TRANSIT STOP SAFETY STUDY UPDATE

January 2013

Prepared by:

PARSONS BRINCKERHOFF

On Behalf of:

RTC

Regional Transportation Commission of Southern Nevada

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF EXHIBITS

LIST OF TABLES

EXECUTIVE SUMMARY

In the fall of 2008, one person was killed and another seriously injured when a vehicle lost control and crashed into a transit shelter on Boulder Highway near Flamingo Road. The Regional Transportation Commission of Southern Nevada (RTC) commissioned an independent safety study, and in 2009, Parsons Brinckerhoff submitted the original *Transit Shelter Safety Study* to the RTC. The original study developed a ranking methodology and a toolbox of solutions that could be implemented depending on site specific conditions.

Since that time, the RTC has been working aggressively to implement suggested safety measures at transit stops Valley wide. Since 2008, the RTC has spent approximately 15 million dollars implementing new transit stop improvements that incorporate the recommendations of the original study, such as placing pads and shelters behind the sidewalk, and relocating shelters where possible. Each year, a new list of approximately 150 stop locations are prioritized based on available right-of-way, stop ridership, roadway traffic volumes, and cost of construction.

Sadly, on Thursday, September 13, 2012, four people were killed and eight were injured after a speeding car impacted a RTC transit stop. As with nearly all incidents where transit shelters are involved and where a police report was filed, vehicle speed and driver impairment are listed as factors for these crashes.

Since 2007, there have been 112 crashes at transit shelters within the Las Vegas Valley. Due to the large number of crashes at transit shelters, and the recent fatalities on September 13, the RTC has asked Parsons Brinckerhoff to conduct a *Transit Stop Safety Study Update.* This update includes safety measures presented in the original *Transit Shelter Safety Study*, along with additional safety mitigation measures and strategies at transit stops within the Valley.

Through crash analysis it was determined that 94 of the 112 vehicle to transit shelter accidents (84%) occurred when the transit shelter was located on the sidewalk. The percentage of transit shelter accidents correlates to findings in the *2011 AASHTO Roadside Design Guide*[2] that 80 percent of all roadside crashes were with an object that was less than four feet from the roadway. Therefore, moving transit shelters further from the roadway should greatly reduce the chances of a vehicle running off of the roadway and crashing into a transit shelter.

After analyzing numerous options, Parsons Brinckerhoff has developed recommendations for the RTC to consider. These options are ranked in categories of their importance and are described in the following paragraphs. It should be emphasized that this is a work in progress and it is not a one-size-fits-all solution. Addressing this concern is a communitywide issue and requires a significant investment from our community, local entities, engineers, and law enforcement through education and awareness.

Primary Strategies – The “Primary Strategies” category includes options that should be thoroughly considered to increase the safety of transit riders and pedestrians at and around transit stops. It is noted that the RTC is already implementing most of these measures as part of the adopted *Uniform Standards* and annual construction projects. The “Primary Strategies” options include:

- Place shelters at least 6-feet behind the curb
- Implement a pedestrian buffer
- Implement a bus turnout
- Conduct a Public Service Announcement Campaign

Primary Strategies But Needs Collaboration – The “Primary Strategies But Needs Collaboration” category includes options that should be thoroughly considered, however the RTC would need to collaborate with other agencies in order to follow through with the improvements. The “Primary Strategies But Needs Collaboration” options include:

- Implement Complete Streets design concepts including evaluating the reduction of speed limits on arterials with transit routes, where appropriate
- Implement random sobriety checkpoints on all arterials with transit routes

Secondary Strategies – The “Secondary Strategies” category includes options that will improve the safety at transit stops, however not as much as the previous two categories. The “Secondary Strategies” options include:

- Implement concrete planters with trees planted inside
- Relocate shelters where existing block walls prevent adequate offset from the curb
- Add solar powered LED shelter lighting
- Raise curbs at transit stops to allow for level boarding

Secondary Strategies If Other Measures Cannot Be Implemented – The “Secondary Strategies If Other Measures Cannot Be Implemented” category contains options that need to be considered if previous options mentioned are not feasible. The “Secondary Strategies If Other Measures Cannot Be Implemented” options include:

- Implement a low profile barrier
- Implement high containment curbs
- Add “Bus Stop Ahead” pavement markings
- Add shoulder rumble strips
- Brightly paint the curb next to the transit stops
- Brightly paint the transit shelters
- Install a reflective coating on the outside of the transit shelters
- Install rear facing transit shelters

Last Resort – The “Last Resort” category consists of options that could improve the safety of transit riders at transit stops, however they could also introduce additional safety hazards that do not currently exist. These options should be considered only if all other options are not feasible. The "Last Resort" options include:

- Implement a bollard system
- Implement reinforced concrete trash receptacles
- Implement a handrail system
- Move the transit shelter to a side street

The RTC has already begun incorporating most of the measures that are recognized as primary safety enhancement strategies and best practices. The findings and recommendations of this report will provide the RTC additional options to continue to improve transit stop safety and provide a positive experience for our transit community.

1.0 INTRODUCTION

In the fall of 2008, one person was killed and another seriously injured when a vehicle lost control and crashed into a transit shelter on Boulder Highway near Flamingo Road. The Regional Transportation Commission of Southern Nevada (RTC) commissioned an independent safety study, and in 2009, Parsons Brinckerhoff submitted the original *Transit Shelter Safety Study* to the RTC. The original study developed a ranking methodology and a toolbox of solutions that could be implemented depending on site specific conditions. It identified the nationally recognized industry practice of moving the shelter at least 5-feet behind the curb as the most effective safety measure.

Since that time, the RTC has been working aggressively to implement suggested safety measures at transit stops Valley wide. Since 2008, the RTC has spent approximately 15 million dollars per year implementing new transit stop improvements that incorporate the recommendations of the original study, such as placing pads and shelters behind the sidewalk, and relocating shelters where possible. Each year, a new list of approximately 150 stop locations are prioritized based on available right-of-way, stop ridership, roadway traffic volumes, and cost of construction. This work continues as a priority fund expenditure.

The RTC transit system carries over 60 million riders every year. There are 3,156 stop locations in the Las Vegas Valley, and 1,780 of those currently have a transit shelter and/or bench. Since 2008, the RTC has relocated or placed 515 new pads and shelters behind the sidewalk. Additionally, 478 stop locations are located at transit turnouts and nearly 80 percent of all transit stops are located on the far-side of an intersection. New legislation in 2009 (SB173) required ten new bus turnouts to be completed by the end of 2012, and another bill in 2011 (SB137) required a total of 15 new bus turnouts to be completed by the end of 2014.

Sadly, on Thursday, September 13, 2012, four people were killed and eight were injured after a speeding car impacted a RTC transit stop. The incident occurred just before 6:30 AM at the intersection of Decatur Boulevard and Spring Mountain Road.[1] The transit shelter at this location was located on the sidewalk, whereas the shelter in the 2008 incident was located behind the sidewalk. As with nearly all incidents where transit shelters are involved and where a police report was filed, vehicle speed and driver impairment are listed as factors for these crashes.

Since 2007, there have been 112 crashes at transit shelters within the Las Vegas Valley. Due to the large number of crashes at transit shelters, and the recent fatalities on September 13, the RTC has asked Parsons Brinckerhoff to conduct a *Transit Stop Safety Study Update*. This update includes safety measures presented in the original *Transit Shelter Safety Study*, along with additional safety mitigation measures and strategies at transit stops within the Valley.

1.1 Literature And Industry Practices Review Update

The original *Transit Shelter Safety Study* conducted a literature review of industry practices and recommendations for transit stop and transit rider safety. Several national standards have been updated since that time, and a new effort to identify changes in those recommended practices was completed. The most significant change was added to the *2011 AASHTO Roadside Design Guide*[2], which increased the recommended setback for fixed objects to at least 4-feet behind the face of curb. Changes to this and other AASHTO standards reflect longer pedestrian walk times, emphasis on pedestrian and transit rider accessibility issues, and a growing "Complete Streets" initiative nationwide.

As part of the original *Transit Shelter Safety Study*, twenty three peer agencies were identified and contacted. Of the sixteen responses received, it became clear that the Las Vegas Valley experiences a higher rate of transit shelter crashes and transit rider fatalities than other agencies with larger transit systems. For example, the Tri-County Metropolitan Transportation District of Oregon (TriMet) reported an average of ten transit shelters impacted by an errant vehicle per year, compared to an average of almost 19 per year in the Las Vegas Valley since 2007. Additionally, the Los Angeles County Metropolitan Transportation Authority (MTA), which has approximately 16,000 bus stop locations, reported an average of 1.4 shelter crashes per month since 1979; whereas the Las Vegas average is over 1.5 shelter crashes per month since 2007. All other agencies contacted reported significantly fewer incidents of vehicles impacting a transit shelter. A summary of transit agency's incidents and actions are tabulated later in the document.

A new outreach to eighteen peer agencies was conducted to identify new developments and industry practices. The new outreach confirmed the unique nature of the Las Vegas Valley environment, as well as a growing effort to incorporate Complete Streets and traffic calming elements as tools for enhancing the transit rider experience and safety. All agencies are focused on the recognized primary strategies of increased offset and pedestrian buffers. Additionally, those who have considered positive protection strategies do so in limited applications, which are discussed later in the document. Table 1 identifies the agencies contacted and the information obtained regarding their traffic calming measures and safety barriers.

TABLE 1: TRANSIT AGENCY TRAFFIC CALMING MEASURES AND SAFETY BARRIERS		
Agency	**Safety Barriers**	**Traffic Calming Measures**
Arlington County Transit - Arlington VA	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
BC Transit - Victoria, BC, Canada	Does not provide any information on safety bollards design.	Identified traffic calming measures: reduce vehicle speeds and volumes and improve safety for non-motorized users (pedestrians and cyclists)
Chicago Transit Authority - Chicago, IL	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
City and County of Honolulu - Honolulu, HI (Wayne Yoshioka, Director for the City and County of Honolulu)	No information on bollards.	• While location of the bus stop along a street could be a factor in bus stop safety, the issue of far side versus near side is primarily an operational efficiency issue. We have consciously been eliminating mid-block stops where feasible because they generally lead to pedestrian crossings at unsignalized locations. • Location of the bus waiting area is a bus stop safety issue, but if your problem is vehicles leaving the travelled way, what you do in this regard pales in relation to the concern you should have regarding why vehicles are leaving the travelled way in the first place. • Bus stop turnouts are usually a traffic flow efficiency measure: good for traffic flow on the street but decreasing efficiency for the transit operator (under heavy traffic conditions, drivers have difficulty re-entering traffic). Of course, on high-speed roadways, bus turn outs are a good idea to reduce the probability of vehicle-bus accidents.
City of Toronto (Toronto Transit Commission) - Toronto, CA, Canada (Jim Smith, Supervisor, Data Analysis)	No information on bollards.	1. 129 bus shelter incidents. 2. 125 incidents could be classified as "light contact" between the bus and the shelter. These are caused by the operator misjudging clearance as they approach the stop. Typically the only damage is to the bus mirror. 3. 4 incidents were classified as "collision" between the bus and the shelter. Of these, 3 were documented as having excessive speed as a factor. In the 4th collision, a car ran a red light, hit the bus and the bus in turn hit the shelter. 4. In all the 129 incidents, 1 resulted in injury - this injury was sustained during one of the 4 collisions.
Los Angeles County Metropolitan Area Transit Authority - Los Angeles, CA	Have installed bollards at transit station platforms in conjunction with accidents involving errant vehicles.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
Massachusetts Bay Transportation Authority - Boston, MA	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
Metro Transit - Seattle, WA	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
New Jersey Transit - Newark, NJ	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	A Bus Stop Safety toolbox acknowledged that traffic calming measures can be used to reduce speed and improve pedestrian access to bus stops. Bicycle lanes buffer pedestrians from vehicles and lower speeds by narrowing the road. It also mentioned that traffic speed is more critical to pedestrian safety because at higher speeds, motorists are less likely to see a pedestrian or stop in time.
New York City Department of Transportation - New York, NY	Does not provide any information on safety bollards design.	Several traffic calming measures were identified to enhance pedestrian safety. Lane narrowing benefits include the reduced opportunities for speeding and aggressive driving, reducing the severity and frequency of crashes. Curb extensions can enhance pedestrian safety by reducing crossing distances and creates space that may be used for bus stops, etc. The traffic calming measures did not specify improvement of pedestrian safety at bus stops.

TABLE 1: TRANSIT AGENCY TRAFFIC CALMING MEASURES AND SAFETY BARRIERS		
OmniTrans - San Bernardino, CA	Vehicle barriers were identified in the DRAFT Transit Design Guidelines to provide pedestrian safety from both errant and terrorist vehicle attacks. Structural barriers were identified as natural and fabricated barriers such as bollards, guardrails, fences, and walls.	Traffic calming techniques such as curb extensions, chokers, speed bumps, and raised sidewalks are suggested to be used to channel traffic and minimize impacts on the community. Does not identify such traffic calmers to improve safety at bus stops though it slows the speed of traffic.
Orange County Transportation Authority - Orange, CA	Cannot locate any information regarding safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
Pace Suburban Bus - Arlington Heights, VA	Does not provide any information on design guidelines for transit stops, amenities, and safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
San Francisco Municipal Transportation Agency - San Francisco, CA	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	SFMTA has a traffic calming program through their Livable Streets initiative. The program addresses issues such as speeding, reckless driving, pedestrian safety, to name a few. It does not specify any information regarding reduction of speeds within a bus stop that will aid in enhancing pedestrian safety.
Southeastern Pennsylvania Transportation Authority - Philadelphia, PA	Cannot locate any information regarding transit stop design guidelines and safety features such as bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
Tri-County Metropolitan Transportation District - Portland, OR	Provides information on safety bollard design.	In "Pedestrian Network Analysis Report", roadway narrowing is identified as a vehicle speed reducer and increases safety for all roadway users including pedestrians. Curb extensions and crossing islands are different traffic calming measures listed to reduce vehicular speeds in roadways. The report indicated that high speeds contribute to higher chances of pedestrian fatality if struck by the moving vehicle. It also suggests ways of assessing areas for pedestrian and transit stop accessibility.
Utah Transit Authority - Salt Lake City, UT (Dave Goeres, UTA Chief Safety Officer)	No information on bollards in Salt Lake City, but he believes the RTD in Denver uses bollards in front of sawtooth cutouts at bus stops.	Most bus stops are located behind the sidewalk, which is behind a 6' pedestrian buffer. Therefore stops are located 10' - 15' from the roadway. Flagpoles are places to shield bus shelters. Railings around shelters that are closer to the roadway. Reflector sticks placed at bus shelters to alert bus drivers that a passenger is waiting. Cannot have top bar on a fence within 18" of curb. Bicyclists loading their bikes on the front of buses have stepped out in front of the bus before it has stopped.
Valley Metro - Phoenix, AZ	Identified bollards as a safety feature in bus stop design with shelter, but does not provide any design for bollards.	Does not identify any traffic calming measures nor mentioned any information regarding reducing speeds on roadways to improve safety at transit stops.
Source: Parsons Brinckerhoff, January 2013		

2.0 CRASH COMPARISON

A crash analysis was performed within Clark County to compare the difference between crashes involving vehicle to vehicle, vehicle to pedestrian, vehicle to bicycle, and vehicle to transit shelter. Crash data (January 2007 through July 2012) for all reported crashes was supplied by the Nevada Department of Transportation (NDOT). Whereas, crash data (January 2007 through October 2012) for vehicle to transit shelter crashes was supplied by the RTC. A breakdown for each year and the total combined crashes can be viewed in Table 2.

Table 2: Crash Type Comparison						
Crash Type	**Total Crashes**	**Percent of Total Crashes**	**Total Injuries**	**Percent of Total Injuries**	**Total Fatalities**	**Percent of Total Fatalities**
2007						
All	49,939	100.00%	25,619	100.00%	244	100.00%
Pedestrian	712	1.43%	926	3.61%	38	15.57%
Bicycle	320	0.64%	341	1.33%	6	2.46%
Transit Shelter	24	0.05%	0	0.00%	0	0.00%
2008						
All	45,658	100.00%	23,594	100.00%	200	100.00%
Pedestrian	733	1.61%	1,062	4.50%	43	21.50%
Bicycle	243	0.53%	250	1.06%	6	3.00%
Transit Shelter	30	0.07%	2	0.01%	1	0.50%
2009						
All	41,450	100.00%	22,595	100.00%	144	100.00%
Pedestrian	612	1.48%	664	2.94%	25	17.36%
Bicycle	421	1.02%	432	1.91%	5	3.47%
Transit Shelter	17	0.04%	0	0.00%	0	0.00%
2010						
All	40,756	100.00%	23,076	100.00%	148	100.00%
Pedestrian	557	1.37%	571	2.47%	28	18.92%
Bicycle	380	0.93%	399	1.73%	3	2.03%
Transit Shelter	8	0.02%	3	0.01%	0	0.00%
2011						
All	34,523	100.00%	20,852	100.00%	50	100.00%
Pedestrian	1,057	3.06%	1,023	4.91%	31	62.00%
Bicycle	371	1.07%	347	1.66%	1	2.00%
Transit Shelter	17	0.05%	0	0.00%	0	0.00%
2012* (All, Pedestrian, and Bicycle Crashes Are From January 2012 - July 2012. Transit Shelter Crashes Are From January 2012 - October 2012)						
All	15,415	100.00%	9,205	100.00%	24	100.00%
Pedestrian	360	2.34%	332	3.61%	7	29.17%
Bicycle	165	1.07%	154	1.67%	1	4.17%
Transit Shelter	16	0.10%	13	0.14%	4	16.67%
2007 - 2012*						
All	227,741	100.00%	124,941	100.00%	810	100.00%
Pedestrian	4,031	1.77%	4,578	3.66%	172	21.23%
Bicycle	1,900	0.83%	1,923	1.54%	22	2.72%
Transit Shelter	112	0.05%	18	0.01%	5	0.62%
Source: NDOT Traffic and Safety Division, November 2012; RTC, November 2012; Parsons Brinckerhoff, November 2012						

From January 2007 through July 2012, there were a total of 227,741 crashes resulting in 124,941 injuries and 810 fatalities. The most common vehicle involved in the crashes was a 4-door sedan. Out of the total number of crashes, vehicle to pedestrian crashes only accounted for 1.77% of the total crashes (4,031 vehicle to pedestrian crashes). However, they accounted for 3.66% of the total injuries (4,578 vehicle to pedestrian injuries) and 21.23% of the total fatalities (172 vehicle to pedestrian fatalities). The calculations show that it is much more likely for a fatality to occur in a vehicle to pedestrian crash than a vehicle to vehicle crash. Additionally, it is highly likely that an injury will occur when a vehicle to pedestrian crash takes place. Similar to vehicle to pedestrian crashes, vehicle to bicycle crashes also have a high likelihood of resulting in an injury. However, the fatality rate isn't as high as it is for pedestrians.

Vehicle to transit shelter crashes have lower rates of injuries and fatalities than vehicle to pedestrian crashes, because most of the shelters were hit at night when no one was occupying the transit shelter. However, it is still alarming that 112 vehicle to transit shelter crashes have occurred since 2007; resulting in 18 injuries and 5 fatalities. The question that keeps getting asked is why? Why have there been almost 20 crashes a year at transit shelters? What do these crashes have in common?

After a field review and evaluating the crash data supplied by the RTC, the most common type of vehicle to transit shelter crashes occur with transit shelters located on the sidewalk on 45 mph major arterials. 94 of the 112 vehicle to transit shelter crashes (84%) occurred when the transit shelter was located on the sidewalk. A list of the each vehicle to transit shelter crash and a corresponding map can be viewed in Appendix.

The percentage of crashes where the driver was under the influence is unknown due to the large number of shelters that were hit at night and the driver left the scene of the accident. However, according to the RTC, there have been 12 fatalities in the last 10 years at transit stops caused by vehicles leaving the roadway. In every instance the driver was impaired, distracted, or was not following the law. Therefore, this factor needs to be considered when focusing on protecting transit stops, transit riders, and pedestrians.

The original *Transit Shelter Safety Study* cited other agencies where vehicle to transit shelter crashes occurred and the agency's action to the crashes. The summary of the findings can be viewed in Table 3.

