Transpo
It is recommended that no immediate action will be taken in response to this finding. At the time that the curb ramps are scheduled for reconstruction, OC Transpo may consider implementing a yellow tactile marking but must continue to comply with all accessibility codes and legislation.

2.4 LONGFIELDS STATION

Issue 27: No energy attenuation at median barrier ends
Auditor's Suggestion: Replace the sloped ends with appropriate TL-3 crash cushions.

Analysis
The sloped ends of the concrete median barrier at the Longfields station present an elevated crash severity risk. The prevailing guidelines for traffic barriers in Ontario, do not recommend these types of end treatments for new installations and repairs. Having stated the above, it is recognized that the Longfields installation is not a new installation and is not currently in need of repair. This being the case, the typical approach for deciding on whether to retrofit an out-dated barrier end treatment is to conduct a risk assessment and economic analysis (e.g., benefit-cost ratio).

The crash risk proposed by the exposed median end was estimated using the procedures and methods included in the Roadside Evaluation Manual (MTO, 2018). The parameters and inputs for the evaluation are as follows:

- Current volume of traffic passing through the Longfields station: 260 vehicles per day [Source: OC Transpo]
- Design speed: 60 km/h design speed [OC Transpo Transitway Design Guidelines]
- Four-lane, two-way, divided highway;
- Straight and flat alignment;
- Lane width: 3.5 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Median shoulder width: 1.0 m [Figure 4.2.3a of Transitway and Station Design Guidelines]
- Length of exposed end of barrier: 7.25 m [OPSD 923.383]

[18] As measured from Google aerial photography dated 2021, https://www.google.ca/maps/place/Fallowfield+Station,+Ottawa,+ON/@45.2990235,-75.7359828,38m/data=!3m1!1e3!4m5!3m4!1s0x4ccdfd69744d4af9:0x20b3e5cd65f46df7!8m2!3d45.2991173!4d-75.7364612?hl=en
[19] Contrast ratios calculated by WebAIM Contrast Check, University of Utah, https://webaim.org/resources/contrastchecker/

- Width of exposed end of barrier: 0.8 m [Figure 4.2.3a of Transitway and Station Design Guidelines]

Based on the above parameters, the expected number of crashes with each exposed barrier end is 0.00093 crashes per year, or one crash every 1,075 years. Within a typical crash risk profile (see Table 1), this is considered a low risk.

Due to the relatively low crash risk there is no urgency to this safety issue. The recommended action is to leave the current end treatment in-service, and to replace the end treatment with a TL-3 crash cushion when this section of the Transitway is reconstructed or when the barrier needs to be replaced. However, it is acknowledged that the current end treatment is technically a hazard, and it should be delineated accordingly with proper signing.

Recommendation for OC Transpo
It is recommended that OC Transpo install TL-3 crash cushion attenuators at each end of the median barrier when the Transitway at this location is due to be reconstructed, or the median barrier is due to be replaced. In the interim, OC Transpo should review the traffic signs and ensure that a KEEP RIGHT sign (Rb-25) and an OBJECT MARKER (Wa-33L) are properly posted at each median end, per the guidance of Ontario Traffic Manual Book 6 – Warning Signs.

Issue 28: Faded red edge on platform with no tactile quality
Auditor's Suggestion: Install AODA approved high tonal contrast tactile surface. The suggested high contrast colour is yellow.

Analysis
The current OC Transpo guidelines require a 500 mm wide, red coloured concrete along the full length of the platform.[20] This standard is applied consistently across all Transitway station platforms and offers a similar visual contrast as any curb-faced sidewalk in the Ottawa area. Consistency in the application of accessibility measures is a desirable trait of station design.

At any rate, the *Integrated Accessibility Standards* of the Accessibility for Ontarians with Disabilities Act (AODA) state that elements of high tonal contrast are required at stairs, curb ramps, and depressed curbs within pedestrian walking paths. A high tonal contrast element is not required (or recommended) to demarcate the upper edge of a 150 mm barrier curb.

Recommendations of OC Transpo
OC Transpo should remain committed to providing facilities that are accessible to all Ontarians and comply with all local codes and ordinances respecting accessibility, including the Integrated Accessibility Standards of the Accessibility for Ontarians with

[20] Page 4.2

Disabilities Act (AODA). The use of a higher contrast strip along the full length of the platform *may* be considered when the OC Transpo design standards are updated.