TABLE 3: TRANSIT AGENCY INCIDENTS AND ACTION		
Agency	**Incidents**	**Action**
Maryland Transit Administration	Incident of a passenger struck by an encroaching automobile while waiting at a bus stop.	No actions were taken to reduce the likelihood of future incidents.
San Francisco Metropolitan Transit Authority (SFMTA)	Variety of problems with pedestrian-vehicle incidents. However, passengers struck by errant vehicles while at a transit stop are uncommon and not currently addressed by SFMTA.	At specific stops, those which utilize loading islands, handrails are used to keep passengers on the loading island.
Oahu Transit Services (TheBus)	Does not directly address transit stop safety related to roadside encroachments by errant automobiles.	The agency attempts to set bus stops back from the curb to account for ADA guidance relating to the distance between the bench and the curb. This moves waiting passengers away from the flow of traffic, creating separation between passengers and the adjacent traffic stream.
Southwest Regional Transit Authority (Ohio Metro) in Cincinnati, Ohio	No information on and does not directly address incidents of automobiles encroaching into the roadside and striking passengers waiting at bus stops.	In reaction to an accident at a light rail station, design modifications were made at two major transit centers. Bollards designed to arrest a bus traveling under 5 mph were installed at the end of sawtooth bays in these transit centers.
Washington Metropolitan Area Transit Authority (WMATA) in Washington, DC	Does not directly address transit stop safety related to errant automobiles encroaching into the roadside and striking passengers.	Currently developing new bus stop guidelines in order to provide consistency to bus stop design. The guidelines will recommend new bus stop setbacks of at least 5 feet from the face of curb.
Pace Suburban Bus in the suburbs of Chicago, IL	Has not had an incident like this in recent memory and does not keep data related to roadside encroachments resulting in automobile-passenger accidents at transit stops.	Planning staff have considered (but not acted on) various items, such as rumble strips, corner guard rail, illumination, and passenger education programs. Rumble strips installed around the dedicated space for a bus stop might alert drivers that they are leaving the roadway if a transit stop is near. This noise could also alert waiting passengers that the bus (or an errant vehicle) was approaching. Corner guardrails installed when a bus stop is located very close to a corner can be used to keep automobiles from encroaching on the roadside during the turn. In some instances in Chicago, bus shelters are oriented with the solid side of the shelter facing the roadway. This is done to protect passengers from street-splash during wet weather conditions. Increasing illumination at bus stops and initiating education programs reminding passengers to remain alert and stay back from the curb could be effective in promoting safety, according to Pace staff.
Arlington County Transit	Among the 11,000 bus stops in Arlington County, there have only been two incidents of an encroaching automobile striking a bus stop in recent years. Both transit stops were unoccupied when the incidents occurred. Staff recalls that one incident was due to drunk driving while the other occurred when a driver swerved to avoid another vehicle. However, the agency does not keep specific data related to these types of incidents.	Arlington County Transit published bus stop guidelines that include a recommendation for the installation of a crash barrier on roads which have a speed limit of 45 mph or over. Currently no crash barriers have been installed at Arlington County transit shelters for this express purpose.

TABLE 3: TRANSIT AGENCY INCIDENTS AND ACTION		
Tri-County Metropolitan Transportation District of Oregon (TriMet)	Replaces or repairs approximately 10 shelters per year because of accidents involving errant vehicle roadside encroachment. According to staff, most of these incidents occur late at night when buses are not in service. No occupied shelters have been hit in recent memory. One particular shelter, located on an island at the intersection of three streets (52nd, Powell, and Foster), has been hit three times by errant vehicles.	TriMet does not directly address transit stop safety related to roadside encroachments.
Chicago Transit Authority (CTA)	Has not had recurring problems with transit shelters stuck by encroaching automobiles.	In general, CTA routes are not located on high-speed arterials but operate in urban settings with relatively low travel speed and ample on-street parking. The presence of on-street parking plays a vital role in curbing roadside encroachments (the parked cars act as a barrier). CTA is conducting a study of pedestrian safety near bus stops, but this work focuses on the crossing behavior of passengers and pedestrian interactions inside the roadway, not the roadside.
Shelter Express in New York City (one of the transit stop operations and maintenance contractors for the New York Metropolitan Transportation Authority (MTA)	Transit stop accident rates in New York are relatively low and average two accidents per year.	The low travel speeds of congested Manhattan may serve to reduce the accident rates. On-street parking also provides positive separation between the roadway and the roadside.
Los Angeles County Metropolitan Transportation Authority	Has accident rates for transit shelters similar to those of the Las Vegas area (two per month) in recent years. However, since September 1979, the Los Angeles MTA has seen 244 shelter accidents, or an average of 1.4 shelter accidents per month. The majority of shelter accidents happen overnight when service is not running and no staff members could remember any fatalities.	The MTA has discussed bollards as a solution to shelter accidents but concluded bollards to be unsafe, cost ineffective, and jurisdictionally infeasible. Shelter Clean-LA, the MTA's operations and maintenance contractor, maintains transit shelters throughout the county.
Valley Metro in Phoenix	Accident rates in the Phoenix area are low (two to three per year). An encroaching automobile hit an occupied shelter in October 2008. Two transit passengers were hospitalized, and the incident was recorded on surveillance video.	Shelter Clean-Phoenix maintains transit shelters for Valley Metro.
New Jersey Transit (NJTransit)	Limited information.	Installed bollards at 24 transit shelters. The infrequent installations are primarily due to safety concerns. In general, the bollards installed by NJTransit are located at malls, parking lots, and transit stations or anywhere travel speeds are anticipated to be low.
Source: *Transit Shelter Safety Study*		

The following pages focus on presenting mitigation measures that will improve rider safety. It is followed by Parsons Brinkerhoff's recommendations for the RTC.

3.0 MITIGATION MEASURES

3.1 Reduce Speed Limit

The majority of the transit routes within the Las VegasValley exist on major arterials. These major arterials typically have 6-lanes (3-lanes in each direction) with a 45 mph speed limit. However, drivers typically travel faster than the posted 45 mph speed limit. According to America Walks[3]:

> If a pedestrian is hit by a vehicle that is traveling 20 mph, the pedestrian survival rate is 95 percent. This drops to 60 percent at 30 mph, and just 20 percent at 40 mph.

The relationship between vehicle speed and accident outcome severity is well established. An OECD/ECMT report[4] states "a 5% decrease in average speed leads to approximately a 10% decrease in injury accidents and a 20% decrease in fatal accidents." A couple of examples where speed reduction decreased the number fatalities include:

- France – Over three years (2002 through 2005), the average speed on French roads decreased by 5 km/h (3.1 mph) and fatalities decreased by over 30%.
- Hungary – The speed limit was reduced from 60 km/h (37.3 mph) to 50 km/h (31.1 mph) and resulted in a reduction of 18.2% accident fatalities.

In order to help reduce the fatality rate of pedestrians, bicyclists, transit riders, and drivers, the speed limit could be reduced from 45 mph to 35 mph on major arterials with transit routes. However, people tend to drive at the speed limit they feel is safe. Therefore, the only way to keep everyone at the newly posted 35 mph speed limit is through Engineering, Enforcement, and Education.[5] In addition, regional consensus for this measure would be required, after demonstrating that system-wide delays and air quality standards would not be compromised. Effective ways to enforce a 35 mph speed limit include:

- Synchronizing traffic signals to turn green based off of a vehicle traveling at 35 mph. In other words, if a vehicle is stopped at a traffic signal and the signal turns green, that vehicle would have to stop at the next traffic signal if it traveled faster than an average speed of 35 mph between the consecutive traffic signals. The synchronization process could be accomplished through coordination between the local entities and the RTC's Freeway and Arterial System of Transportation (FAST) department. Signage would be crucial in alerting drivers that the signals are set for a vehicle traveling at 35 mph. An example of a sign that could be used to alert drivers is shown in Figure 1.
- Increase the police enforcement along arterials with transit routes and pull over drivers that are speeding and running red lights.

Figure 1: Signals Set For 35 MPH Sign

- Incorporate traffic calming through the implementation of Complete Streets concepts. "Traffic calming consists of engineering and other measures put in place on roads for the intention of slowing down or reducing motor-vehicle traffic. This is done in order to improve the living conditions for residents living along the road as well as to improve the safety for pedestrians and cyclists."[6] The RTC has approved a Complete Streets policy and is in the process of developing a *Complete Streets For Living Communities Design Guide* to support local entity efforts. Complete Streets are described in more detail later in this document.

A common fear that exists for motorists is that decreasing the speed limit will greatly increase their travel time. However, according to the Monash University Research Centre[7], this is often a misleading assumption. Table 4 summarizes the amount of time lost when decreasing the speed limit by 5 km/h (3.1 mph) for a trip of 10 km (3.1 mph).

TABLE 4: EXTRA TRAVEL TIME ON A JOURNEY OF 10 KM (6.2 MILES) WHEN AVERAGE SPEED IS REDUCED BY 5 KM/H (3.1 MPH)

Original Speed [km/h (mph)]	35 (21.7)	45 (28.0)	55 (34.2)	65 (40.4)	75 (46.6)	85 (52.8)
Reduced Speed [km/h (mph)]	30 (18.6)	40 (24.9)	50 (31.1)	60 (37.3)	70 (43.5)	80 (49.7)
Travel Time Difference [mins:secs]	2:51	1:40	1:05	0:46	0:34	0:26

Source: Monash University Accident Research Centre, January 2008; Parsons Brinckerhoff, January 2013

From Table 4, it can be calculated that reducing the travel time from 45 mph to 35 mph will only decrease your travel time for a 10-mile trip by approximately 3.5 minutes (roughly 20 seconds per mile), as shown in Table 5.

TABLE 5: EXTRA TRAVEL TIME ON A JOURNEY OF 10 MILES WHEN AVERAGE SPEED IS REDUCED FROM 45 MPH TO 35 MPH					
Original Speed [km/h (mph)]	65 (40.4)	70 (43.5)	75 (46.6)	75 (46.6)	**72.4 (45)**
Reduced Speed [km/h (mph)]	60 (37.3)	65 (37.3)	70 (43.5)	60 (37.3)	**56.3 (35)**
Travel Time Difference per 10 km [mins:secs]	0:46	0:40	0:34	2:00	**2:08**
Travel Time Difference per km [mins:secs]	0:04	0:04	0:03	0:12	**0:12**
Travel Time Difference per Mile [mins:secs]	0:07	0:06	0:05	0:19	**0:20**
Travel Time Difference per 10 Miles [mins:secs]	1:14	1:04	0:54	3:13	**3:27**
Source: Parsons Brinckerhoff, January 2013					

Lowering the speed limits along transit routes within the Las VegasValley will help reduce the number of fatalities, while minimally affecting travel times, and help start the process of changing the culture of focusing primarily on vehicular traffic.

3.2 Sobriety Checkpoints

A large number of vehicles that left the roadway and struck a transit shelter occurred at night and were not reported to the police because the drivers left the scene of the accident. However, it is assumed that those crashes occurred because the person driving was under the influence of alcohol and/or drugs. Additionally, a large percentage of the crashes that were reported involved a driver who was under the influence of alcohol and/or drugs.

Las Vegas is unlike most cities because it is a 24-hour city where people are allowed to drink alcohol at public establishments at all times of the day. This characteristic alone could account for the higher than average vehicle to transit shelter crash rate. If sobriety checkpoints are placed on the major arterials where transit routes are located, drivers will be less likely to drink and drive on those arterials. According to the National Highway Traffic Safety Administration (NHTSA):

> The number of DUI arrests made by roving patrols is nearly three times the average number of DUI arrests made by officers at a sobriety checkpoint. However, police officers believe that roadblocks are effective, even if drunk drivers get around them, because they show the public that driving under the influence is not tolerated.[8]

Additionally, the Centers for Disease Control and Prevention (CDC) found that alcohol-related crashes were reduced by approximately 20% when sobriety checkpoints were implemented.[9] An example of a sobriety checkpoint can be viewed in Figure 2.

Implementing more sobriety checkpoints along roads that have transit routes, and continuing to use existing sobriety checkpoint locations, will help reduce the number of drivers who are under the influence of alcohol and/or drugs. In turn, fewer crashes will occur at transit stops.

Figure 2: Sobriety Checkpoint[10]

3.3 Public Service Announcement

The Clark County Regional Flood Control District does an excellent job of educating the public about the dangers of flash flooding and informing the community about the progress of flood control in Clark County.[11] Figure 3 is an example of one of their billboards, which was designed around their annual License Plate Billboard Contest.

Similarly, the RTC should educate drivers about watching out for pedestrians, bicyclists, and transit riders. A large percentage of local residents and tourists are unaware of the number of pedestrians, bicyclists, and transit shelters that are hit every year. Therefore it is necessary to get the word out about the incidents.

One method to increase awareness would be to come up with a campaign revolving around pedestrian, bicycle, and transit rider awareness. This campaign can be advertised on billboards, television commercials, radio commercials, newspapers, internet, and mailings. Additionally, RTC staff can go to local schools and educate children on the importance of watching out for pedestrians, bicyclists, and transit riders when driving and riding in a car. The goal is to educate, which will help prevent crashes from occurring.

Figure 3: Clark County Regional Flood Control District Public Service Announcement

Educating the public, particularly drivers, about the importance of watching out for pedestrians, bicyclists, and transit riders will help prevent crashes from occurring at transit stops. Local efforts through the Pedestrian Safety Task Force, the UNLV Safe Communities Coalition, the NDOT Strategic Highway Safety Plan teams, Metro, and other collaborative programs have provided progressive advertising and outreach efforts to enhance pedestrian awareness. By continuing to work alongside these groups, the RTC can improve the focus on transit rider safety.

3.4 Lighting

Many transit shelters and stop locations throughout the Las Vegas Valley are not well-lit, which could be a safety concern for transit riders. According to the American Public Transportation Association[12]:

> Station lighting serves several functions. It provides illumination, assists in station location and identification, and makes station features visible during periods of darkness. It aids bus operators in locating stations and determining whether passengers are waiting to board. Station lighting provides a sense of security for riders waiting to board a vehicle. Attractive station lighting can further highlight station architectural and design elements, which enhance the rider experience and the appeal of the BRT station for the community. Lighting also communicates when a station is closed, such as by changing the color and intensity of the lighting when the station is closed.

There are some very positive improvements underway by the different local entities to improve street lighting along roadways. The City of Henderson has completed a system wide upgrade to inductive lighting and the other entities are in the process of upgrading their lighting systems to LED lighting technologies. These new technologies provide significant object visibility improvements over the current High Pressure Sodium technology in use. The light spectrum and average luminance increases will allow drivers to better identify objects and people within the roadway cross section. This is anticipated to have a significant impact on nighttime incidents.

By utilizing the amount of sunshine Las Vegas receives, along with low energy LED lighting, the transit shelters could run off of solar energy alone. The RTC has already started adding new solar-powered bus shelters throughout the Las Vegas Valley. According to the Clark County, Nevada website[13]:

> The Regional Transportation Commission of Southern Nevada (RTC) will install 150 new solar-powered bus shelters throughout the Las Vegas Valley as part of its federally funded transit amenities program. These new transit shelters will not only provide an attractive, comfortable and shaded place for riders to wait for transit, but it will also save thousands of dollars in energy costs.
>
> The new shelters feature energy-saving LED lighting and solar panels that enable the shelters to power their own illumination without being connected to the local power grid. As a result, these 150 new bus shelters are estimated to save taxpayers about $54,000 a year in energy costs. They are built with recyclable materials; have room to accommodate a passenger in a wheelchair and will feature a bench, a receptacle bin, a display case for transit information, and two advertising panels that will improve the experience of transit riders.
>
> The purchase and installation of the 150 new energy-saving shelters was funded by a $1.8 million formula grant from the Federal Transit Administration (FTA) for transit enhancement projects. All 150 transit shelters are scheduled to be installed by Dec. 31 in Las Vegas, Henderson, North Las Vegas and unincorporated Clark County

It should be noted that the RTC will continue to install 150 new solar-powered bus shelters throughout the Las Vegas Valley each year. An example of a solar powered bus stop located in the Las Vegas Valley can be viewed in Figure 4.

Well-lit transit shelters will not only make transit riders feel safer, they will also help drivers locate them on the side of the road. Additionally, easier identification of transit shelters will help prevent drivers from hitting them. The RTC has made the effort to light transit shelters using solar/LED lighting, and should continue to achieve adequate lighting at all transit shelters throughout the system.

Figure 4: Las Vegas Valley Solar-Powered Bus Shelter

3.5 Move Shelter Behind Sidewalk

The most common theme of the transit shelters hit since 2007 is the location. Eighty four percent of the transit shelters hit were located within the sidewalk. When the transit shelters are placed within the sidewalk, they are typically within two to three feet from the edge of the curb. Not only does this create an Americans with Disabilities Act (ADA) problem, it leaves little room for a vehicle to avoid crashing into a transit shelter if it has left the roadway. According to the *2011 AASHTO Roadside Design Guide*[2]:

> In an urban environment, approximately 80 percent of roadside crashes involved an object with a lateral offset from the curb face equal to or less than 4 feet and more than 90 percent of urban roadside crashes have a lateral offset less than or equal to 6 feet.

This is strongly corroborated by local crash data, where 84 percent of shelters impacted were less than 4 feet from the face of curb. Hence, if transit shelters can be moved beyond 6-feet from the curb face, it will greatly diminish the amount of crashes that occur at transit stops.

The RTC is currently in the process of altering 150 bus stops per year, which includes moving transit shelters behind the sidewalk. According to Carl Scarbrough (RTC Transit Amenities Manager), "We've already moved back 515 shelters. We now have 478 turnouts, which is also a way to move bus stops back."[14] Figure 5 illustrates a bus stop that is located within the sidewalk, whereas Figure 6 illustrates a bus stop that is located on a bus pad behind the sidewalk.

Figure 5: Las Vegas Valley Bus Shelter Located On Sidewalk

Figure 6: Las Vegas Valley Bus Shelter Located On Bus Pad Behind Sidewalk

Moving the transit shelters back behind the sidewalk will greatly reduce the number of transit shelters that are struck by a vehicle that has left the roadway. The RTC has made the effort to move transit shelters further away from the road, however there are multiple locations where easement rights or right-of-way is not available behind the sidewalk to implement this strategy. Given the economic and right-of-way constraints, strides should continue to be made to move all transit shelters at least 6-feet from the edge of the curb throughout the Las Vegas Valley.

3.6 Move Shelter Away From Block Wall

According to the American Public Transportation Association (APTA)[12], bus shelters should have no entrapment areas and should provide escape routes, wherever possible. Putting shelters against block walls leaves transit riders limited opportunity to move out of the way if an oncoming vehicle has left the roadway and is heading toward the transit stop. Note: The entrapment concern is not as critical as the offset distance to the curb, since prior analyses have demonstrated that the reaction time available to a pedestrian who identifies a vehicle approaching is insufficient to allow for any type of evasive action.

The real issue of stops and shelters against block walls in the Las Vegas Valley is that the stop or shelter is often too close to the curb. All shelters against block walls should be considered for relocation or the right-of-way could be purchased to move the wall and shelter back. Positive shelter protection measures could be implemented where relocation is not feasible.

Figure 7 is an example of a transit shelter that is located against a block wall. This transit shelter could be moved to a different location that offers a greater offset distance from the curb or other positive protection measures could be implemented.

Figure 7: Las Vegas Valley Transit Shelter Located Against A Block Wall

3.7 Bus Turnouts & Bus Bulbs

A bus turnout, or bus bay, is a special zone on the side of the main roadway for buses to stop in order to pick up and drop off passengers. The purpose of the bus bay is to help buses avoid blocking a lane of traffic and to improve passenger safety during boarding and alighting. Additionally, bus turnouts add extra distance between the vehicles traveling on the roadway and the transit shelter. An example of a bus turnout in the Las Vegas Valley can be viewed in Figure 8.

Figure 8: Las Vegas Valley Bus Turnout

A bus bulb, or bus boarder, is where a sidewalk is extended outwards for a bus stop and typically it replaces a portion of an existing parking lane. The purpose of the bus bulb is to allow a bus to stay in its traffic lane to pick-up and drop-off passengers, without having to pull over to the curb. Similar to bus turnouts, bus bulbs add extra distance between the vehicles traveling on the roadway and the transit shelter. An example of a bus bulb can be viewed in Figure 9.

Figure 9: Bus Bulb[15]

Bus turnouts and bus bulbs help keep transit shelters further than 6-feet from the roadway, which accomplishes the same goal as moving bus shelters back behind the sidewalk. Bus turnouts are much more common in the Las Vegas Valley because there is not an abundance of on-street parking; in fact 478 bus turnouts have already been implemented. Therefore, bus turnouts should be added in all transit shelter locations where right-of-way is available.

3.8 Raised Curb

Raising the curb at transit stops may deter vehicles from leaving the roadway and help make drivers visually aware of the transit stop location. The original *Transit Shelter Safety Study* briefly describes how the height of a curb can help redirect a vehicle.

In addition to providing a buffer between vehicles and transit riders, raising the curb at bus shelters allows for level or near-level boarding onto buses. According to the APTA[12]:

> This option attempts to most closely resemble rapid transit applications by eliminating the vertical and horizontal gap between the vehicle and the platform. While no comprehensive empirical data yet exist, level boarding suggests a seamless transition into the vehicle and a perception of reduced dwell times and faster boarding attributed to customer ease… Depending on the vehicle type,

station platform heights are raised to 14 to 15 inches above the roadway… The benefits of a level platform include increased customer perception of service; ease of boarding for all customers (anticipated to manifest as quicker boarding and reduced dwell times); potentially the elimination of the need for wheelchair access ramps or lifts; stronger brand identity; and greater similarity to rail-type services.