Issue 29: Concrete barrier - Blunt end with no energy attenuation
Auditor's Suggestion: Remove the concrete barriers with a blunt end. Install drivable delineators along the base of the building on a 200 mm white line to keep buses away the station and allow the bus to remain in the departure lane. Alternatively, remove the concrete barriers and install a low concrete curb against the base of the station. In either case remove the concrete barrier with the blunt end as it is a hazard. Note potential design guideline implications for clear zone considerations and station offsets from the transitway.

Analysis
Traffic barriers are installed in an attempt to protect users from a greater hazard. They are only employed when the overall risk presented by the barrier is less than the situation without the barrier present. The barrier itself is considered a hazard, and the blunt end of a concrete barrier can exacerbate the severity of a crash by bringing an errant vehicle to a rather sudden halt.

The auditor recommendation to remove the barrier and better guide operators around the hazard, through a white edge line and driveable delineators, is a technically sound recommendation. Good risk management of roadside hazards also recommends that the hazard itself be made conspicuous to operators.

Recommendations for OC Transpo
OC Transpo should remove the concrete barriers, install drivable delineators along the base of the building, and mark a 200 mm white edge line, as suggested.

Issue 30: Concrete barrier - Forces abrupt bus maneuvers
Auditor's Suggestion: Remove the concrete barriers with a blunt end. Install drivable delineators along the base of the building on a 200 mm white line to keep buses away the station and allow the bus to remain in the departure lane. Alternatively install a low concrete curb against the base of the station.

Analysis
Traffic barriers are installed in an attempt to protect users from a greater hazard. They are only employed when the overall risk presented by the barrier is less than the situation without the barrier present. The barrier itself is considered a hazard, and the blunt end of a concrete barrier can exacerbate the severity of a crash by bringing an errant vehicle to a rather sudden halt.

The auditor recommendation to remove the barrier and better guide operators around the hazard, through a white edge line and driveable delineators, is a technically sound recommendation. Good risk management of roadside hazards also recommends that the hazard itself be made conspicuous to operators.

Recommendations for OC Transpo
OC Transpo should remove the concrete barriers, install drivable delineators along the base of the building, and mark a 200 mm white edge line, as suggested.

Issue 31: Concrete barrier - Rear swept path of double decker rear out swing intrudes onto platform
Auditor's Suggestion: Remove the concrete barriers with a blunt end from the travel lane. Or install a TL-3 F-Shape concrete barrier along the edge of the platform with a pedestrian railing 1000mm high of appropriate length of need and taper to shield passengers on the platform from the swept path of the articulated bus.

Analysis
The rear swept path of the double decker buses should be minimized by removing the traffic barrier that has been placed in the travelled way. Traffic barriers are installed in an attempt to protect users from a greater hazard. They are only employed when the overall risk presented by the barrier is less than the situation without the barrier present. The barrier itself is considered a hazard, and the blunt end of a concrete barrier can exacerbate the severity of a crash by bringing an errant vehicle to a rather sudden halt. The auditor previous recommendation to remove the barrier and better guide operators around the hazard, through a white edge line and driveable delineators, is a technically sound recommendation and should also minimize intrusions on the platform.

Recommendations for OC Transpo
OC Transpo should remove the concrete barriers, install drivable delineators along the base of the building, and mark a 200 mm white edge line, as suggested.

2.5 HURDMAN STATION

Issue 32: Main Active Transportation Crossing - Unclear guidance for users
Auditor's Suggestion: It should be confirmed whether a mixed crossride is appropriate and desirable for this location. OTM Book 18 notes that mixed crossrides are "for low volume crossings, particularly at unsignalized locations where practitioners do not anticipate queuing of pedestrians or cyclists." This does not appear to be a low volume crossing, and queuing of users would be anticipated after trains disembark creating a surge of users.
If a mixed crossride is deemed to not be appropriate, the crossing could be converted to a traditional crosswalk. Alternatively, it could be converted to a separate or combined crossride. These are suitable for higher volume crossings but would require physical modifications to widen the depressed curbs and reconfigure the approaches.
Regardless of the crossing type selected, the pavement markings should be made clear to users. Markings that are still in effect should be refreshed, and markings that are no longer in effect should be removed by abrasive blasting.
The intended use of the approaches should also be made clear to users. If a mixed crossride is deemed to be suitable, "cyclist yield to pedestrians" signs should be installed

on the MUP approaches. This would give positive guidance to users that cycling is permitted and reinforce that cyclists must yield to pedestrians in mixing zones. If it's decided to convert the crossing to a traditional crosswalk, "dismount and walk" signs should be installed on the MUP approaches. If it's decided to convert the crossing to a separate or combined crossride, the approaches should be modified to separate users. Markings, signage, and tactile delineation would be required to clearly indicate the separation to users.