Level boarding already exists at some of the Las Vegas MAX transit shelters and along the Sahara and Boulder Highway BRT routes. The curb height along these alignments is 10 or 11 inches to accommodate the vehicles in use, and this height is much less effective in redirecting a vehicle than the 14 or 15 inch height mentioned in the APTA document. As such, raising the curb height as a safety measure is marginally effective, given the types of crash incidents experienced and the types of transit vehicles in service locally. Figure 10 illustrates the curb height at a Las Vegas MAX stop and Figure 11 illustrates the ease of riders boarding and leaving the Las Vegas MAX.

Figure 10: Raised Curb At Las Vegas MAX Stop

Figure 11: Las Vegas MAX Level Boarding[16]

Although raised curbs provide limited protection in preventing vehicles from leaving the roadway, they allow for easier access into and out of the bus. The RTC has made the effort to raise curbs at numerous transit stops, and consideration should be given to raise curbs at other stops throughout the system where high boarding rates or ADA access needs are demonstrated.

3.9 High Containment Curbs

The original *Transit Shelter Safety Study* briefly described an alternative curb design known as anti-vehicular curbs. These curbs are designed to promote the redirection of errant vehicles back into the roadway.

High containment curbs, a type of anti-vehicular curb, "are used to prevent traffic leaving the carriageway and are often used to protect vulnerable footpaths or sensitive roadside equipment, such as fuel pumps at filling stations, pedestrian islands, dangerous curves, etc."[17] An example of a high containment curb, used in the United Kingdom, can be viewed in Figure 12.

High containment curbs are an alternative to simply raising the curb and are used to not only prevent vehicles from leaving the roadway, but actually safely redirect the vehicle back onto its intended path.

Figure 12: High Containment Curb

3.10 Barrier

Positive (crashworthy) barriers were briefly discussed in the original *Transit Shelter Safety Study*. According to the *2011 AASHTO Roadside Design Guide*[2]:

> A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way. It also may be used to protect bystanders, pedestrians, and cyclists from vehicular traffic under special conditions.

It is important to note that barriers are "used to protect bystanders, pedestrians, and cyclists", which is the goal of this study. Barriers are an intimidating obstruction that will help prevent drivers from leaving the roadway and crashing into transit stops. A couple of examples of barrier rails can be viewed in Figure 13 and Figure 14.

The *2011 AASHTO Roadside Design Guide* recognizes low profile barrier rails as an acceptable barrier on roadways with a speed limit of 45 mph or less. They are an alternative to high containment curbs and raised curb options previously described. Barriers are described in more detail later in this document.

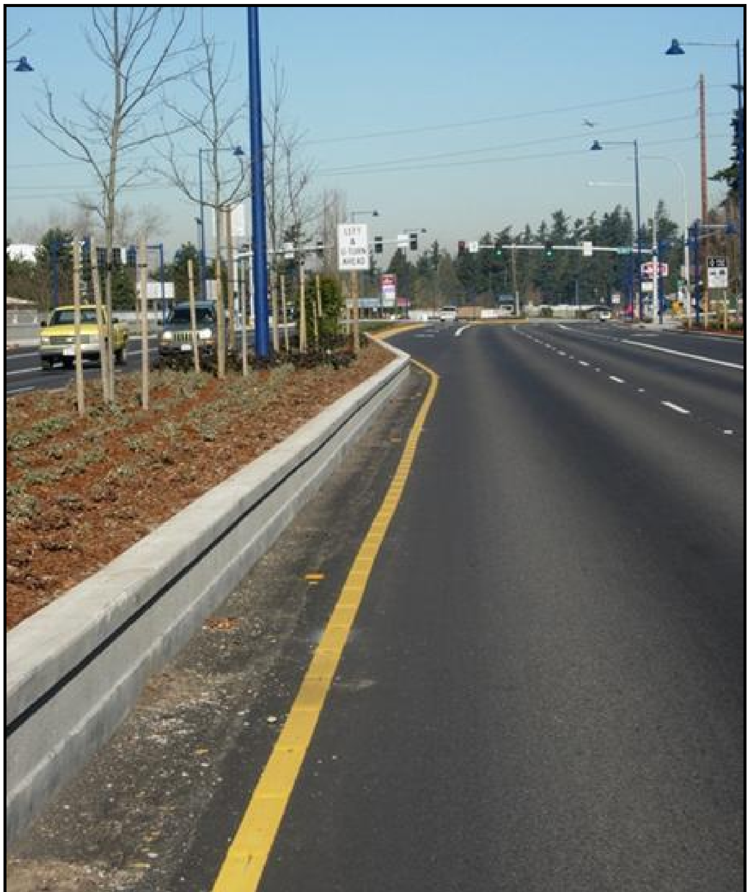


Figure 13: Low Profile Barrier In Des Moines[18]

Figure 14: Caltrans' "Test" Low Profile Barrier[19]

3.11 *Bollards*

In general, bollards are typically used on low speed facilities, such as parking lots. However, due to the circumstances that exist in the Las Vegas Valley, it is necessary to consider bollards as an alternative to help prevent vehicles from running off of the road and crashing into transit stops.

Other agencies have implemented bollards, however they have done so in limited scenarios. For example:

- Palm Beach County, Florida uses bollards, but only at the end of bus bay turnouts at transfer stations to prevent the bus from encroaching into pedestrian waiting areas[20].
- As of December 20011, the Singapore Land Transit Authority had provided 2,659 out of 4,600 bus stops with safety bollards. However, the standards used for implementation violate current US national standards for offset, strength, and layout[21].
- Miami Dade County considered implementing bollards in 2007 for transit shelter protection, but the study recommended against bollards for multiple reasons, including minimum clearance from the curb, underground utility conflicts, vehicle impact damage concerns, and the limited protection provided[22].

Bollards could have a couple of benefits to help prevent vehicles from leaving the roadway and hitting transit stops. First, bollards are intimidating and would catch the eye of a person driving a vehicle. Vehicles would be less likely to leave the roadway for fear of crashing into the bollard. Second, a properly placed bollard system would stop a vehicle from approaching a transit stop and striking people waiting at the stop. However, there is a concern that a bollard could break apart a vehicle, causing a shrapnel effect, and potentially increase the number of injuries in an impact. An example of a bollard system protecting pedestrians from vehicles on a low speed roadway can be viewed in Figure 15.

Bollards are an available option, when other measures cannot be implemented, to help reduce the number of vehicles crashing into transit stops. However, the safety of motorists cannot be ignored when adding bollards because little is gained by trading one type of injury for another. In addition, when determining the location of a transit stop, it would be desirable to utilize existing features to shield and protect transit passengers; such as existing utility poles, trees, and fire hydrants. Since other measures such as moving transit stops away from the curb and providing landscape buffers are recognized successful primary strategies, bollards should only be considered after these measures are not feasible. Additional bollard information can be found in the Appendix.

Figure 15: Bollards Separating The Roadway And The Sidewalk[23]

3.12 Handrail

In addition to the raised curb, a handrail could help pedestrians adjust to the changing slope in the sidewalk. Furthermore, it could be a supplementary barrier between vehicles and pedestrians and can be used as an alternative to bollards. The handrail would have a similar visual affect as the bollard system, in that it would catch the eye of a driver and it would help prevent a vehicle from leaving the roadway and hitting a transit shelter. Additionally, a handrail would be more aesthetically pleasing than a traditional bollard. However, the handrail could have similar issues as the bollard system, in that it could actually endanger people by causing a shrapnel effect when impacted by a vehicle. In addition, the end of the top of the handrail would need to be designed to prevent the handrail from becoming a spear and injuring the driver of an oncoming vehicle. An example of a handrail protecting a sidewalk from a roadway can be viewed in Figure 16.

A handrail is an option to not only help reduce the number of vehicles crashing into transit stops, but as an assistance mechanism for pedestrians who need help adjusting to the change in slope of the sidewalk.

Figure 16: Handrail Separating Sidewalk And Roadway[24]

3.13 Concrete Planters

Concrete planters, with trees planted inside of them, could be used as an alternative to a bollard system. The concrete planter and tree would prevent a car from hitting a shelter and provide much needed shade during the hot summer months. In addition, it would be a much more aesthetically pleasing option than a typical bollard system. However, the width required to incorporate planters behind the curb is a major consideration, moreover the RTC would need to resolve the maintenance issue. One possibility would be to give property owners an option between the concrete planters or other measures, and if the owners choose the concrete planters they must agree to maintain the trees. Figure 17 and Figure 18 are examples of concrete planters that could be used as a barrier between pedestrians and vehicles.

Concrete planters with trees, placed in front of transit shelters, would not only provide shade but they could help stop or slow down vehicles that are airborne, similar to the one described at the beginning of the document. However, the trees would have a negative effect on solar panel operation. If implemented, it is recommended that they are placed at least 6 feet from the edge of the curb.

Figure 17: Concrete Planters With Trees[25]

Figure 18: Concrete Planters With Trees[26]

3.14 Concrete Trash Receptacles

Similar to concrete planters, the concrete trash receptacle can double as a bollard. They can be cast-in-place with reinforcing steel to act as a barrier between an on-coming vehicle and a transit rider. An example of a concrete trash receptacle can be viewed in Figure 19.

Figure 19: Concrete Trash Receptacle[27]

Since trash receptacles are necessary at all transit shelters, it could be beneficial to construct heavy-duty trash receptacles that could be used as a barrier to help stop a vehicle approaching a transit stop. If implemented, it is recommended that they are placed at least 6 feet from the edge of the curb.

3.15 Side Street Placement

If safety measures cannot be made at particular transit stops, it may be possible to move the transit stop to a side street that has lower traffic volumes. The original *Transit Shelter Safety Study* briefly discusses placing transit shelters on side streets when operated in conjunction with a passenger actuated bus stop sign.

Side street placement should only be used if the existing transit stop cannot be relocated to a safe location on the existing transit route.

3.16 Complete Streets With Pedestrian Buffer

Complete streets are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists, and transit riders of all ages and abilities.[28] Incomplete Streets focus mainly on vehicular traffic and vehicular traffic alone.

One option included in many Complete Street studies involves the implementation of a pedestrian buffer, which adds a more comfortable distance between the transit stop and the roadway, and it makes pedestrians feel safer when walking alongside a major arterial. Additionally, it is aesthetically pleasing and could be used for trees which would provide much needed shade in the hot summer months. Figure 20 is an example of a pedestrian buffer between the roadway and meandering sidewalk within the Las Vegas Valley.

Figure 20: Pedestrian Buffer Between Roadway And Meandering Sidewalk

The RTC recently completed a *Regional Complete Streets Study* and is in the process of developing a *Complete Streets For Living Communities Design Guide* which will focus on improving corridors throughout the Las Vegas Valley with Complete Streets in mind. Items that have already been implemented include bicycle lanes (see Figure 21) and "Bus Only" lanes (see Figure 22). The "Bus Only" lanes are another way to add distance between passenger vehicles on the roadway and the transit stop.

Complete Streets keep all modes of travel in mind which makes it safer for pedestrians, bicyclists, and transit riders at transit stops. The RTC has started to make the effort to implement Complete Streets throughout the Las Vegas Valley, however strides should continue to keep the focus of transportation projects on all modes of travel.

Figure 21: Bicycle Lane Within The Roadway

Figure 22: Diamond Lane For Buses And Right-Turning Vehicles

3.17 Rumble Strips And "Bus Stop Ahead" Pavement Markings

Rumble strips are a road safety feature that alerts inattentive drivers, by causing a tactile vibration and audible rumbling, transmitted through the wheels, into the car body.[29] They could be used to help alert drivers that a transit stop is approaching, which will make them less likely to run off the road and crash into a transit shelter.

Two types of rumble strips that could be used in this situation include transverse ruble strips and shoulder rumble strips. Transverse rumble strips are either raised bars or groves placed across the travel lane. They would be placed on the far outside lane only, which would cause cars to avoid traveling in the lane closest to the sidewalk to steer clear of the rumble strips. The further a vehicle is away from the curb, the less likely it is to run off of the road. An example of transverse rumble strips can be viewed in Figure 23.

Figure 23: Roadway Rumble Strips[30]

Shoulder rumble strips are either raised bars or grooves placed along the edge of the curb. They would help alert drivers if they started to get too close to the edge of the curb and the sidewalk. If a driver is alerted that they are too close to the curb, they will adjust their vehicle and avoid running off of the road and crashing into a transit shelter. An example of a shoulder rumble strip along the edge of the road can be viewed in Figure 24, an example of a shoulder rumble strip separating the edge of a roadway and a bicycle lane can be viewed in Figure 25, and an example of a shoulder rumble strip at a bus stop in the United Kingdom can be viewed in Figure 26. Due to the impact to bicycle riders and the types of transit shelter crashes experienced locally, rumble strips should be used only where other measures are not available, or where site conditions demonstrate a driver lane drift problem.

Figure 24: Shoulder Rumble Strips[31]

Figure 25: Shoulder Rumble Strips Between Roadway And Bike Lane[32]

Figure 26: Shoulder Rumble Strips At Bus Stop In The United Kingdom[33]

In addition to or an alternative to the rumble strips would be "Bus Stop Ahead" pavement markings. The pavement markings would alert drivers that a transit stop is ahead. Similar to the rumble strips, if a driver is alerted that a transit stop is ahead, they will become more aware of the transit stop location and be less likely to run off the road and crash into a transit stop. The implementation of pavement markings should be used only where considered site-appropriate. An example of a "Bus Stop" pavement marking that exists in Massachusetts can be viewed in Figure 27.

Rumble strips, "Bus Stop Ahead" pavement markings, or a combination of the two would help drivers become aware that a transit stop is approaching. This awareness would help reduce the number of crashes that occur at transit stops each year.

Figure 27: "Bus Stop" Pavement Markings In Massachusetts[34]

3.18 Additional Options

Numerous options were considered when trying to find the best ways to reduce, and eventually eliminate, the number of crashes at transit stops throughout the Las Vegas Valley. These additional options are available as an added tool to enhance shelter and stop location visibility and safety, and are not necessarily a system wide application. A few additional options that were discussed include:

- Brightly Painted Transit Shelters – the more noticeable a transit shelter is, the less likely a vehicle will run off the road and crash into it. The transit shelters could have a similar theme that is aesthetically pleasing to the community; each one could be designed by a local artist within the community; and/or a contest could be held to allow people to design their own transit shelter (could coincide with the public service announcement described earlier in this document).

- Brightly Painted Curbs – similar to the transit shelters, the more noticeable a transit stop is, the less likely a vehicle will run off the road and crash into it.
- Reflective Coating – add a reflective coating to transit shelters that will enhance the visualization of the transit shelters during the night. Similar to the brightly painted transit shelters, the more noticeable a transit stop is, the less likely a vehicle will run off the road and crash into it.
- Rear-Facing Transit Shelters – rather than having the transit shelters open facing the road, transit shelters could be designed to have a protective barrier between the roadway and the shelter. The design would have to accommodate for easy access in and out of the shelter and still allow for riders to sit and see if a bus is approaching. An example of a rear-facing transit shelter can be viewed in Figure 28. Note: This would require a redesign of the current general market shelters to accommodate advertising panels that do not restrict visibility. In addition, this option normally places the shelter closer to the curb, therefore supplemental protection measures may be needed.

Figure 28: Rear-Facing Transit Shelter[35]

Brightly painted and reflective transit shelters and curbs could make a transit stop more recognizable, which would help prevent some of the vehicle to transit shelter crashes. Additionally, designing a transit shelter that protects riders from the roadway traffic would be beneficial to the transit riders and increase their sense of safety at transit stops.

4.0 BARRIER RAIL DESIGN

One objective of this study was to develop a prototypical barrier system concept suitable to deter damage at transit stops and injury to transit users. The barrier layouts developed are based on guidelines in the *2011 AASHTO Roadside Design Guide*. The discussion of the barrier layouts is based on the assumption that the reader is familiar with the guide.

The majority of barrier rail systems are continuous and longitudinal in nature. They are laid out, in general, with the concepts depicted in Figure 29.

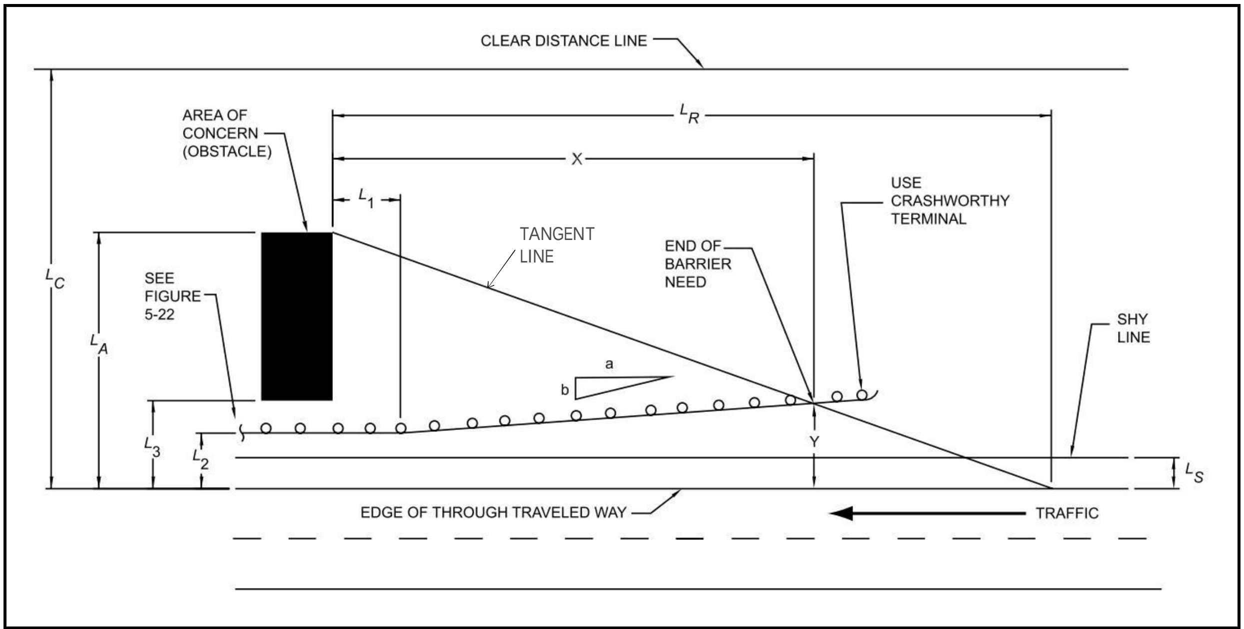


Figure 29: Approach Barrier Layout Variables[2]

The runout length (L_R) is 230 feet for a 50 mph roadway, which equates to a 45 mph speed limit, the most common speed limit along transit routes within the Las Vegas Valley.

The triangular area, located between the "edge of through traveled way" and the "tangent line", is the area where physical barriers can shield the transit stop from a vehicle running off of the roadway. Note: Existing features, such as utility poles and street trees, can shield the transit shelter from oncoming vehicles. However, no protection is provided if the existing features are located behind the sidewalk where the transit shelter is located on the sidewalk.

The required length-of-need (X) is the length of barrier rail needed in advance of the "area of concern" (in this case, a transit shelter) for a straight section of roadway. For a typical transit shelter placed on a 5-foot sidewalk, the length-of-need is approximately 165 feet. However, the standard placement of a transit shelter is typically 70 to 200 feet from the end of the curb return to the nose of the transit shelter. Thus, in many cases, the length-of-need will exceed the available length.

To address this concern, it is necessary to consider the angle of incidence for roadside crashes. Studies indicate that the median angle of incidence for a roadside crash on a city street is about

16°, with a standard deviation of 7.44°, resulting in a range from 8° to 24°. By comparison, the angle of incidence for the tangent line to a shelter located on a 5-foot sidewalk is approximately 1.75°. Therefore, the placement of a longitudinal barrier rail should be site specific to provide the longest length-of-need possible. Additionally, the length may be adjusted if other existing features can provide additional shielding to transit shelters.

In most urban settings, it is impractical to provide a longitudinal barrier of sufficient length to fully protect a transit stop from an errant vehicle. However, providing a combination of barriers in the immediate vicinity of the transit stops can provide the needed protection. Section 4.3 of this document provides conceptual plans for the installation of barriers, low profile barriers, and bollards for the protection of five separate transit stop scenarios.

4.1 Low Profile Barrier

The *2011 AASHTO Roadside Design Guide* identifies a low profile barrier that has been developed for use in urban environments. A low profile barrier is typically an 18-inch to 20-inch high vertical curb and is appropriate where Test Level 2 barrier systems are suitable. Test Level 2 barrier systems are used where the "design vehicle" consists of passenger cars and pickup trucks. Note: As mentioned earlier in this document, the most common vehicle involved in crashes within Clark County are 4-door sedans. Hence, Test Level 2 barrier systems account for this type of vehicle.

The low profile barrier system was tested in 1998 by the Texas Department of Transportation and has subsequently been approved for use by the Federal Highway Administration. Low profile barriers, using various designs, are now in use in Iowa, Florida, California, and Texas:

- Iowa – the barrier section described earlier in the document includes a photo of a low profile barrier in Des Moines, IA. This type of low profile concrete barrier is more aesthetically pleasing than traditional concrete barriers.[18]
- Florida – the state has standard plans for portable precast low profile concrete barrier systems.[36]
- California – the barrier section described earlier in the document includes a photo of Caltrans' "test" low profile barrier. This type of barrier was developed to address design criteria relating to the protection of trees on low-speed highways.[19]
- Texas – in April 1998, the Texas Department of Transportation sponsored a study for compliance testing of an end treatment for the low profile concrete barrier system. The study included a full-scale crash testing of the end treatment and recommended its implementation for Test Level 2 applications, per NCHRP Report 350, for terminals and re-directive crash cushions. The end treatment tested was a tapered concrete element, 15-feet in length, with a 20-inch maximum height and a 4-inch minimum height. Figure 30 illustrates the geometry of the low profile end treatment. Note: The *2011 AASHTO Roadside Design Guide* recommends that where end treatments are used, the curb and gutter should be terminated in advance of the end treatment, which is not practical at urban bus stop locations. However, there is an allowance to install a modified curb-to-barrier end transition on lower speed urban roadways. Therefore, the RTC would need to

determine the appropriate curb-to-barrier end treatment allowed if barrier protection is implemented.

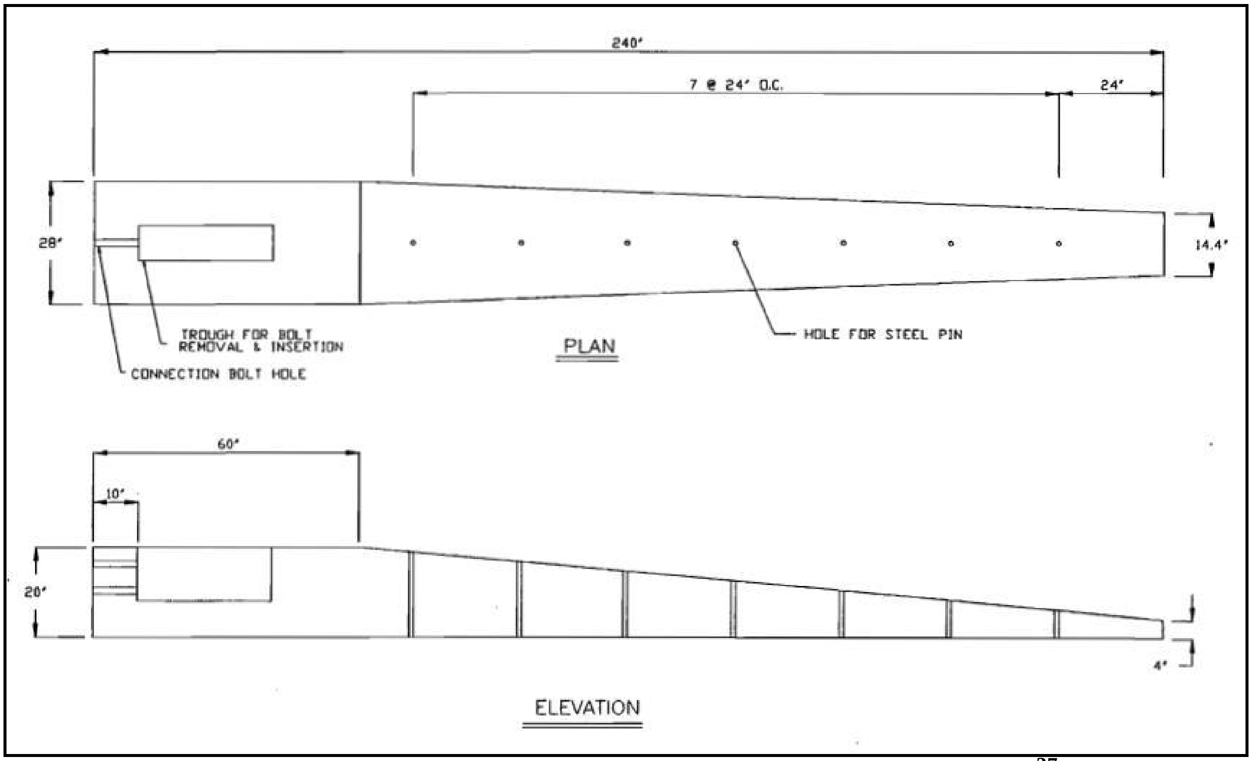


Figure 30: Geometry Of Low Profile End Treatment In Texas[37]

4.2 Conceptual Transit Stop Barrier Designs

Prototypical barrier system concepts have been developed for transit shelters with five different site conditions:

- Shelter located on 5-foot sidewalk (see Exhibit 1)
- Shelter located behind 5-foot sidewalk (see Exhibit 2)
- Shelter located on 5-foot sidewalk with 5-foot landscape buffer (see Exhibit 3)
- Shelter located behind 5-foot sidewalk with 5-foot landscape buffer (see Exhibit 4)
- Shelter located at bus turnout (see Exhibit 5)

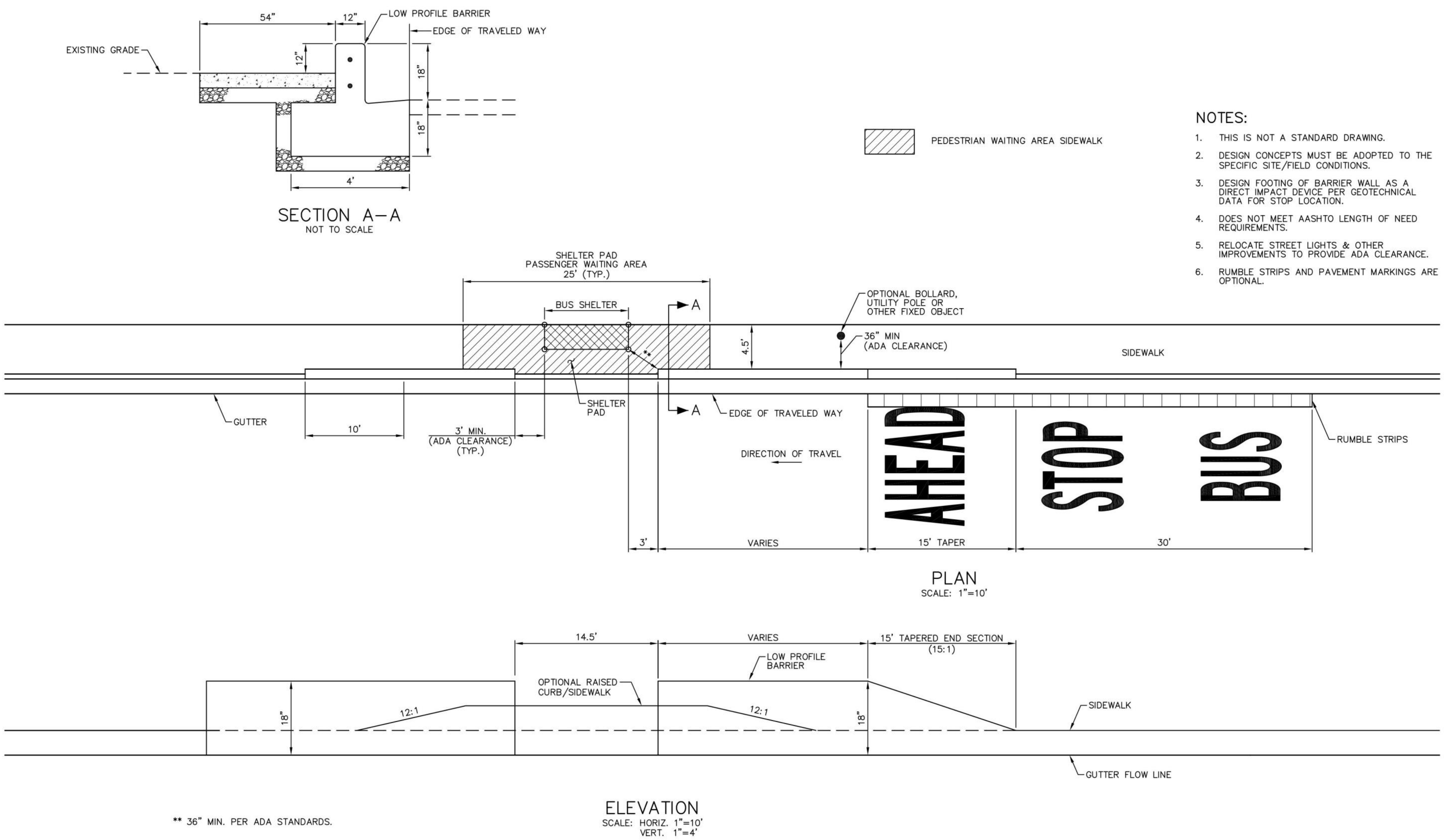
The development of these conceptual barrier plans were designed using concepts and criteria included in the *2011 AASHTO Roadside Design Guide*. The designs are based on a typical vehicle that leaves the roadway at a speed of 45 mph. Specific site conditions will necessitate adjustments to the design for each site.

4.3 Conceptual Transit Stop Barrier Cost Estimates

Cost estimates for the five different site conditions were performed. The cost estimates are based on the assumption that one shelter stop will be done per construction contract. The improvements involve a variety of trades, pavement markings, concrete placement, saw cutting, traffic control, etc.; each of which require different equipment and skilled labor. Due to the small quantities involved for many of the bid items, historical cost data is often unavailable.

The unit price for installing pavement markings on a typical arterial roadway project is about $10 per square foot. However, this unit price is for projects installing thousands if not tens of thousands of square feet of markings at one time. For example, the cost to install 68 feet of "BUS STOP AHEAD" is driven more by the time it takes the crew to prepare and clean up than it does for the actual placement of the markings. Because of this, you will notice that the unit prices vary between estimates for many of the items. The unit prices are marked up to include the estimated cost of labor and equipment traveling to and from the contractor's yard.

Each cost estimate is based on the existing shelter configuration, in other words, the cost of additional right-of-way to move the transit shelter was not included. (Table 6 corresponds with Exhibit 1; Table 7 corresponds with Exhibit 2; Table 8 corresponds with Exhibit 3; Table 9 corresponds with Exhibit 4; and Table 10 corresponds with Exhibit 5.)



PARSONS BRINCKERHOFF

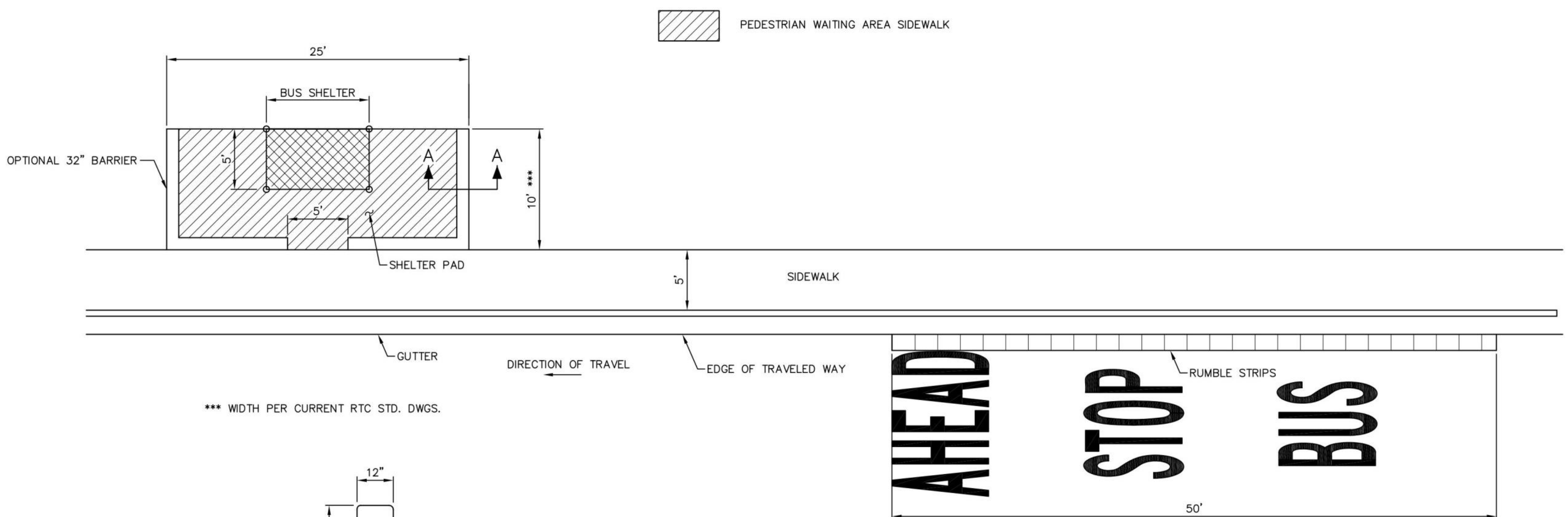
TRANSIT STOP SAFETY STUDY UPDATE

SHELTER LOCATED ON 5-FOOT SIDEWALK AASHTO LOW PROFILE BARRIER

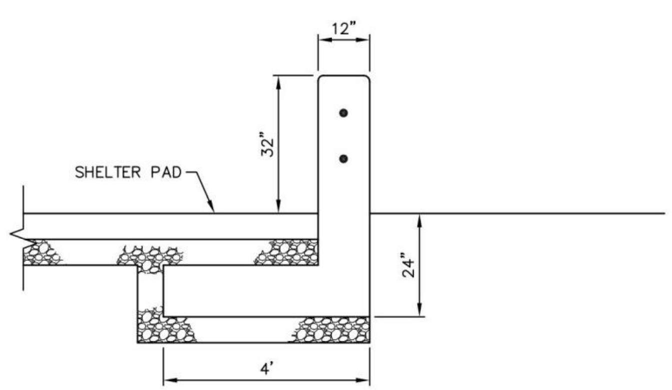
RTC

EXHIBIT - 1

TABLE 6: COST ESTIMATE FOR SHELTER LOCATED ON 5-FOOT SIDEWALK				
ITEM DESCRIPTION	**UNIT**	**QUANTITY**	**UNIT COST**	**AMOUNT**
REMOVAL OF CONCRETE SIDEWALK	SY	39	$15.00	$585.00
REMOVAL OF CURB AND GUTTER	LF	70	$12.00	$840.00
REMOVE AND RESET BUS SHELTER	EA	1	$2,000.00	$2,000.00
SAWCUT OF CONCRETE SIDEWALK	LF	10	$25.00	$250.00
MILLED RUMBLE STRIP	LF	45	$40.00	$1,800.00
SAFETY BOLLARD	EA	1	$1,200.00	$1,200.00
LOW PROFILE BARRIER W/GUTTER - 18 INCH	LF	40	$70.00	$2,800.00
CURB - 12 INCH	LF	14	$25.00	$350.00
LOW PROFILE BARRIER TAPER	LF	15	$65.00	$975.00
CONCRETE SIDEWALK	SY	30	$50.00	$1,500.00
AGGREGATE BASE (TYPE II) (CLASS B)	CY	11	$100.00	$1,100.00
PAVEMENT MARKING (BUS STOP AHEAD)	SF	68	$20.00	$1,360.00
TRAFFIC CONTROL	LUMP SUM	1	$5,000.00	$5,000.00
CONSTRUCTION SUBTOTAL				$19,760.00
30% CONTINGENCY				$5,928.00
TOTAL				**$25,688.00**



PLAN
SCALE: 1"=10'



SECTION A–A
NOT TO SCALE

NOTES:

1. THIS IS NOT A STANDARD DRAWING.
2. DESIGN CONCEPTS MUST BE ADOPTED TO THE SPECIFIC SITE/FIELD CONDITIONS.
3. DESIGN FOOTING OF BARRIER WALL AS A DIRECT IMPACT DEVICE PER GEOTECHNICAL DATA FOR STOP LOCATION.
4. DOES NOT MEET AASHTO LENGTH OF NEED REQUIREMENTS.
5. RELOCATE STREET LIGHTS & OTHER IMPROVEMENTS TO PROVIDE ADA CLEARANCE.
6. BARRIER HEIGHT 32" TO 42".
7. RUMBLE STRIPS AND PAVEMENT MARKINGS ARE OPTIONAL.

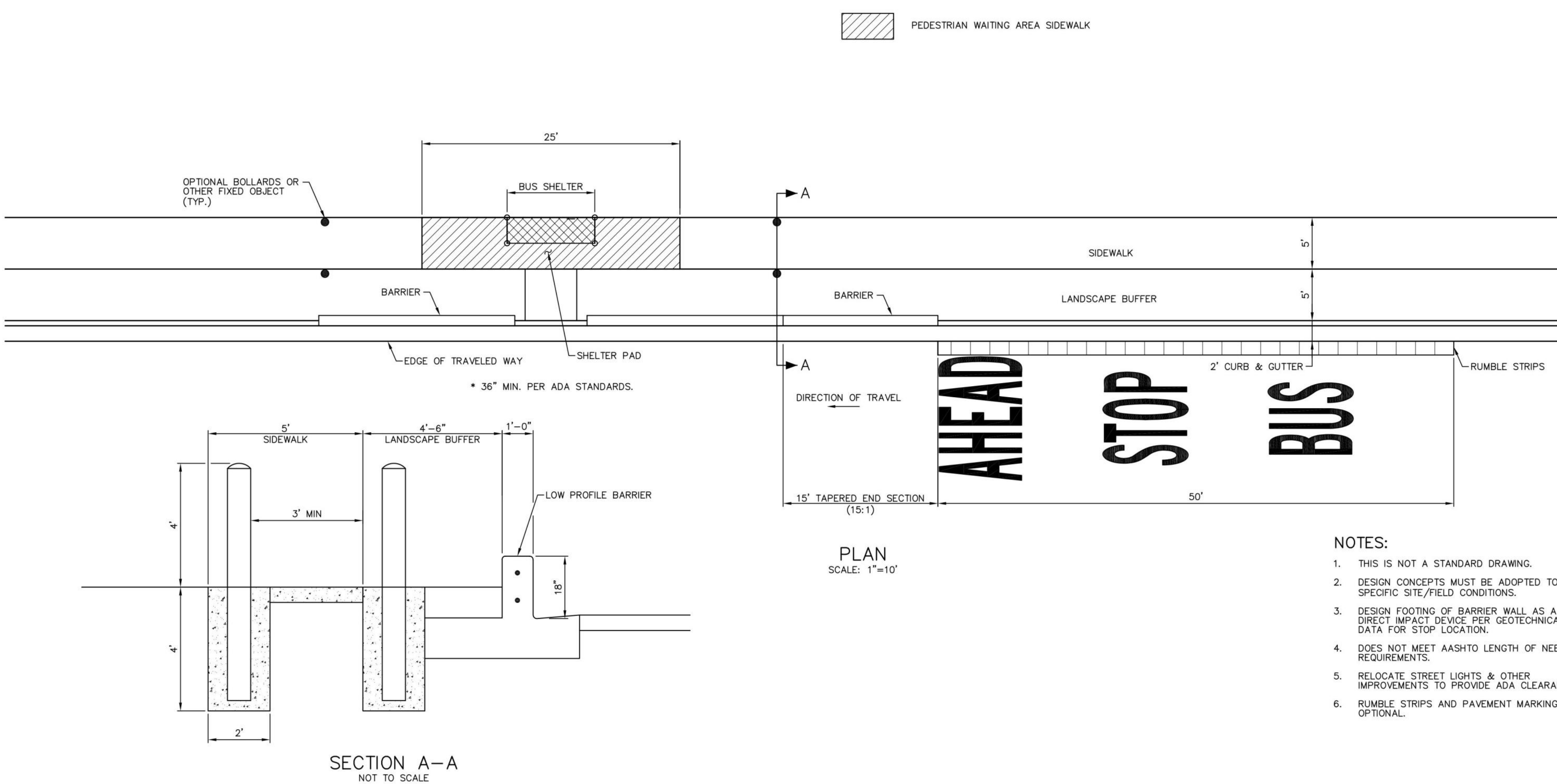
PARSONS BRINCKERHOFF

TRANSIT STOP SAFETY STUDY UPDATE

SHELTER LOCATED BEHIND 5-FOOT SIDEWALK

EXHIBIT - 2

TABLE 7: COST ESTIMATE FOR SHELTER LOCATED BEHIND 5-FOOT SIDEWALK				
ITEM DESCRIPTION	**UNIT**	**QUANTITY**	**UNIT COST**	**AMOUNT**
REMOVAL OF CONCRETE BUS PAD	SY	17	$200.00	$3,400.00
SAWCUT CONCRETE BUS PAD	LF	29	$25.00	$725.00
MILLED RUMBLE STRIP	LF	50	$40.00	$2,000.00
BARRIER - 32 INCH	LF	40	$70.00	$2,800.00
AGGREGATE BASE (TYPE II) (CLASS B)	CY	3	$100.00	$300.00
PAVEMENT MARKING (BUS STOP AHEAD)	SF	68	$20.00	$1,360.00
TRAFFIC CONTROL	LUMP SUM	1	$5,000.00	$5,000.00
CONSTRUCTION SUBTOTAL				$15,585.00
30% CONTINGENCY				$4,675.50
TOTAL				**$20,260.50**



NOTES:

1. THIS IS NOT A STANDARD DRAWING.
2. DESIGN CONCEPTS MUST BE ADOPTED TO THE SPECIFIC SITE/FIELD CONDITIONS.
3. DESIGN FOOTING OF BARRIER WALL AS A DIRECT IMPACT DEVICE PER GEOTECHNICAL DATA FOR STOP LOCATION.
4. DOES NOT MEET AASHTO LENGTH OF NEED REQUIREMENTS.
5. RELOCATE STREET LIGHTS & OTHER IMPROVEMENTS TO PROVIDE ADA CLEARANCE.
6. RUMBLE STRIPS AND PAVEMENT MARKINGS ARE OPTIONAL.