Analysis
Conformance with OTM guidelines is significant and important for the safety of Ontario road users. Consistency in the application of measures and devices results in the right device being used in the right situation, accommodates driver expectations, and promotes good user behaviours. The subject crossride should be reviewed to determine which type of crossride is appropriate.

Recommendation for OC Transpo
Staff should review the crossing to determine the most appropriate type of crossride (i.e., a separate, combined, or mixed crossride), and ensure that signs and markings comply with OTM Book 18 – Cycling Facilities.

Issue 33: Main Crosswalk - STOP sign for pedestrians mounted too high
Auditor's Suggestion: If the stop sign is to be retained (refer to issue 32), the sign should be mounted at a height of 2m from the sidewalk to the base of the sign to improve the conspicuity for cyclists.

Analysis
It is noted that during the site visit, OC Transpo had already repositioned the sign to comply with the Ontario Traffic Manual recommendations for sign height, per the auditor suggestion[21].

Recommendation for OC Transpo
No further action is recommended or required.

Issue 34: East Crosswalk - Luminaires not over crosswalk
Auditor's Suggestion: The RSA Team suggests a luminaire or alternatively consider a Rapid Rectangular Flashing Beacons (RRFB). The auditors note there is a commercial product that combines a luminaire that comes on when the RRFB is activated.

Analysis
The night-time visibility of pedestrians in or near a crosswalk is dependent on the vertical illuminance and not on horizontal illuminance, as suggested by the auditor. Vertical illuminance at crosswalks is best accomplished by installing a luminaire upstream of the crosswalk, and not over the crosswalk. It is unclear if the position of the current luminaires results in insufficient lighting of the crosswalk.

[21] As noted during a June 21, 2021 site visit.

Recommendation for OC Transpo
OC Transpo should review the level of illumination at the crosswalk and ensure that it meets the prevailing standards. Furthermore, while there is no indication that the current unprotected pedestrian crossing is not functioning safely, staff should review the site to determine if a higher level of pedestrian protection is warranted according to the City of Ottawa policy respecting pedestrian crossovers.

Issue 35: East Crosswalk - Pavement markings faded
Auditor's Suggestion: Refresh the crosswalk pavement markings. Consider Thermoplastic as this appears to be a high use area.

Analysis
Pavement markings provide important guidance information to road users, and maintaining pavement markings so that they remain visible and conspicuous are similarly important.

Recommendation for OC Transpo
OC Transpo should review the existing pavement markings and refresh the pavement markings. The use of thermoplastic markings should be reviewed by technical staff and implemented if warranted according to City of Ottawa policy.

Issue 36: Passenger Pick-up and Drop-off
Auditor's Suggestion: This is a guide sign and should comply with the Manual of Uniform Traffic Control Devices for Canada in terms of size colour and shape for guide signs.

Analysis
The prevailing guideline concerning public transportation services signs and markers in Ontario is *Ontario Traffic Manual Book 8 – Guide and Information Signs* and not the *Manual of Uniform Traffic Control Devices for Canada*. OTM Book 8 states that public transportation services signs and markers shall be in the primary colours of the transit service[22] – which in the instance of OC Transpo is red, white, and black.

Recommendation for OC Transpo
It is recommended that no action will be taken on this issue.

Issue 37: Transit patrons walking in transit vehicle path to avoid crowded platform
Auditor's Suggestion: Install a pedestrian railing 1000mm high and signs indicating do not walk on roadway.

Analysis
There are instances where transit patrons may walk in the vehicular travelled way (i.e., the bus loop) due to platform overcrowding. It is noted that sightlines between pedestrians and operators in this area is sufficient, and the posted speed limit for vehicles

[22] Page 169 of OTM Book 10, May 2010

is 30 km/h. Both of these considerations already serve to limit the vehicle-pedestrian crash risk in this area. The frequency of these occurrences appears to be low but is uncertain.

Recommendation for OC Transpo
Staff should investigate the frequency of these occurrences to determine if the auditor suggestion of erecting a handrail is a technically appropriate solution.

2.6 COMPARISON OF BRT DESIGN GUIDELINES

Clear Zone Considerations
Auditor's Suggestion: Future updates to the OC Transpo Transitway Station Design Guidelines should consider located [sic] the fixed object structural elements of stations outside of the desirable clear zone.
The auditors recommend that OC Transpo, for future Transitway Station designs, consider "Bus Rapid Transit Stations and Stops" RECOMMENDED PRACTICE, American Public Transportation Association, Report APTA BTS-BRT-RP-002-10, Approved October 2010

Analysis
Clear zone requirements are a key component of roadway design and safety management on Ontario road systems. The concepts and principles of roadside safety are well-developed and directly applicable to the Transitway. These concepts should be employed by OC Transpo to continue delivering safe infrastructure.