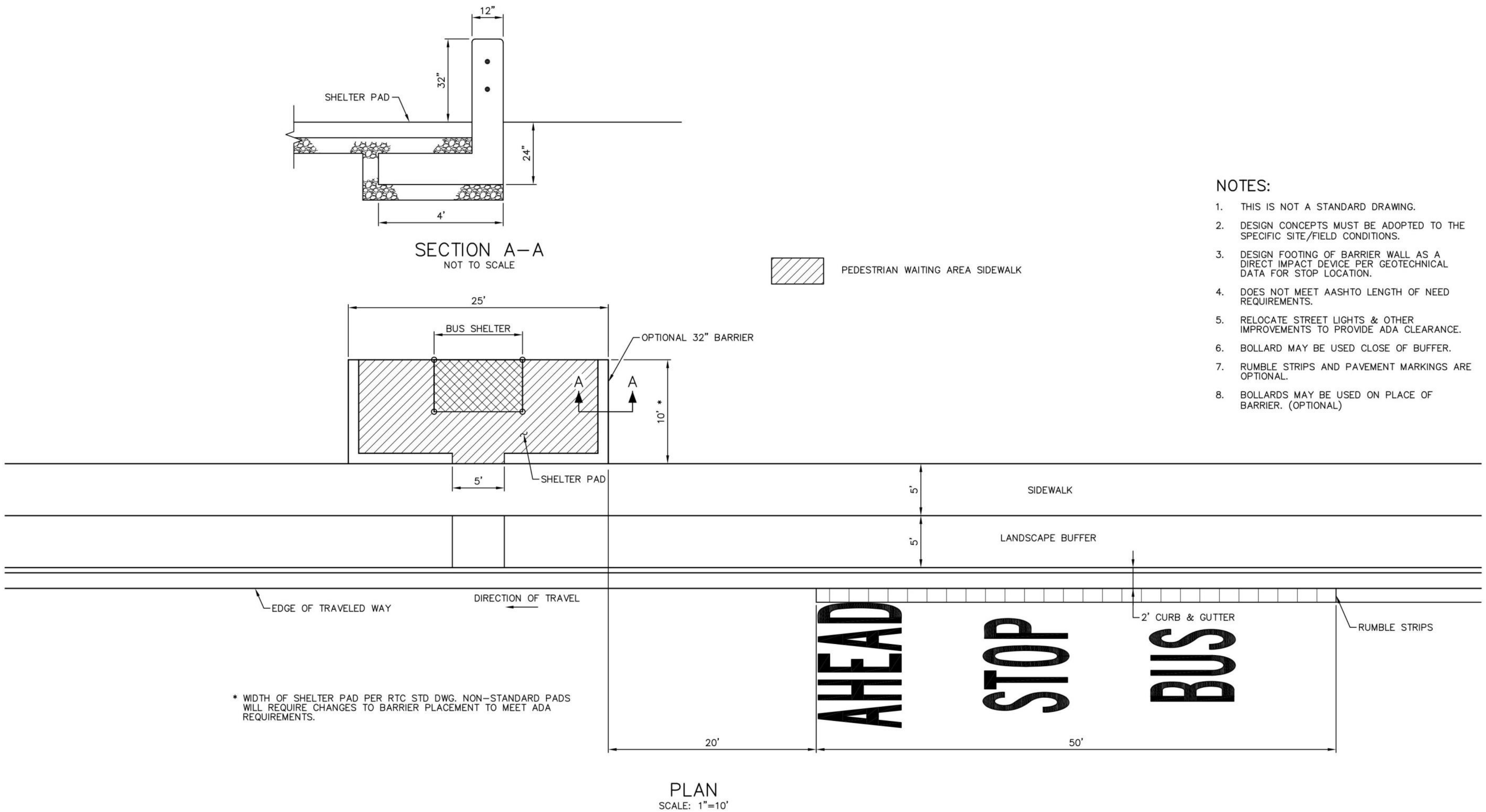
PARSONS BRINCKERHOFF

TRANSIT STOP SAFETY STUDY UPDATE

SHELTER LOCATED ON 5-FOOT SIDEWALK WITH 5-FOOT LANDSCAPE BUFFER

EXHIBIT - 3

TABLE 8: COST ESTIMATE FOR SHELTER LOCATED ON 5-FOOT SIDEWALK WITH 5-FOOT LANDSCAPE BUFFER				
ITEM DESCRIPTION	**UNIT**	**QUANTITY**	**UNIT COST**	**AMOUNT**
REMOVAL OF CURB AND GUTTER	LF	55	$12.00	$660.00
MILLED RUMBLE STRIP	LF	50	$40.00	$2,000.00
SAFETY BOLLARD	EA	4	$1,200.00	$4,800.00
LOW PROFILE BARRIER W/GUTTER - 18 INCH	LF	40	$70.00	$2,800.00
LOW PROFILE BARRIER TAPER	LF	15	$65.00	$975.00
AGGREGATE BASE (TYPE II) (CLASS B)	CY	4	$100.00	$400.00
PAVEMENT MARKING (BUS STOP AHEAD)	SF	68	$20.00	$1,360.00
TRAFFIC CONTROL	LUMP SUM	1	$5,000.00	$5,000.00
CONSTRUCTION SUBTOTAL				$17,335.00
30% CONTINGENCY				$5,200.50
TOTAL				**$22,535.50**



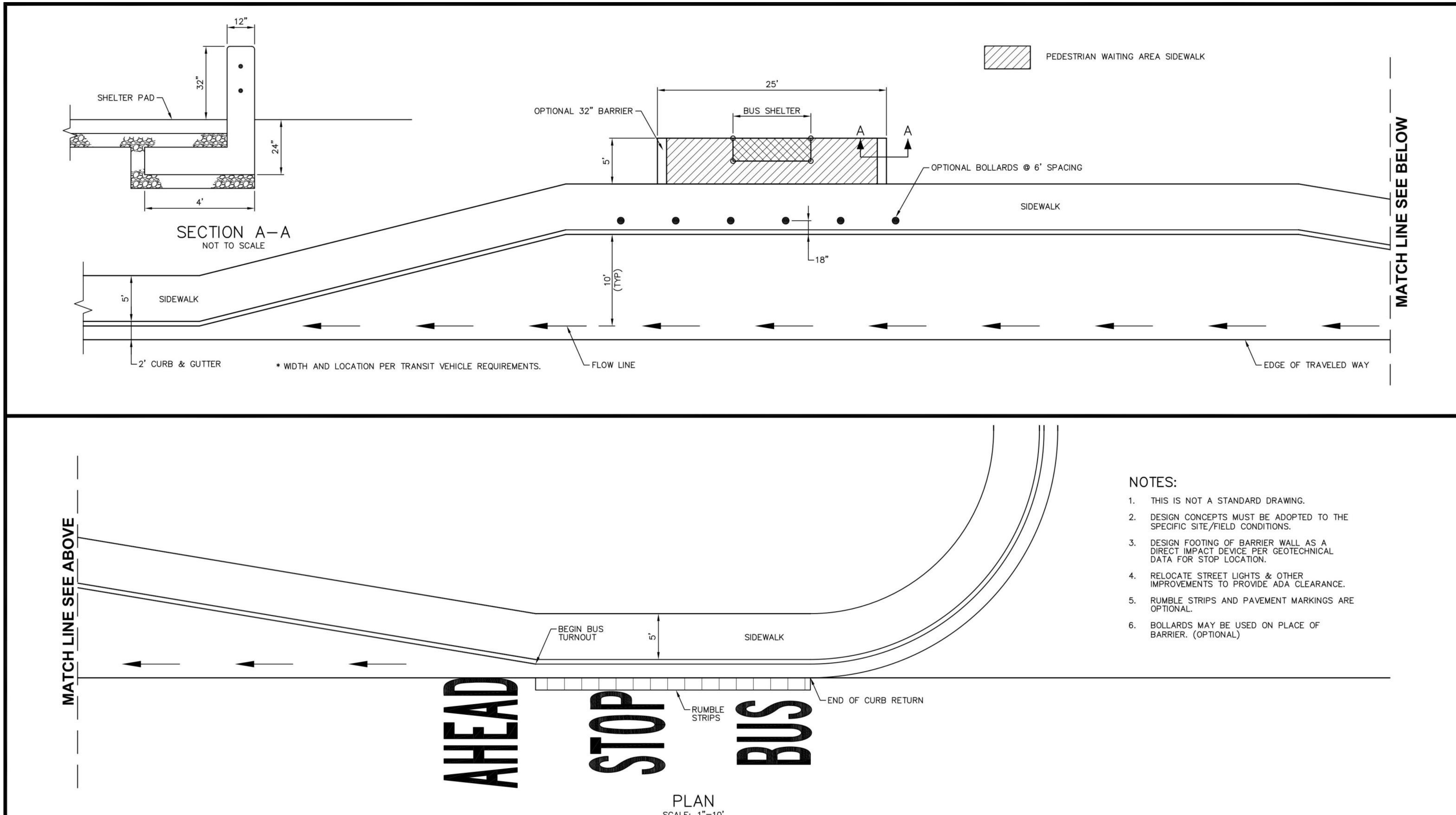
PARSONS BRINCKERHOFF

TRANSIT STOP SAFETY STUDY UPDATE

SHELTER LOCATED BEHIND 5-FOOT SIDEWALK WITH 5-FOOT LANDSCAPE BUFFER

EXHIBIT - 4

TABLE 9: COST ESTIMATE FOR SHELTER LOCATED BEHIND 5-FOOT SIDEWALK WITH 5-FOOT LANDSCAPE BUFFER				
ITEM DESCRIPTION	**UNIT**	**QUANTITY**	**UNIT COST**	**AMOUNT**
REMOVAL OF CONCRETE BUS PAD	SY	17	$200.00	$3,400.00
SAWCUT CONCRETE BUS PAD	LF	29	$25.00	$725.00
MILLED RUMBLE STRIP	LF	50	$40.00	$2,000.00
BARRIER - 32 INCH	LF	40	$70.00	$2,800.00
AGGREGATE BASE (TYPE II) (CLASS B)	CY	3	$100.00	$300.00
PAVEMENT MARKING (BUS STOP AHEAD)	SF	68	$20.00	$1,360.00
TRAFFIC CONTROL	LUMP SUM	1	$5,000.00	$5,000.00
CONSTRUCTION SUBTOTAL				$15,585.00
30% CONTINGENCY				$4,675.50
TOTAL				**$20,260.50**



NOTES:

1. THIS IS NOT A STANDARD DRAWING.
2. DESIGN CONCEPTS MUST BE ADOPTED TO THE SPECIFIC SITE/FIELD CONDITIONS.
3. DESIGN FOOTING OF BARRIER WALL AS A DIRECT IMPACT DEVICE PER GEOTECHNICAL DATA FOR STOP LOCATION.
4. RELOCATE STREET LIGHTS & OTHER IMPROVEMENTS TO PROVIDE ADA CLEARANCE.
5. RUMBLE STRIPS AND PAVEMENT MARKINGS ARE OPTIONAL.
6. BOLLARDS MAY BE USED ON PLACE OF BARRIER. (OPTIONAL)

TRANSIT STOP SAFETY STUDY UPDATE

SHELTER LOCATED AT BUS TURNOUT

EXHIBIT - 5

TABLE 10: COST ESTIMATE FOR SHELTER LOCATED AT BUS TURNOUT				
ITEM DESCRIPTION	**UNIT**	**QUANTITY**	**UNIT COST**	**AMOUNT**
REMOVAL OF CONCRETE SIDEWALK	SY	8	$15.00	$120.00
REMOVAL OF CONCRETE BUS PAD	SY	5	$200.00	$1,000.00
SAWCUT	LF	46	$10.00	$460.00
MILLED RUMBLE STRIP	LF	30	$40.00	$1,200.00
SAFETY BOLLARD	EA	6	$1,200.00	$7,200.00
LOW PROFILE BARRIER - 18 INCH	LF	10	$58.00	$580.00
CONCRETE SIDEWALK	SY	7	$50.00	$350.00
AGGREGATE BASE (TYPE II) (CLASS B)	CY	1	$200.00	$200.00
PAVEMENT MARKING (BUS STOP AHEAD)	SF	68	$20.00	$1,360.00
TRAFFIC CONTROL	LUMP SUM	1	$5,000.00	$5,000.00
CONSTRUCTION SUBTOTAL				$17,470.00
30% CONTINGENCY				$5,241.00
TOTAL				**$22,711.00**

5.0 RECOMMENDATIONS

After analyzing numerous options, Parsons Brinckerhoff has developed recommendations for the RTC to consider. These options are ranked in categories of their importance and are described below.

5.1 Primary Strategies

The "Primary Strategies" category includes options that should be thoroughly considered to increase the safety of transit riders and pedestrians at and around transit stops. Implementing just one of these options will increase the safety at transit stops, however it is recommend that a combination of the options will be considered.

The RTC is already implementing most of these measures as part of the adopted *Uniform Standards* and annual construction projects. Ideally, all of the options listed in this section will be implemented, which will greatly improve the safety at transit stops. The "Primary Strategies" options include:

- Place shelters at least 6-feet behind the curb
- Implement a pedestrian buffer
- Implement a bus turnout
- Conduct a Public Service Announcement Campaign

5.2 Primary Strategies But Needs Collaboration

The "Primary Strategies But Needs Collaboration" category includes options that should be thoroughly considered, however the RTC would need to collaborate with other agencies in order to follow through with the improvements. Similar to the "Primary Strategies" category, implementing just one of these options will increase the safety at transit stops. Ideally, both of the options will be implemented which will greatly improve the safety at transit stops. The "Primary Strategies But Needs Collaboration" options include:

- Implement Complete Streets design concepts including evaluating the reduction of speed limits on arterials with transit routes, where appropriate
- Implement random sobriety checkpoints on all arterials with transit routes

5.3 Secondary Strategies

The "Secondary Strategies" category includes options that will improve the safety at transit stops, however not as much as the previous two categories. It is recommended to consider the options in this category, on the other hand it is much more important to implement the options listed in the "Primary Strategies" and "Primary Strategies But Needs Collaboration" categories. The "Secondary Strategies" options include:

- Implement concrete planters with trees planted inside
- Relocate shelters where existing block walls prevent adequate offset from the curb

- Add solar powered LED shelter lighting
- Raise curbs at transit stops to allow for level boarding

5.4 Secondary Strategies If Other Measures Cannot Be Implemented

The "Secondary Strategies If Other Measures Cannot Be Implemented" category contains options that need to be considered if previous options mentioned are not feasible. These options will improve the safety at transit stops, however they may not be necessary if previous options are implemented. The "Secondary Strategies If Other Measures Cannot Be Implemented" options include:

- Implement a low profile barrier
- Implement high containment curbs
- Add "Bus Stop Ahead" pavement markings
- Add shoulder rumble strips
- Brightly paint the curb next to the transit stops
- Brightly paint the transit shelters
- Install a reflective coating on the outside of the transit shelters
- Install rear facing transit shelters

5.5 Last Resort

The "Last Resort" category consists of options that could improve the safety of transit riders at transit stops, however they could also introduce additional safety hazards that do not currently exist. These options should be considered only if all other options are not feasible. The "Last Resort" options include:

- Implement a bollard system
- Implement reinforced concrete trash receptacles
- Implement a handrail system
- Move the transit shelter to a side street

6.0 POLICY & GUIDELINES

The RTC should evaluate existing stop locations and implement the measures and strategies mentioned in this report where appropriate. The expanded range of measures provided will accommodate a variety of site conditions and facilitate policy and site design decision making.

7.0 CONCLUSION

The RTC has already begun incorporating most of the measures that are recognized as primary safety enhancement strategies and best practices. The findings and recommendations of this report will provide the RTC additional options to continue to improve transit stop safety and provide a positive experience for our transit community.

REFERENCES

[1] Schoenmann, Joe. *Accident Pushes Concerns About Bus Stop Safety Back Into Spotlight.* http://www.lasvegassun.com/news/2012/sep/14/accident-pushes-concerns-about-bus-stop-safety-bac/ Published 14 September 2012. Accessed 19 November 2012.

[2] *AASHTO Roadside Design Guide*. 4th Edition. Published 2011.

[3] *America Walks' Position Statement: Speed: A National Pedestrian Safety Issue*. www.americawalks.org/wp-content/upload/Speed2.pdf Accessed 19 November 2012.

[4] Organisation For Economic Co-operation And Development, European Conference Of Ministers Of Transport. *Speed Management*. www.internationaltransportforum.org/Pub/pdf/06Speed.pdf Published 2006. Accessed 19 November 2012.

[5] *Demonstration Projects On Setting And Enforcing Rational Speed Limits*. http://safety.fhwa.dot.gov/speedmgt/eng_spd_lmts/ Accessed 19 November 2012.

[6] *Traffic Calming*. http://en.wikipedia.org/wiki/Traffic_calming Accessed 19 November 2012.

[7] Monash University Accident Research Centre. *The Impact Of Lowered Speed Limits In Urban And Metropolitan Areas*. Published January 2008.

[8] *Do DUI Roadblocks Make Roads Safer?* http://www.duicheckpoints.org/ Accessed 19 November 2012.

[9] *Research Update: Sobriety Checkpoints Are Effective In Reducing Alcohol-Related Crashes*. http://www.cdc.gov/MotorVehicleSafety/Impaired_Driving/checkpoint.html Published December 2002. Accessed 19 November 2012.

[10] Warner, Charles J. *DUI Checkpoint Dedicated To Family Devastated By Impaired Driver*. http://www.franklintn.gov/index.aspx?page=25&recordid=1247&returnURL=%2Findex.aspx Published 23 January 2012. Accessed 19 November 2012.

[11] *Public Information Program*. http://www.ccrfcd.org/publicinformation.htm Accessed 19 November 2012.

[12] *APTA Standards Development Program, Recommended Practice, Bus Rapid Transit Stations And Stops*. www.aptastandards.com/Portals/0/Bus.../002_RP_BRT_Stations.pdf Published October 2010. Accessed 19 November 2012.

[13] *New Solar-Powered Transit Shelters Make A Debut*. http://www.clarkcountynv.gov/Depts/newsletters/districtc/Pages/DistrictCNewsletterJune2012.aspx Published Summer 2012. Accessed 19 November 2012.

[14] Smith, Trevor. *RTC Making Changes Before Deadly Crash*. http://lasvegas.cbslocal.com/2012/10/03/rtc-making-changes-before-deadly-crash/ Published 3 October 2012. Accessed 19 November 2012.

[15] *Quick Bus and Ped Improvements Coming to Lower Broadway*. http://www.streetsblog.org/2007/03/11/quick-bus-and-ped-improvements-coming-to-lower-broadway/ 11 March 2007. Accessed 16 January 2013.

[16] *Better Boarding: Platform And Bus Design*. http://www.tstc.org/issues/brt/brtshow/boarding4.html Accessed 19 November 2012.

[17] *Road Kerbs & Channels, High Containment Kerb*. http://www.pavingexpert.com/edging5.htm Accessed 19 November 2012.

[18] *FHWA Mitigation Strategies For Design Exceptions, Chapter 7, Case Study 3 – State Route 99 Reconstruction, Low-Profile Barrier*. http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter7/7_lowbarrier.htm Published July 2007. Accessed 19 November 2012.

[19] *California Department Of Transportation, Development And Testing Of A Low-Profile Barrier*. http://www.dot.ca.gov/newtech/operations/roadsidesafety/low_profile_barrier/index.htm Published 20 April 2012. Accessed 19 November 2012.

[20] Palm Tran. *Transit Design Manual.* August 2004.

[21] Land Transportation Authority. *Safety Bollards.* http://www.onemotoring.com.sg/publish/onemotoring/en/on_the_roads/road_safety/safety_bollards.html Published 20 February 2012. Accessed 9 January 2013.

[22] Miami-Dade County. *Bus Bench And Shelter Cylindrical Post Protection Feasibility Study*. Published 31 August 2007.

[23] *Removable Bollards Offer "Flexible" Streetscapes*. http://landscapeonline.com/research/article/12514 Accessed 19 November 2012.

[24] Interclamp. *Handrails: Pedestrian Road Safety Barrier With Mesh Infill.* http://www.interclamp.com/en/gallery1-3 Accessed 9 January 2013.

[25] *Nitterhouse Concrete Planters*. http://www.nitterhouse.com/masonry/products/site_amenities/planters.php Accessed 19 November 2012.

[26] *Modrono, Native Plants Through A Modern Lens, Stormwater Infiltration Sidewalk Planters*. http://www.madrono.org/san-francisco-landscape/water/stormwater/stormwater-infiltration-sidewalk-planters.html Published 19 November 2012. Accessed 19 November 2012.

[27] Elysian Custom Concrete Products. *Concrete Landscape Products for Schools, Parks and Institutions*. http://www.elysianproducts.com/school-products.htm Accessed 9 January 2013.

[28] *Smart Growth America, Making Neighborhoods Great Together, National Complete Streets Coalition*. http://www.smartgrowthamerica.org/complete-streets/complete-streets-fundamentals/complete-streets-faq Accessed 19 November 2012.

[29] *Rumble Strip*. http://en.wikipedia.org/wiki/Rumble_strip Accessed 19 November 2012.

[30] *KSA, Community, High Street Crosswalks*. https://ksacommunity.osu.edu/mckee518osuedu/blog/2012/10/high-street-crosswalks Published 13 October 2012. Accessed 19 November 2012.

[31] http://dttocs.smugmug.com/photos/359850988_Xedxm-M.jpg Accessed 19 November 2012.

[32] http://rogerkramercycling.org/blog/wp-content/uploads/2010/12/021_21.jpg Accessed 19 November 2012.

[33] Marshalls. *Bus Stop Kerbs*. http://www.marshalls.co.uk/select/kerb Accessed 9 January 2013.

[34] Massachusetts Bay Transportation Authority. *Key Bus Route Improvement Program.* http://www.mbta.com/about_the_mbta/t_projects/default.asp?id=19047 Accessed 9 January 2013.

[35] *Metshelter Bus Shelter System*. http://www.metshelter.com/Gallery.php Accessed 19 November 2012.

[36] *2008 FDOT Design Standards, Low Profile Barrier.* www.dot.state.fl.us/rddesign/DS/08/IDx/412.pdf Accessed 19 November 2012

[37] Beason, W. Lynn; Menges, Wanda L.; Ivey, Don L. *Compliance Of An End Treatment For The Low-Profile Concrete Barrier*. d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/1403-S.pdf Published April 1998. Accessed 19 November 2012.

- Advance Transit. *Hanover Bus Stop Feasibility Study*. December 2008.
- Albuquerque, Sicking, and Stolle. *Roadway Departure And Impact Conditions*. 15 November 2009.
- APTA Standards Development Program. *Bus Stop Design And Placement Security Considerations*. 26 June 2010.
- APTA Standards Development Program. *Crime Prevention Through Environmental Design (CPTED) For Transit Facilities*. 24 June 2010.
- APTA Standards Development Program. *Fencing Systems To Control Access To Transit Facilities*. October 2009.
- Arlington Virginia. *Transit Development Plan: Fiscal Years 2011-2016*. 14 December 2010.
- ART – Arlington Transit. http://www.arlingtontransit.com/ Accessed 9 January 2013.
- Auckland Regional Transport Authority. *Bus Stop Infrastructure Design Guidelines*. May 2009.
- BC Transit. *Infrastructure Design Guidelines*. November 2010.
- BC Transit: British Columbia Transit Service. http://www.transitbc.com/ Accessed 9 January 2013.
- Brett Landscaping. *Kassel – Specialist Bus Boarding Kerb For Safe And Easy Passenger Access*.
- Caltrans. *Informing A Pedestrian Safety Improvement Program*. 14 December 2009.
- Caltrans. Pedestrian Accessibility *Guidelines For Highway Projects*. 18 August 2010.
- Caltrans. *Traffic Manual, Chapter 7, Traffic Safety Systems*. January 2012.
- Chicago Transit Authority. http://transitchicago.com/ Accessed 9 January 2013.
- City Of Peoria. *Bus Stop Design Standards*. June 2010.

- City Of Raleigh. *Passenger Amenity Guidelines & Transit Design Standards*. March 2011.
- City Of Toronto. *Accessibility Design Guidelines*. 2004.
- Civic Voice. *Street Pride Briefing 3: Bollards*. April 2010.
- Designing With Transit. *Making Transit Integral To East Bay Communities*. 2004.
- El Dorado County Transit Authority. *Transit Design Manual*. 9 November 2007.
- EPA. *Water Security: Security Product Guides: Passive Security Barriers*. 5 December 2012.
- Fairfax County. *Bus Stop Guidelines*. July 2004.
- FEMA. *Site and Urban Design for Security*. December 2007.
- Florida Department of Transportation. *District 4, Transit Facilities Guidelines, Version 3*. October 2007.
- Frederic County, Maryland. *Transit-Friendly Design Guidelines*. Marcy 2009.
- Geissler, Rebecca. *Mapping Safe Crossings And Bus Stops: A Case Study In Chicago To Improve Pedestrian Safety*. 30 March 2012.
- Georgia Department Of Transportation. *Design Policy Manual, Complete Streets Design Policy*. 21 September 2012.
- Georgia Department Of Transportation. *Georgia Bicycle And Pedestrian Safety Action Plan.*
- Institute Of Transportation Engineers. *Design And Safety Of Pedestrian Facilities*. 1998.
- LA Metro. http://www.metro.net/ Accessed 9 January 2013.
- Los Angeles County Metropolitan Transportation Authority. *Advanced Transportation Management System (ATMS) Overview.* June 2010.
- Los Angeles County Metropolitan Transportation Authority. *Corporate Safety Report*. 2012.

- Los Angeles County Metropolitan Transportation Authority. *2012 Metro Transit Service Policy*. 2012.

- Massachusetts Bay Transportation Authority. http://www.mbta.com/index.asp Accessed 9 January 2013.

- Metro Transit. http://metro.kingcounty.gov/ Accessed 9 January 2013.

- Metropolitan Transit. *Bicycle And Pedestrian Connections To Transit Infrastructure Study*. 12 February 2009.

- National Capital Planning Commission. *Designing And Testing Of Perimeter Security Elements*.

- National Cooperative Highway Research Program. *Report 500, Volume 6: A Guide For Addressing Run-Off-Road Collisions*. 2003.

- National Cooperative Highway Research Program. *Report 500, Volume 10: A Guide For Reducing Collisions Involving Pedestrians*. 2004.

- National Cooperative Highway Research Program. *Report 500, Volume 14: A Guide For Reducing Crashes Involving Drowsy And Distracted Drivers*. 2005.

- National Cooperative Highway Research Program. *Report 500, Volume 16: A Guide For Reducing Alcohol-Related Collisions*. 2005.

- National Cooperative Highway Research Program. *Report 500, Volume 23: A Guide For Reducing Speeding-Related Crashes*. 2009.

- National Cooperative Highway Research Program. *Report 537, Recommended Guidelines For Curb And Curb-Barrier Installations*. 2005.

- National Cooperative Highway Research Program. *Report 612, Safe And Aesthetic Design Of Urban Roadside Treatments*. 2008.

- New Jersey Transit. http://njtransit.com/ Accessed 9 January 2013

- New Jersey Transportation Planning Authority. *Pedestrian Safety At And Near Bus Stops Stud*y. June 2011.

- New York City Department of Transportation. http://www.nyc.gov/html/dot/html/home/home.shtml Accessed 9 January 2013.

- New York City Department Of Transportation. *School Safety Engineering Project*. April 2004.
- New York City Department Of Transportation. *The New York City Pedestrian Safety Study & Action Plan*. August 2010.
- NDOT. *Nevada Traffic Crashes, 2007-2009*. 2010.
- NDOT. *Nevada Traffic Crashes, 2010*. 2011.
- Omnitrans. http://www.omnitrans.org/ Accessed 9 January 2013.
- Omnitrans. *Bus Stop Design Guidelines*. 4 October 2006.
- Omnitrans. *Transit Design Guidelines.*
- Orange County Transportation Authority. http://www.octa.net/Index.aspx Accessed 9 January 2013.
- Orange County Transportation Authority. *Bus Stop Safety And Design Guidelines*. 24 March 2004.
- Pace Suburban Bus Service. http://pacebus.com/ Accessed 9 January 2013.
- Pima County Department Of Transportation. *Transit Guidelines For Roadway Design And Construction*. January 2009.
- Regional Public Transportation Authority. *RPTA Bus Stop Program And Standards.* March 2008.
- Regional Transportation District. *RTD Transit Access Guidelines*. January 2009.
- *San Francisco Better Streets Plan.* December 2010.
- San Francisco Municipal Transportation Agency. http://www.sfmta.com/cms/home/sfmta.php Accessed 9 January 2013.
- Sound Transit. *Design Standards And Guidelines For Transit Projects: Sounder & ST Express Passenger Facilities*. 22 January 2007.
- *South Los Angeles Transportation Master Plan*. April 2009.

- Southeastern Pennsylvania Transportation Authority. http://www.septa.org/index.html Accessed 9 January 2013.
- State Of Florida Department Of Transportation. *From Bus Shelters To Transit Oriented Development*. March 2004.
- State Of Florida Department Of Transportation. *Integrating Transit Into Traditional Neighborhood Design Policies – The Influence Of Lane Width On Bus Safety*. June 2010.
- State Of Florida Department Of Transportation. *Safer Stops For Vulnerable Customers*. March 2003.
- State Of Florida Department Of Transportation. *Transit Facility Handbook*. 11 October. 2007.
- State Of Oregon. *Toolkit For The Assessment Of Bus Stop Accessibility And Safety*. August 2011.
- The City and County of Honolulu. http://www.honolulu.gov/government/ Accessed 9 January 2013.
- The Institute Of Transportation Engineers Traffic Engineering Council. *Lower Speed Limits*.
- Titan High Containment Concrete Kerb System. http://www.marshalls.co.uk/select/kerb/high-containment/titan-kerb Accessed 19 November 2012.
- Toronto Transit Commission. http://www.ttc.ca/ Accessed 9 January 2013.
- Toronto Transit Commission. *Transit City Bus Plan*. August 2009.
- Transit Cooperative Research Program. *Report 46, The Role Of Transit Amenities And Vehicle Characteristics In Building Transit Ridership: Amenities For Transit Handbook And The Transit Design Game Workbook*. 1999.
- Transit Cooperative Research Program. *Report 125, Guidebook For Mitigating Fixed-Route Bus-And-Pedestrian Collisions*. 2008.
- Transport. *State Transit Bus Infrastructure Guide*. July 2011.
- Transportation Alternatives. *Rethinking Bollards: How Bollards Can Save Lives, Prevent Injuries, And Relieve Traffic Congestion In New York City*. July 2007.

- Transportation For America. *Dangerous By Design: Solving The Epidemic Of Preventable Pedestrian Deaths*. 2011.
- Transportation Research Board. Chapter 4, Curb-Side Factors. onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_19-c.pdf Accessed 19 November 2012.
- Trimet. *Bus Stops Guidelines*. July 2010.
- Trimet. *Pedestrian Network Analysis*.
- TriMet: Public Transit in the Portland Area. http://trimet.org/ Accessed 9 January 2013.
- Truong, Long Tien; Somenahalli, Sekhar V.C. *Using GIS To Identify Pedestrian-Vehicle Crash Hot Spots And Unsafe Bus Stops*. 2011.
- U.S. Department Of Transportation, Federal Transit Administration. *Transit Security Design Considerations*. November 2004.
- U.S. Department Of Transportation Federal Highway Administration, Institute Of Transportation Engineers. *Toolbox Of Countermeasures And Their Potential Effectiveness For Intersection Crashes*. September 2007.
- Utah Transit Authority. http://www.rideuta.com/ Accessed 9 January 2013.
- Valley Metro. http://www.valleymetro.org/ Accessed 9 January 2013.
- Washington Metropolitan Area Transit Authority. Bus Stop Design, Information, And Placement. 19 November 2009.
- Washington Metropolitan Area Transit Authority. *Guidelines For The Design And Placement Of Transit Stops For The Washington Metropolitan Area Transit Authority*. December 2009.
- WSDOT. *Design Manual, Transit Facilities*. June 2009.
- World Health Organization. *Road Safety Is No Accident*. November 2003.

APPENDIX

Vehicle to Transit Shelter Crashes

- Table
- Map

Detailed Bollard Findings

Vehicle to Transit Shelter Crashes – Table

VEHICLE TO TRANSIT SHELTER CRASHES						
#	LOCATION	FATAL	INJURED	SIDEWALK?	ROW?	DESCRIPTION
	SHELTERS HIT 2007					
1	WB TROPICANA W/O RAINBOW NS			On sidewalk	No ROW	
2	NB RAINBOW N/O CHARLESTON ES			On sidewalk		Moved behind sidewalk
3	STEPHANIE/WARM SPRINGS			On sidewalk	ROW	Stop closed
4	NB BOULDER HWY S/O RUSSELL ES			On sidewalk	ROW	
5	WB BONANZA W/O MOJAVE SS			On sidewalk	No ROW	
6	SB MARYLAND PKY S/O DI WS			On sidewalk	No ROW	Bench
7	WB MARYLAND E/O CASHMAN CTR NS			Behind sidewalk		
8	WB PASEO VERDE W/O PALOMINO NS			On sidewalk		Stop closed
9	WB DI W/O SANDHILL NS			On sidewalk	No ROW	
10	WB MEADOWS .2 MILE W/O VALLEY VIEW NS			On sidewalk	No ROW	Asked for easement - no
11	EB LAKE MEAD BLV E/O DECATUR SS			On sidewalk	No ROW	
12	WB CHEYENNE W/O MICHAEL WAY NS			On sidewalk	No ROW	
13	SB PARADISE S/O TROPICANA WS			On sidewalk		Stop closed
14	EB SAHARA E/O FT APACHE SS			On sidewalk		BRT Station
15	WB SAHARA W/O RANCHO NS			On sidewalk		BRT Station
16	CIMARRON / TROPICANA			On sidewalk	No ROW	
17	SB LVB S/O OAKEY WS			On sidewalk	No ROW	
18	NB LVB N/O 4TH ST ES			On sidewalk	No ROW	Stop closed
19	WB CHARLESTON @ PECOS NS			On sidewalk		Moved behind sidewalk
20	NB MLK N/O ALTA ES			On sidewalk	No ROW	
21	SB VALLEY VIEW S/O ALTA WS			On sidewalk		Moved behind sidewalk
22	EB LAKE MEAD BLV. E/O CIVIC CENTER SS			Behind sidewalk		Turnout
23	EB WASHINGTON E/O MLK SS			On sidewalk	No ROW	
24	SB MLK S/O BULZAR WS			On sidewalk	No ROW	
	SHELTERS HIT 2008					
1	NB CIVIC CENTER N/O MCDANIELS ES			Behind sidewalk		
2	WB CHEYENNE E/O MIRAMAR NS			On sidewalk	No ROW	
3	NB ARROYO GRANDE N/O WIGWAM ES			On sidewalk		Stop Closed
4	SB MLK S/O GOWAN WS			On sidewalk	No ROW	
5	SB PECOS S/O LAKE MEAD BLV WS			On sidewalk	PUE	
6	SB LVB S/O SILVERADO RANCH WS			On sidewalk	No ROW	9' sidewalk
7	WB SAHARA W/O ATLANTIC NS			On sidewalk	ROW	BRT Station
8	WB PASEO VERDE W/O CORP CTR ENTRANCE			On sidewalk	No ROW	Stop Closed
9	SB RANCHO S/O MICHAEL WAY (N OF CHEYENNE)			On sidewalk	No ROW	
10	SB RAINBOW S/O ALTA WS			On sidewalk	PUE	
11	SB BOULDER HWY S/O 95 ENTRANCE WS			On sidewalk		Stop Closed
12	SB LAMB S/O OWENS WS			Behind sidewalk		
13	WB TROPICANA W/O JONES NS			On sidewalk	PUE	
14	SB RAINBOW S/O CHARLESTON WS			On sidewalk	ROW	
15	WB LAKE MEAD BLV W/O MLK NS			On sidewalk		Turnout
16	WB TROPICANA W/O MTN VISTA NS (repaired shelter)			On sidewalk	No ROW	
17	WB FLAMINGO W/O DUNEVILLE NS (charles pulled)			On sidewalk	No ROW	
18	SB RANCHO S/O SANTE FEE WS (charles pulled)			On sidewalk	ROW	
19	EB CHARLESTON E/O PALM SS			On sidewalk	No ROW	
20	NB BOULDER HWY N/O GLEN ES (city removed??)			On sidewalk	ROW	Stop Closed
21	SB EASTERN S/O BONANZA WS			On sidewalk	No ROW	
22	NB BOULDER N/O LAKE MEAD ES			On sidewalk	ROW	Stop Closed
23	WB TROPICANA W/O PARADISE NS			On sidewalk	No ROW	Airport Property
24	NB BOULDER HWY N/O FLAMINGO ES (1 fatility)	1	1	Behind sidewalk		BRT Station
25	SB LVB N/O BONANZA WS			On sidewalk	No ROW	
26	EB TROPIANA E/O MOJAVE SS	0	1	On sidewalk	PUE	
27	SB BOULDER HWY N/O LAKE MEAD PKY WS			Behind sidewalk		no curb
28	WB CHEYENNE W/O PECOS NS (CALIFORNIA SHELTER			Behind sidewalk		
29	WB SPRING MTN W/O JONES NS			On sidewalk	No ROW	
30	WB SPRING MTN W/O VALLEY VIEW NS			On sidewalk	No ROW	
	SHELTERS HIT IN 2009					
1	EB CRAIG W/O BERG SS (E/O Losee)			On sidewalk	No ROW	
2	EB LAKE MEAD BLV. E/O LOSEE SS			On sidewalk	ROW	
3	SB RAINBOW S/O DEWY WS (100 YD N/O RUSSELL)			On sidewalk	No ROW	
4	WB SAHARA W/O SANDHILL NS			On sidewalk	No ROW	