Recommendation for OC Transpo
OC Transpo should consider including roadside safety and clear zone recommendations in future updates to the Transitway Station Design Guidelines.

Platform height
Auditor's Suggestion: Future updates to the OC Transpo Transitway Station Design Guidelines should consider a higher platform height to gain a level floor between the station platform and transit vehicle, and the [sic] enhance the effectiveness of the barrier curb to deflect errant vehicles.

Analysis
Higher platforms are not typically a safety measure implemented to deflect errant vehicles. The auditor periodically reference APTA documents which state "[c]urrent BRT applications differ as to the optimal treatment of curb heights" and that in general, three types of platform heights are available: standard curb (150mm); level or near-level boarding (14 to 15 inches); and raised platform (8 to 10 inches). The document also states that "no standard industry practices have yet emerged" with respect to platform height. Furthermore, the advantages/disadvantages of the various curb heights pertain to ease of boarding/alighting from the bus, dwell times, and branding. No mention is made

of patron safety because, curbs up to 300 mm (12 inches) have no significant redirection capabilities.

Recommendation for OC Transpo
OC Transpo should consider curb higher platform heights in future updates to the Transitway Station Design Guidelines.

Location of service vehicle entrance to station platform
Auditor's Suggestion: Future updates to the OC Transpo Transitway Station Design Guidelines should consider locating service vehicle accesses at the far side of stations.

Analysis
Locating service accesses on the far side of the station platform will remove service vehicles from the near side of the station platform, thereby reducing visual clutter, and provide operators with a better view of patrons standing on the platform.

Recommendation for OC Transpo
OC Transpo should consider recommending service vehicle accesses on the downstream side of the platform in future updates to the Transitway Station Design Guidelines.

Approach speed to stations
Auditor's Suggestion: Future updates to the OC Transpo Transitway Station Design Guidelines should consider a 30 km/h posted speed at the transitway stations to lessen the severity of possible future crashes.

Analysis
The research is definitive in concluding lower operating speeds result in a lower crash probability and a lower crash severity. However, the research is also definitive in that lowering the posted speed limit without making any significant changes to the visual scene is ineffective in achieving lower operating speeds. In brief, motorists operate at a speed that they feel is comfortable based on the visual scene. At present, the Transitway stations have a design speed of 60 km/h, which permits a posted speed limit of 50 km/h.[23] Simply lowering the speed limit to 30 km/h will have a no material impact on operating speeds.

It is understood that in a safe system approach, a 30 km/h speed limit is preferred in areas with heavy pedestrian activity, because the chances of a pedestrian surviving a vehicle-pedestrian crash at 30 km/h is significantly greater than the chances of a pedestrian surviving a vehicle-pedestrian crash at 50 km/h. That said, the Transitway is not an area where pedestrians and motor vehicles are in conflict. Pedestrians rarely are required to cross (or walk in) the Transitway, and when they are required to do so, they are provided with marked pedestrian crossings and buses are required to stop (e.g., a STOP sign is erected).

[23] Transitway Design Guidelines, OC Transpo, June 2013

Finally, the use of a 30 km/h speed limit at transit stations is not an industry practice. Both Mississauga and Winnipeg use 50 km/h speed limits at stations along their BRT routes, and APTA recommends a minimum design speed for stations and CBD areas of 60 km/h (which is consistent with a posted speed limit of 50 km/h).

Recommendation for OC Transpo
OC Transpo should continue to use a 50 km/h speed limit at Transitway stations and only consider reducing the posted speed limit at Transitway stations to 30 km/h on a case-by - case basis.

Colour of Tactile Surfaces for the Visually Impaired
Auditor's Suggestion: Future updates to the OC Transpo Transitway Station Design Guidelines should consider harmonizing standards for tactile surfaces with other more broadly applied design guidelines for the mobility challenged.

Analysis
Conformance with industry practices and guidelines is significant and important for the safety of Ontario road users. Consistency in the application of measures and devices results in the right device being used in the right situation, accommodates driver expectations, and promotes good user behaviours.

Recommendation for OC Transpo
OC Transpo design standards for the Transitway and associated facilities should continue to comply with prevailing legislation for accessibility, and should, to the extent possible, be harmonized with industry-accepted guidelines for the mobility-challenged.

END OF REPORT