Vehicle to Transit Shelter Crashes – Table

VEHICLE TO TRANSIT SHELTER CRASHES						
#	LOCATION	FATAL	INJURED	SIDEWALK?	ROW?	DESCRIPTION
5	WB CHARLESTON W/O PALMHURST NS			On sidewalk	No ROW	
6	EB SUNSET E/O ATHENIAN SS			On sidewalk	No ROW	
7	WB CHEYENNE W/O RANCHO NS			On sidewalk	PUE 3'	Phase III
8	SB PARADISE S/O GUS GIUFFRE WS			On sidewalk	No ROW	Airport Property
9	WB SUNSET W/O MTN. VISTA NS			On sidewalk	No ROW	
10	WB TROP E/O NELLIS NS			On sidewalk	No ROW	Bench
11	EB LAMB E/O BOULDER HWY SS			On sidewalk	No ROW	
12	NB STEPHANIE N/O SANTIAGO ES			On sidewalk	ACA	8.5' sidewalk. Low ridership
13	NB RAINBOW N/O PALMYRA ES (CC)			On sidewalk	No ROW	
14	SB LVB N/O PECOS WS			On sidewalk		Closed
15	SB RANCHO S/O BONANZA			On sidewalk		City planning turnout
16	SB TORRY PINES S/O LAKEMEAD			Beind Sidewalk		Closed
17	NB BOULDER HWY S/O LOWES ES			On sidewalk	ROW	Phase I
SHELTERS HIT IN 2010						
1	EB SAHARA E/O TORREY PINES SS			On sidewalk		BRT Station
2	NB LVB S/O WALNUT ES			On sidewalk	ROW	Stop Closed
3	WB CRAIG RD W/O WALNUT NS			On sidewalk	No ROW	
4	EB CHARLESTON W/O JONES SS			On sidewalk		Partial pad
5	NB RANCHO N/O LAKEMEAD BLVD ES	0	3	On sidewalk	No ROW	Talked to hotel
6	NB DECATUR N/O OAKEY ES			On sidewalk	PUE	Breakdown lane
7	SB EASTERN N/O WARM SPRINGS			On sidewalk	PUE	
8	NB EASTERN N/O WASHINGTON			On sidewalk	No ROW	9/5' sidewalk
SHELTERS HIT IN 2011						
1	EB WASHINGTON AVE E/O MINNESOTA			On Sidewalk	No ROW	Breakdown Lane
2	WB LAKE MEAD BLV W/O BUFFALO DRIVE NS			Behind Sidewalk		
3	SB GREEN VALLEY PARKWAY LA MESA DRIVE WS			On Sidewalk		
4	EB CHARLESTON BLVD E/O DURANGO DRIVE SS			On Sidewalk	No ROW	
5	EB CAREY AVE E/O LVB SS			Behind Sidewalk		
6	EB SPRING VALLEY PKY W/O RAINBOW BLVD SS			On Sidewalk	PUE	Low Ridership
7	EB FLAMINGO RD E/O JONES BLV SS			On Sidewalk	PUE	Phase III
8	EB TROPICANA AVE E/O SEPUVEDA SS			On Sidewalk	No ROW	
9	NB MARYLAND PKY N/O ROCHELLE AVE ES			On Sidewalk	No ROW	
10	NB VAN WAGENEN N/O PACIFIC ES			On Sidewalk	No ROW	
11	EB TROPICANA AVE E/O BOULDER HWY SS			On Sidewalk	No ROW	
12	SB RAINBOW BLV S/O SMOKE RANCH RD WS			On Sidewalk	No ROW	
13	SB JONES BLV S/O EUGENE AVE WS			Behind Sidewalk		
14	WB FLAMINGO RD W/O BOULDER HWY NS			On Sidewalk	No ROW	
15	NB RAINBOW BLV N/O ALTA DR ES (LVMPD 111110-0340)			Behind Sidewalk		Phase I
16	WB SAHARA AVE W/O SLOAN LANE NS			Behind Sidewalk		Turn Lane
17	SB MLK BLV N/O VEGAS DRIVE WS			On Sidewalk		Phase I
SHELTERS HIT IN 2012						
1	EB TROPICANA AV E/O MARYLAND PKY SS #1			On Sidewalk		Phase III
2	EB TROPICANA AV E/O MARYLAND PKY SS #2			On Sidewalk		Phase III
3	WB SPRING MTN RD W/O EL CAMINO RD NS	0	1	On Sidewalk	PUE	Phase III
4	WB CHARLESTON BLV W/O DECATUR BLV			Behind Sidewalk		Turn Lane
5	NB 13TH ST N/O STEWART AVE ES			Behind Sidewalk		
6	WB TROPICANA W/O SPENCER NS			On Sidewalk	No ROW	
7	SB NELLIS BLV S/O SAHARA AVE WS			On Sidewalk	No ROW	Turnout
8	EB LAKE MEAD BLV E/O TORREY PINES DR SS			Behind Sidewalk		Turn Lane
9	NB MLK BLV N/O GOWAN			On Sidewalk	No ROW	Block Wall
10	WB SPRING MOUNTAIN RD W/O ARVILLE ST NS			On Sidewalk	No ROW	
11	EB TROPICANA AVE E/O ARVILLE ST SS			On Sidewalk	No ROW	
12	SB EASTERN AVE S/O OWENS WS	0	3	On Sidewalk	No ROW	
13	WB CHARLESTON BLV W/O RAINBOW BLV NS			Behind Sidewalk		Phase II
14	EB CHARLESTON E/O LAMB SS	0	1	On Sidewalk	No ROW	
15	EB SPRING MOUNTAIN E/O DECATUR SS	4	8	On Sidewalk	No ROW	
16	EB Craig E/O Clayton	0	0	Behind Sidewalk		3' pad
	TOTAL	5	18			

Vehicle to Transit Shelter Crashes – Map

Detailed Bollard Findings

OMNITRANS – DRAFT Transit Design Guidelines (November 2012)

The uses of bollards in the Transit Design Guidelines are outlined as follow:

- Used as a physical separator between Dedicated Bus-Only Lanes and mixed-flow traffic. (pg. 156)
- Physical security feature that enhances patron and personnel security. Barriers/bollards can be used to provide: safety; theft deterrence; asset protection; pedestrian vs. vehicle separation; pedestrian control; and traffic control. Properly designed and installed barriers are effective in controlling both pedestrian and vehicular movement inside a facility, within a facility's perimeter, or gaining access to the exterior of the facility. (pg. 175)

Tri-County Metropolitan Transportation District of Oregon (TriMet) – Bus Stop Guidelines (July 2010)

- Figure 23 shows a detail of Bollard design and Figure 24 shows Bollard Installation details. According to the bollard installation detail, the bollard is mainly used as a separation between a bus shelter and a parking area behind it. No further write-up regarding bollard use or any other application for bollards was discussed in the literature.

APTA Standards Development Program – Recommended Practice - APTA SS-IS-RP-008-10 "Bus Stop Design and Placement Security Considerations" (2010) – *This Recommended Practice provides guidance on the security concerns to transit agencies when considering the design and placement of bus stops.*

- At high-consequence locations as identified in the agency's risk assessment, the use of bollards and other barriers such as planters to assist in buffer zone protection and stand-offs to mitigate vehicle encroachment and enhance pedestrian safety should be considered.

USDOT/FTA – Transit Security Design Considerations (November 2004)

This document provides an overview of the major assets of transit systems—bus vehicles, rail vehicles, and transit infrastructure and communications—as well as a preliminary assessment of the vulnerabilities to various methods of attack inherent in each asset. In addition, this document addresses the topics of access management, systems integration, and communications—all crucial to the protection of transit assets. Although many of the subject areas are addressed discretely in the document, users of the resource must recognize the interconnectivity of the considerations and hardening strategies that are presented. For this reason, consulting the sections on both infrastructure and access management will provide additional value when developing a strategy for protecting and hardening a maintenance facility or rail terminal.

Developed by the Federal Transit Administration in collaboration with transit industry public and private sector stakeholders, these design considerations provide actionable steps that transit agency staff can select from to create a security strategy.

- Bollards are identified as a fabricated/structural barrier in many situations within the literature. It could be used as:
  - Perimeter-control barrier – establish a secure boundary around an area, and limit access to and from that area to admission-control points. They may be designed to prevent some types of movement while permitting others and barriers can be placed to direct passenger flow and deter access to isolated or hidden locations.
  - Passive vehicle barrier – can be used on inbound and outbound roadways to control vehicle speed and slow incoming vehicles before they reach the facility gate/active barrier so that security personnel have adequate time to respond to unauthorized activities. Barriers protect facilities, critical infrastructure, and people from both errant and terrorist vehicle attacks. Other applications of barriers are outlined below:
    - Asset Protection – barriers can protect assets from intentional or unintentional ramming by vehicles. For example, bollards can be used around fueling stations, around guardhouse entrances to protect guards and equipments, or at station entrances to protect pedestrians.
    - Vehicle Speed – barriers can limit vehicle speeds on facility approaches using speed controls.
    - Vehicle Stops – barrier can stop unauthorized vehicles from proceeding through vehicle checkpoints/entryways.
    - Vehicle Restriction – barriers can be used to restrict vehicle entry, limiting access to agency vehicles only.
    - Traffic Direction – barriers can channel traffic at an approach or within a facility.
    - Revenue Collection – barriers can enforce revenue collection at parking lots and garages.
    - Theft Deterrence – barriers can deter theft at parking lots and garages.

New York City Department of Transportation (NYCDOT) – School Safety Engineering Report General Mitigation Measures – Final Report (April, 2004)

This report is a general discussion of traffic safety measures that could be used in the vicinity of schools. The mitigation measures presented in this document offer a range of actions - from simple programs to more costly capital investments—that can be taken to achieve the desired goal of improving a child’s safety as he or she travels to and from school. The report enumerates different applications of bollards and is discussed below:

- NYCDOT Design Considerations for Neckdowns, Geometric and Construction Requirements – Bollards, planters, or other street furniture may be included in the neckdown. The design and placement of street furniture shall not impede pedestrian flow, present a trip hazard, or interfere with “day-lighting” the intersection, emergency operations, or sight lines. A sign, bollard, or other vertical device shall be placed on the neckdown to alert drivers to the presence of the neckdown. The design placement of the device shall not obstruct emergency operations or sightlines.

- Chapter 4: Passive Traffic Calming – These elements do not force a change in driver behavior, but provide visual or other cues that can encourage drivers to travel at slow speeds.
    - Streetscape Improvements
        - Bollards – are a form of rigid traffic barrier used to prevent vehicles that leave the roadway from hitting a pedestrian or hitting an object that has a greater crash severity potential than the bollard itself. Because bollards are a source of crash potential themselves, their use must be carefully considered. The NYCDOT policy for bollards are given below:
        - Purpose – the purpose of rigid bollards is to protect pedestrians from collisions with motor vehicles, usually at location with unusual roadway geometry. This is accomplished by: redirecting or decelerating errant motor vehicles away from pedestrians; preventing motor vehicles from entering sidewalks o other off-street locations where frequent unlawful incursions occur; defining appropriate locations for vehicles to travel and for pedestrians to assemble.
        - Consideration – bollards should be considered:
            - There is a need to better manage vehicular movements;
            - Accidents analyses demonstrate a safety issue involving off-street impacts with pedestrians;
            - There are a substantial number of pedestrians present;
            - The bollards would not create a significant roadway hazard to motor vehicles;
            - Alternatives to bollards (e.g. guide rail, planters, crash cushions) have been explored and found unsuitable.
            - Additional factors need to be considered in the placement of bollards: loading and unloading of goods and passengers; access for fire, ambulance, police or other emergency vehicles; sidewalks access for persons parking their vehicles; bus stops; fire hydrants, utility access and other street furniture.
        - Design Issues
            - Bollards should only be installed off-street on sidewalks or raised median refuge areas.
            - Bollards should be set back from the curb from 18” to 24”.
            - When installed on curves, bollards should be installed on the outside of the horizontal curve of the roadway.
            - Bollards should not interfere with access to pedestrian ramps.
            - A minimum distance of 60” should be provided between bollards if the pedestrian path moves between the bollards or 48” where additional impact resistance must be provided.
            - Bollards should not adversely affect pedestrian level of service (i.e., maintain LOS B or better).
            - Bollards may be used in conjunction with other rigid barriers including raised planters and seating.
        - Construction and Installation Issues
            - The height of the bollard should be from 30” to 42”.

  - Bollards may be made of metal, stone, or a combination.
  - Bollards may be of an energy-absorbing design.
  - Bollards should be configured as a post, inverted U, or bell-shaped.
  - Bollards should have a pleasing appearance appropriate to their surroundings.
  - Bollards should be set into the ground with permanent footings.
  - Maintenance agreements and revocable consent agreements should be established for installation of non-DOT bollards.
- Recommendation
  - Bollards may have application as a school safety measure. Potential uses include placement perpendicular to the curb to delineate driveways where school buses or other vehicles may enter school property.

Civic Voice – Street Pride Campaign – Briefing Note 3 – Bollards, United Kingdom (April 2010)

Street Pride is Civic Voice's national campaign supporting local action to help rid streets of unnecessary clutter. Street Pride is focused on the four most widespread sources of street clutter: bollards; signs; posts (including lampposts and traffic lights) and guard rails.

According to the campaign pamphlet, bollards are primarily used to protect a footway area from access by vehicles. This may be to prevent parking, to guide moving vehicles and protect pedestrians at a tight junction or crossover, or just to highlight an informal pedestrian crossing. They may also be used as part of traffic calming or cycle priority measures. Bollards are used more out of expediency than design as pavements tend not to be constructed sufficiently strongly to support over running vehicles. Many towns and cities have wide pavements in areas of parking control, and highway authorities will use bollards to prevent pavement parking either on the pavement itself, or on the forecourts behind them.

Street Pride suggests that bollards should be avoided if possible, and, if used, should be part of a coordinated street furniture design, and even then, only in moderation. Highway authorities have powers to erect bollards under the Highways Act 1980. Town and parish councils do not have express powers to erect bollards though they have a power to maintain footways. Parking on private forecourts is legitimate however access to such parking space is usually illegally across a footway and prevention of this often involves bollard installation. Bollards are not erected at any regulated or standard distances, though they should be clear of the main carriageway, usually 450 mm minimum from the kerb.

Street Pride mentions that there should be a presumption against installing bollards unless absolutely necessary. Strengthening pavements and improving pavement parking enforcement should be reviewed first. Bollards might be retained where they prevent access to the pavement where there is a high probability of pavement parking or casual over-run that might endanger a pedestrian, particularly those with mobility impairment. Removing bollards is justifiable where the circumstances of vehicle overrun are substantially reduced only occasional, and where the likelihood of conflict with the pedestrians is or can be made negligible.

The first steps for alternative are to see if the vehicle control can be carried out in another way. This means reviewing whether the highway might be altered to accommodate more parking, or improving parking enforcement. Reinforced paving slabs are now available that allow occasional vehicular over-run on the footway, for use where street clutter reduction is a priority. Other traffic control methods include:

- Raising the kerb height to dissuade vehicle over-run
- Raising the pavement height using a double kerb
- Using cycle racks and lamp posts instead.

Shared surface pedestrian zones are often cluttered with bollards to delineate a vehicle track. There are plenty of pedestrian schemes that do not use bollards that show this is not necessary. Where bollards are used, alternatives to standard functional types can add character to the street. Regeneration schemes are excellent opportunities to provide bollards that are locally distinctive and provide an opportunity for public art.

United States Environmental Protection Agency (EPA) Water Security Product Guides – Passive Security Barriers

One of the most basic threats facing any facility is from intruders accessing the facility with t he intention of causing damage to its assets. These threats may include intruders actually entering the facility, as well as intruders attacking the facility from outside without actually entering. One of the most effective ways to counter the threat of intruders accessing a facility or the facility perimeter is to install security barriers around the facility's perimeter. Security barriers (bollards or security planters) can be used along the facility perimeter to establish a protective buffer area between the facility and approaching vehicles.

Passive security barriers are typically used in areas where access is not required or allowed – such as long building perimeters on in traffic control areas. Passive security barriers are typically large, heavy structures that are usually several feet high, and they are designed so that even heavy-duty vehicles cannot go over or through them. Therefore, they can be placed in a roadway parallel to the flow of traffic so that they direct traffic in a certain direction, or perpendicular to traffic such that they prevent a vehicle from using a road or approaching a building or area.

- Bollards – cylindrical barriers that are place at discrete intervals in a traffic area such that they block vehicles from passing between then, while allowing pedestrians through. The concept behind a bollard barrier system is to obstruct the part of the pathway of a vehicle. The bollards are typically placed 4-5 feet apart so that vehicles cannot pass between them without hitting the bollards. Bollards are typically at least 3 feet high (some may be 7 feet tall or higher) so that vehicles cannot go over them without becoming stuck or damaging their transmissions. Typical bollards are 1-2 feet in diameter, and many are specifically designed to withstand vehicular impacts without crumbling or breaking off. Thus, even if a vehicle hits a bollard directly, it cannot pass over or through it.

  Bollards can be fixed in place, removable or retractable. Fixed bollards can be constructed from any type of material. They are anchored in place as needed, and are typically used along sidewalks or in areas where traffic can be blocked permanently. These types of bollards are anchored by imbedding them into the ground/driveway surface using some type of anchoring material. Some bollards have side pins that extend out from the bollard's base into the imbedding matrix. These pins can provide extra impact stability to the bollard. Typical applications of fixed bollards are for roadways and sidewalks. The advantage of fixed bollards is that it can be spaced to prevent vehicles from passing them and minimal maintenance after installation. The disadvantage is that once installed, fixed bollards cannot be moved to adapt to changing security needs.

The San Francisco Better Streets Plan, sfbetterstreets.org – (December 2010)

San Francisco's policies encourage the design and development of 'Better Streets' sometimes referred to as 'Complete Streets,' that work for all users. The San Francisco Better Streets Plan, adopted in December 2010, states:

> Better Streets are designed and built to strike a balance between all users regardless of physical abilities or mode of travel. A Better Street attends to the needs of people first, considering pedestrian, bicyclists, transit, street trees, stormwater management, utilities, and livability as well as vehicular circulation and parking.

Street furnishings provide important amenities for pedestrians by adding functionality and vitality to the pedestrian realm. They announce that pedestrians are welcome and that the street is a comfortable place to be. These amenities provide functional service to the pedestrian and provide visual detail and interest. Pedestrian amenities should be considered a requisite public expenditure just as other necessary elements of the street, such as traffic signals and signage. Improved street vitality has been shown to improve public safety and comfort, health of local businesses, local real estate value, and transportation habits.

Bollard is a short vertical post or similar structure that can define areas in the streetscape and provide an attractive design element. Bollards are primarily a safety element often used to separate pedestrians or streetscape elements from vehicles. By placing them in a line, bollards are used to prevent motor vehicles from encroaching on pedestrian space such as sidewalks or plazas. Attractively designed bollards add color and interest to streetscapes, help define pedestrian spaces, and provide a spot to lean on or rest at.

Location of Bollards:

- Bollards should be used at sidewalk locations where vehicles attempting to park are damaging sidewalk structures, trees or plantings, furnishings, or adjacent private property, especially on narrow streets.
- Bollards should be considered for installation on median islands, curb extensions (except transit bulb-outs), and mid-block curb extensions, where there is a risk of danger to pedestrians due to proximity of travel lanes.
- Attractive bollards can also be used in special locations, including pedestrian-oriented spaces such as shared public ways or pedestrian-only streets, to designate unique spaces. Lighted bollards can create a special pedestrian environment, and may be particularly useful to provide additional pedestrian lighting in median refuges.

- Removable bollards should be placed at entrances to streets that are closed to vehicles for pedestrian use, to alert drivers to the changed nature of the street. Similarly, removable bollards can define the outside edge of Parklets where the space has been converted to pedestrian use.
- Bollards should be placed 18 inches from the back of the curb. If there is no parking in the bollard placement area, the bollard may be installed immediately adjacent to the back of the curb.
- Standard bollard spacing is approximately 10 feet on center, but may need to be reduced where there is a need to block vehicular traffic. Spacing should vary to sync with the rhythm of lighting fixtures, trees and landscaping, and other elements in the streetscape.

Design of Bollards:

- Bollards typically range in size from 4 to 10 inches in diameter; decorative bollards can be larger and vary in form.
- Bollards should have articulated sides and tops to provide design detail. Bollards should be painted in colors other than gray to be easily seen by the visually impaired, in colors that complement other streetscape elements.
- Bollards should be designed within a ‘family’ of streetscape elements.
- In circumstances where bollards are used to temporarily close a street or flexible parking space, removable bollards should be designed with long sturdy pipe projections from the bottom that fit into a hole in the ground. Removable bollards should be designed and installed such that, when in place, they are sturdy and look permanent. Electronic retractable bollards that can be lowered into the roadway to selectively allow vehicles to pass, should be considered where streets are closed to allow emergency vehicle access.

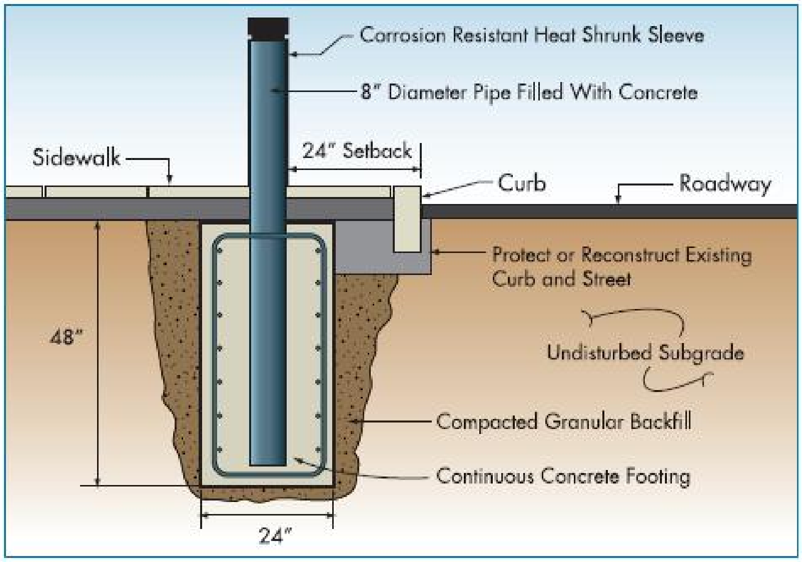
Federal Emergency Management Agency (FEMA) – Site and Urban Design for Security: Guidance against Potential Terrorist Attacks – FEMA 430 (December 2007)

This publication has been developed to provide information and design concepts for protection of buildings and occupants, from site perimeters to the faces of building. The main objective of this manual is to reduce physical damage to buildings and related infrastructure through site design, the purpose of FEMA 430 is also to ensure that security design provides careful attention to urban design values by maintaining or even enhancing the site amenities and aesthetic quality in urban and semi-urban areas.

Chapter 4 discusses the general issues of barrier system design, with emphasis on striking a balance between security needs and the preservation of the amenity and day-to-day functions of the site. This section ends with a description of the present barrier crash test standards. This chapter also describes and illustrates the various types of passive and active barriers that are currently available and in use.

Fixed Bollards – identified as a passive vehicular barrier consisting of a cylinder, usually made of steel and filled with concrete placed on end in a deep concrete footing in the ground to prevent vehicles from passing, but allowing the entrance of pedestrians and bicycles. Bollards are also constructed of steel sections and reinforced concrete. An anti-ram bollard system must be designed to effectively arrest vehicle and its cargo as quickly as possible and not create an opening for a second vehicle.

Figure 1: bollard installation. To illustrate concept only: dimensions and reinforcing will vary.



A typical fixed anti-ram bollard consists of a ½-inch thick steel pipe, eight inches in diameter projecting about 30 inches above grade and buried about 48 inches in a continuous strip foundation (Figure 1). The bollard shown in Figure 1 would be capable of stopping a 4,500-lb vehicle traveling at 30 mph. Rated bollards are also a available that would provide protection up to DOS K12 level.

Bollards can be specified with ornamental steel trim attached directly to the bollard or with selected cast sleeves of aluminum, iron, or bronze that slip over the crash tube. Bollards can be galvanized against corrosion and fitted with internal illumination for increased visibility. Figure 2 shows a number of decorative bollards with high-performance ratings. Bollards may be custom designed for an individual project to harmonize with the materials and form of the building, but to ensure adequate protection, they would need to be tested by an independent laboratory.

Figure 2: Decorative bollards with high-performance ratings.

Commonly used decorative bollards without deep foundations do not have anti-ram capacity, though they may provide some deterrence value by making the building look more protected than it is.

Bollards are by their nature an intrusion into the streetscape. A bollard system must be very thoughtfully designed, limited in extent and well integrated into the perimeter security design and the streetscape in order to minimize its visual impact

The visual impact of bollards can be reduced by limiting height to no more than 2 feet 6 inches. However, the height of the curb and its position relative to the bollard also relates to the bollard height. This and other site specific conditions such as road surface grade, may help to maintain an effective bollard for impact while making the bollard appear visually less obtrusive. In addition, the design basis threat, in terms of vehicle size and speed, also influences bollard height. In no case should bollards exceed a height of 38 inches inclusive of any decorative sleeve.

A bollard reduces the effective sidewalk width in a pedestrian zone by the width of the curb to bollard (typically 24 inches, plus the width of the bollard). In several high-pedestrian and narrow-sidewalk areas of a central business district, the reduction in effective sidewalk width can prove critical.

Other bollard system guidelines are:

- Spacing between 36 and 48 inches depending on the kind of traffic expected and the needs of pedestrians, people with strollers and wheel chairs and the elderly must be considered.

- In long barrier systems, the bollards should be interspersed with other streetscape elements such as hardened benches, light poles, or decorative planters.
- They should be kept clear of ADA access ramps and the corner quadrants at streets.
- They should be arranged in a linear fashion in which the center of the bollards is parallel to the center line of existing streets.

Palm Tran Transit Design Manual (August 2004)

This manual is intended for use by developers, planners, and engineers who recognize that designing for Transit from project inception leads to better transit, rider convenience, safety, traffic mitigation and other socio-economic benefits. It is a design guide to be used with FDOT and Palm Beach County standards as they exist or are amended.

Street side infrastructures are those features street side of the Bus Stop usually associated with the bus operations interface with a Bus Stop. Bus berths are off-site facilities that offer safer, more convenient locations for riders to leave their automobiles and travel to their destinations. One of the designs, called saw tooth design offers the advantage of appearing more like a formal Transit facility and discourages unauthorized parking. It does require more depth and improved sight distances than the parallel design. It also precludes bus queuing.

Transit facility designs incorporating saw tooth designs or other types of designs that direct errant vehicular traffic toward pedestrian-occupied areas should include provisions for positive separation between the roadway and pedestrian areas sufficient to stop a bus operating under normal parking area speed conditions from progressing into the pedestrian area. Typically bollards are placed at the forward ends of saw tooth bus parking spaces. A single bollard is designed to stop a 36,600-pound vehicle traveling 4 MPH. Three bollards of concrete-filled, 8-inch diameter, heavy wall steel pipe should be used at each parking space. The pipe is set vertically in a 6-foot, auger-drilled hole, and retained by reinforced concrete.

Curbside infrastructure are those features curbside of the bus stop and are usually associated with the Rider’s off-board interface with the bus stops. Bus stops should be located so as to limit conflicts with pedestrians and other activities. Because bus stops are commonly placed near parking lots, bollards and/or raised curb would prevent cards from damaging bus facilities (benches and shelters) or interfering with bus activities and riders.

APTA Standards Development Program – Recommended Practice - APTA SS-IS-RP-007-10 (June 2010)

Crime Prevention through Environmental Design (CPTED) for Transit Facilities - This *Recommended Practice* provides guidance for the application of CPTED principles to enhance safety and security, while reducing risk to people, operations and assets at public transit facilities.

Crime prevention through environmental design (CPTED) is the application of designing safety and security into the natural environment of a specific area. Specifically, CPTED concepts and strategies use the three interrelated principles of natural surveillance, natural access and territoriality, plus activity support and maintenance. By using the behavior of people, knowledge of crime generators, the physical environment, and the space of an area, CPTED can provide benefits of safety and security if applied in the conceptual, design and planning stages of a project. Planning the use of a facility, such as a bus and/or parking garage, transit center, intermodal terminal or a park and ride lot, should also encompass details for providing users with safety and security. CPTED can be the solution to many transit agencies security issues. Additionally, the concepts and strategies of CPTED have been applied for years and incorporated into the designs of several facilities not related to transit. However, there is belief that its principles can assist transit in increasing ridership through a sense of system safety and security.

An excerpt from the *Recommended Practice* indicates the use of bollards to prevent vehicle ramming.

	STRATEGIES FOR TRANSIT STOPS Site layout: ☐ Physical barriers such as bollards and fencing are provided to prevent ramming, or to prevent unauthorized access if the stop has a segregated transit way.

Since this recommended practice focus on crime prevention, it does not outline any information for using bollards at transit stops for pedestrian safety from errant vehicles.

National Capital Planning Commission – Designing and Testing of Perimeter Security Elements

The National Capital Planning Commission is the central planning agency for the federal government in the National Capital Region. The purpose of this document is to identify different security barriers surrounding federal buildings in Washington, D.C. Different security element designs that can enhance streetscapes and also serve as vehicle barriers are as follows:

- Walls, terraces and raised planting beds
- Trees and planters
- Knee walls and fencing
- Gatehouses
- Bollards

In developing security design solutions, the plan recognizes that one size does not fit all. Landscape architects, architects, and urban designers should be consulted during the design development of streetscape elements to ensure that a scheme is appropriate to the setting and security needs of a specific building or site. The physical elements described in this section can be designed to both enhance streetscapes and serve as vehicle barriers.

> Bollards - Curbside bollards can provide security against vehicular attacks. Through careful design and placement, bollards can guide pedestrian circulation, meet accessibility requirements, and enhance the character of the streetscape.

The context of the surrounding streetscape should be considered when designing security measures. Security components can include a wide range of elements beyond walls, planters, and bollards. Through proper design and engineering, a variety of attractive elements and landscape features can serve as anti-ram barriers to stop a moving vehicle. Such elements should foster a sense of openness by allowing for easy pedestrian and bicycle access.

NCPC's National Capital Urban Design and Security Plan encourage designers to consider how ordinary street furniture can be hardened to provide effective security. Utilizing elements typically found along a streetscape—e.g., benches, lamp posts, drinking fountains—helps to prevent clutter and make security appear seamless. Hardening these elements can be as simple as incorporating vehicle anti-ram barriers with decorative sleeves. Items such as newspaper stands, bus shelters, and lampposts can all be designed with sleeves that fit over reinforced bollards or posts to stop a moving vehicle. Bike racks, benches, and drinking fountains also have the potential to serve as perimeter security.

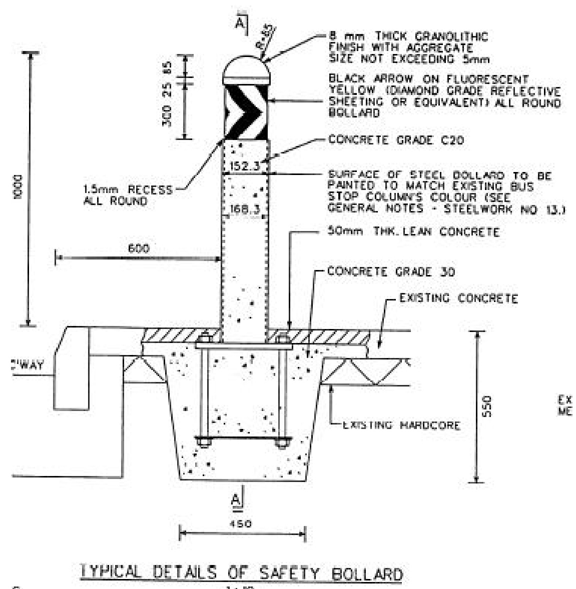
Land Transportation Authority – Singapore Government

The Singapore government through the Land Transportation Authority is committed to ensuring the safety and security of motorist and commuters at all times. LTA, who are responsible for planning, operating, and maintaining Singapore's land transport infrastructure and systems, has safety initiatives for pedestrians which includes the use of safety bollards.

The safety bollards are located at bus stops along high speed roads. The main function is to reduce the severity of impact from errant vehicles. They also alert drivers to the presence of bus stops, especially during night time, and this protect commuters at bus stops. The photo below shows the bollards being used at bus stops in Singapore. According to LTA, safety bollards have proven to be effective in deterring impact from errant vehicles that mount into the bus stop. Singapore has first installed safety bollards at bus stops in 1999.

Left: Bollard installed at bus stops in Singapore.

Right: Excerpt from Standard Detail of Road Elements – Bollard (2001)



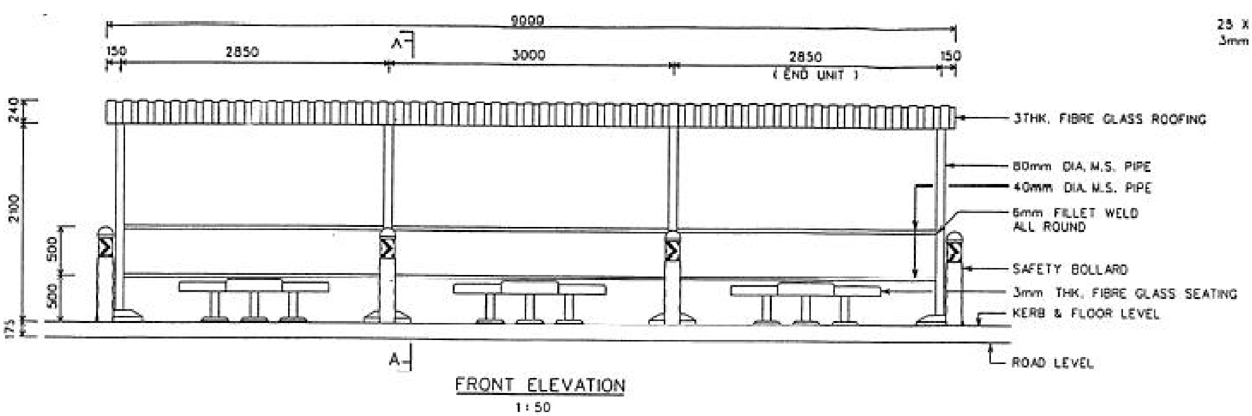
According to One Monitoring, the online portal for LTA, as of December 2011, 2.659 out of 4.600 bus stops have been provided with safety bollards.

A blog post in SG Forum, May 2007 titled "More Bus Stops May Get Safety Bollards" (May, 2007), discussed the efforts of Land Transportation Authority to install safety bollards in all the bus stops. According to the blog, the current LTA guidelines for installation of bollards are:

- At bus stops along roads where the speed limits are at least 60 km/h (37 mph) or above;
- At bus stops located along bends with speed limits of 50 km/h (31 mph);
- At bus stops facing turning traffic from the side the side of road, example, at T-junctions.

About three to four safety bollards are installed at such bus stops. The bollards are about 3 meters apart to sufficiently block any runaway vehicle while still providing adequate space for commuters to board or alight the buses.

Standard drawings for bollards and installation within bus stops can be found in LTA's website and an excerpt from the standard drawing is shown below:



A front view of typical bus shelter with bollards safety bollards

Harbor Freeway - Los Angeles Metropolitan Transportation Authority (February 2012)

On February 22, 2012 an incident occurred on the northbound Metro Silver Line platform during the afternoon. A vehicle struck the northbound platform of the Silver Line (rapid bus transit). The Metro Silver Line bus was not hit by the private truck when it was entering the station. There were 7 passengers who were about aboard the Silver Line bus to Downtown LA as a vehicle struck the platform. The 7 passengers received critical and serious injuries. During the incident, the Metro Silver Line, Metro Express Lines: 450X and 550 were detoured to stop at Figueroa Street/Harbor FWY station entrance. There has never been an incident on the Harbor Transitway ever since it first opened on June 1998. As a result of the incident, Metro's CEO: Art Leahy asked Metro's safety committee to review the station layout and signage of the Silver Line stations on the Harbor Transitway portion. A report was scheduled within 60 days after the incident. The report was complete during April 2012. Bollards were added during early August

2012 at the station. Bollards were also installed at the 37th Street/USC Metro Silver Line Station as well.

Bollards installed at Harbor Freeway, Silver Line Station to enhance pedestrian safety

Transportation Alternatives – Rethinking Bollards (July 2007)

Bollards are suggested as an effective way to calm traffic and protect pedestrians. This report presents examples of how bollards are working at a few select locations in New York City, and makes recommendations for a citywide policy to expand the deployment of bollards and other vertical deflectors to protect all street users. Recommendations for bollard use include the following:

- Experimentation with innovative pedestrian-friendly street designs
- Designation of exclusive pedestrian and bicycle areas
- Preventative safety measures to manage vehicular flow and calm traffic
- Implementation of Bus Rapid Transit (BRT)
- Securing bike lanes, paths & greenways
- Security for government and financial institutions
- Prevention of parking on sidewalks

While bollards have demonstrated efficacy in these and other applications, New York City has been conservative in their use. Currently, the DOT does not have a set policy to guide their prescription, installation or maintenance. A clearly defined city policy and community support for bollards will help the city and local neighborhood interests move forward in installing them. The use of bollards as a preventative safety measure on the City's streets and sidewalks could dramatically reduce the number of people injured and killed by errant motorists.

This report outlines the different bollard designs. New York City agencies use bollards to experiment with new street designs. While temporary bollards or planters will not protect pedestrians from wayward vehicles, they are a powerful tool for testing and demonstrating innovative designs, and ultimately making streets safer for pedestrians and cyclists.

According to the report, Bollards are a simple engineering tool to protect pedestrians and cyclists from vehicles, and designate pedestrian areas by blocking vehicular access while allowing pedestrians and cyclists to enter freely between each bollard. Bollards enforce and manage traffic flow 24 hours a day.

Another aspect of bollard use is to provide a physical barrier to protect pedestrians from encroaching vehicles. But they can also be used as a preventative measure to manage vehicular flow and calm traffic. Used in conjunction with neck downs (a.k.a. bulbouts or sidewalk extensions) and other traffic calming measures, bollards alert drivers to the narrowed roadway, and prevent vehicles from mounting the sidewalk and injuring pedestrians.

Measures for security device are also discussed in the report. Bollards are indentified as an indispensable security device. They can stop a truck at high speeds, and for this reason, they are used at nuclear power plants, embassies, courthouses, the State Department headquarters, the US Supreme Court and military bases around the world. The rapid proliferation of security bollards after September 11th demonstrates the ease of installing them. They City could easily make bollards a standard feature for pedestrian safety, which would respond to another daily threat to public safety.

Several concerns about bollards are discussed and their solutions, according to the report, are outlined below:

- Bollards impede people with visual and mobility impairments.

Bollards can and should be spaced so that wheelchairs may pass but vehicles cannot. Visually impaired pedestrians are, in most cases, equipped with a method of detecting obstacles, such as a guide dog or cane, and are prepared to encounter a bollard. Bollards should be tall enough to prevent a tripping hazard.

- Bollards interfere with snow plowing.

Countries with heavy snowfall such as Canada, Denmark, Norway and Sweden routinely use bollards both on sidewalks and streets. Proper management of areas sectioned off by bollards should be determined and implemented.

- Permanent steel bollards cause damage to vehicles.

While bollards are a boon for pedestrian safety, DOT engineers have limited bollard installation because they perceive them as dangerous to vehicles and their drivers. The DOT's stated fear is that a driver hitting a bollard could cause damage to the car, or even cause injury or death, and the City could be held liable.

As this report demonstrates, there are dozens of successful examples of safe, common sense applications for bollards in New York City. Bollards are no different than street lights, posts or trees that already line our streets. Cars will only come in contact with bollards if they waver out of their lane. Thus, if a bollard is hit, it is preventing injuries and saving lives.

Cars mounting sidewalks is a widely publicized problem in New York City, injuring and killing scores of people each year (see Appendix for articles), and bollards are a proven solution to this problem. According to records kept by the NY State Department of Motor Vehicles, about 10% of New York City pedestrians struck by cars are actually hit off road on the sidewalk or inside their homes.

Reflectors or lights on bollards alert and warn drivers of bollards' location. If a car collides with a fixed bollard, drivers are protected by thousands of pounds of steel. Potential injury to passengers and drivers is much less severe than potential injury to unprotected pedestrians and cyclists who would be struck if there were no bollard.

Where pedestrian safety is not the primary goal of bollard use (such as in lane separation or testing street redesign), plastic bollards, which cause little or no damage to vehicles and their drivers, are used.

- Retractable bollards cause damage to vehicles.

Retractable bollards can cause damage to a vehicle if it passes over the bollard as it rises from the ground. However, the simple installation of an inductive loop in the road prevents a bollard from rising with a vehicle overhead. The coil of wire is embedded in the street surface to detect the presence of a driver above. In addition, the City should also clearly indicate the presence of the bollard, post the time bollards rise if they are set to a timer, and install lights to alert drivers when bollards are about to rise.

Miami-Dade Legislative Report – Item # 072615 Findings of Feasibility Study for the Installation of Cylindrical Posts Between Bus Passenger Benches or Shelters and the Edge of the Road at Bus Stops in Unincorporated Miami-Dade County (September 2007)

This legislative report discussed the findings to the investigation and documentation of the potential benefits, risks, regulatory issues, time and cost of installing cylindrical posts for passenger safety at over 2,300 bus stops throughout Miami-Dade County. The 2,300 bus stops consist of 1,100 bus shelters and 1,200 bus benches. The study includes the investigation of 300 bus stop locations representing the various typical conditions that exist at bus stops with benches or shelters.

According to the legislative report, it was found in the study that most of the bus stops do not have the allowable space required for bollards to be installed and meet Federal, State and County design standards. In nearly all cases, it would not be possible to install bollards in front of bus benches and shelters without violating the standards set in the Florida Manual of Uniform Minimum Standards for Design, Construction and Maintenance of Streets and Highways, also known as the Florida Green Book.

Additional significant findings from the feasibility study are outlined in the legislative report and are as follows:

- Bollards are designed for low speed impact. A high speed collision at bus stop benches or shelters with bollards could result in pedestrians being hit or trapped by a bollard driven out of ground.
- Design for most locations would require a bollard to be installed within four feet of the curb and gutter, or fourteen feet from flush roadways, violating Clear Zone guidelines.
- Objects installed within Clear Zone are designed to bend or break upon impact. Bollards would not bend or break.
- Maintaining 36 inches of clear width for disabled persons restrict bollards from being installed on most sidewalks.
- Bollards can obstruct the driver’s view of traffic at an intersection.
- Large foundations and conflicts with subsurface utilities make designs impractical to implement at most locations.
- Shelter layouts with sufficient distance from roadway are possible locations where bollards can be installed without violating State or County regulations, Based on inventory (in 2007) 11% of bus shelters throughout the county are possible candidates for bollard retrofits. Benches are not recommended.

- The average cost for installation (in 2007) is $22,000. The cost of installation at 121 locations is approximately $2,662,000. Design costs are an average 5% of construction, for a cost of $133,100. Total cost for installation is approximately $2,795,100.
- Design, Permitting and Construction would take approximately 12 months. The County's solicitation of a design consultant and contractor would take approximately 20 months for a total of 32 months.

The report stresses the fact that a bollard specifically designed to withstand high speed collisions may actually increase the risk of a deadly incident as the driver or passenger or the errant vehicle are most likely to suffer serious injury. While the concept of using bollards to protect the patrons of our bus system would at first blush appear to increase public safety, research indicates that it would in all likelihood result in the opposite effect. Therefore, cylindrical posts are not recommended for protection of pedestrians at bus stops against errant vehicles that leave the roadway.

TRANSIT STOP SAFETY STUDY UPDATE

January 2013

Prepared by:

PARSONS BRINCKERHOFF

On Behalf of:

Regional Transportation Commission of Southern Nevada