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Anti-Vehicle Barriers for Public Transit

Abstract: This *Recommended Practice* describes anti-vehicle barriers (AVB) for transit passenger facilities to enhance the security of people, operations, assets and infrastructure.

Keywords: anti-vehicle barriers, barriers, bollards, site survey, design considerations, standoff distance

Summary: Public transit operates in inherently open environments. It provides ease of access and gathers volumes of people in confined spaces to provide passengers with efficient and convenient transportation through regions and their communities. These unique attributes make public transportation vulnerable to adversarial targeting and threats. For these reasons, a sound understanding of anti-vehicle barriers will enable agencies to implement an approach to more effectively manage the risks of their environments. This document provides background information on AVB systems, details the systems that are available, and describes the specific use and capabilities of AVB systems. It outlines the AVB selection process to present options for the best systems to use in specific environments. It also offers considerations to aid in the placement of the systems once the proper barrier is chosen.

Participants

The American Public Transportation Association greatly appreciates the contributions of **Bill Pitard,** who provided the primary effort in the drafting of this *Recommended Practice*.

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1. Anti-vehicle barrier overview

Adversaries may use a vehicle, either on its own or laden with explosives, to carry out attacks against people, operations, assets and infrastructure in the transit environment. To reduce the risk from these threats, the design and placement of anti-vehicle barriers (AVBs) should be considered.

AVB systems differ in and are differentiated by their composition, capability and style. They are constructed of metals, concrete and other materials for durability to resist energy of vehicular penetration, and they may vary in style from being several feet in length to cylindrical in shape. Cylindrical shaped vertically installed AVB systems are referred to as bollards. Bollards vary in their construction and functional design, but they have many of the same capabilities as horizontally installed barriers—that is, to control vehicle access to an area. A security risk assessment will identify the need for and placement of an AVB system.

Following selection, but before placement, a site survey should be performed to include the analysis of the site's existing features. The checklist in Annex A is provided as a guide to completing and documenting a site survey.

1.1 Categories

AVBs are primarily classified into two categories, active or passive. Active barriers have moveable components, and their systems can be operated manually or mechanically to allow or restrict vehicle passage. In contrast, passive barriers are fixed systems that remain static. While AVBs may provide theft deterrence, asset protection, and pedestrian and traffic control, they are primarily used to control authorized vehicle access to an area.

1.2 Stakeholder considerations

The implementation of AVBs serves a meaningful purpose. To the extent possible, AVB application assists agencies in meeting their security program requirements, while maintaining efficient operations. AVB use and design, such as planters and bollards, can be functional for efficient operations and aesthetically pleasing to the communities that host agency properties and operations.

1.3 Benefits

A security system program that includes AVB applications offers the following benefits to an agency:

- Protects against harmful vehicle attacks or intrusions.
- Provides an appropriate standoff distance and clear zones.
- Fosters a sense of physical security.
- Creates a sense of ownership by transit users and employees.
- Manages access to authorized areas.
- Controls access to nonpublic areas.

2. Security risk assessment

Transit agencies should complete a systemwide security risk assessment to determine exposure of the system's people, assets, operations and infrastructure. A risk-based approach that factors threat, vulnerability and consequence should be used to assess transit systems. The findings should be used to select security measures for the protection of people, assets, operations and infrastructure.

For more information regarding risk assessments, consider the following resources:

- Federal Transit Administration (FTA) Transit Safety and Security Bus Program
- Federal Emergency Management Agency Terrorism Risk Assessment and Management (TRAM) Tool Kit
- Department of Homeland Security Analytical Risk Management (ARM-IR)
- American Public Works Association (APWA) Rural Transit Assistance Program (RTAP) Threat & Vulnerability Toolbox
- Community Transportation Association of America (CTAA) Training, Safety Review Program
- National Infrastructure Protection Plan, Transportation Systems Sector (http://www.bhs.idaho.gov/pages/plans/cikr/transportation.pdf)

3. AVB recommended practices

3.1 AVB uses and functions

3.1.1 Uses

While AVBs can be used in many ways, their primary function is to control authorized vehicle access. They can be installed at a facility's gates or entrances (vehicle "checkpoints"), around security guard booths, between designated parking areas and buildings, adjacent to high-value facilities or assets, or as a protective barrier around temporary events or activities. Barriers can be passive or active, manned or unmanned, and remotely or locally controlled.

3.1.2 Functions

Passive AVB systems such as planters, fixed bollards and modular concrete barriers (otherwise known as K-Rails or "Jersey barriers") are intended to remain in a fixed position to preventing vehicle access. Active systems such as a pop-up wedge, retractable bollards and drop-arm barriers manage the access of vehicles. **Table 1** and **Table 2** summarize the Department of State (DoS) K-ratings and the Department of Defense (DoD) K-ratings and L-ratings.

TABLE 1
DoD Certified Anti-Vehicle Barrier Options

K-Rating[1]	Gross Vehicle Weight (lbs)	Vehicle Speed (mph)	L-Rating[1]	Maximum Penetration Distance (ft)	Options
K12	15,000	50	L3	3	AVBs of various K-rating and L-rating combinations are available in the following barrier systems: hydraulic, pneumatic, electric or manual bollards, wedges, or plates; reinforced walls; retractable bollards; cable restraining systems; drop arm; sliding beam; foundation wall; fixed bollards; etc.
K8	15,000	40	L2	20	
K4	15,000	30	L1	50	

Department of Defense (DoD)

1. K-ratings are based on a 15,000-pound gross-weight vehicle impacting a barrier system at a specific speed from a perpendicular direction, with the L-rating determined from the maximum penetration distance of the vehicle past the protected side of the barrier system.

TABLE 2
DoS Certified Anti-Vehicle Barrier Options

K-Rating[1]	Gross Vehicle Weight (lbs)	Vehicle Speed (mph)	Options[2]
K12	15,000	50	Pneumatic, hydraulic, electric or manual bollards, wedges or plates; reinforced planters; reinforced walls; etc.
K8	15,000	40	Retractable bollards, cable restraining systems, etc.
K4	15,000	30	Drop arm, sliding beam, foundation wall, fixed bollards, etc.

Department of State (DoS)

1. The K-ratings for the DoS AVBs are similar to those of the DoD except that the varied penetration ranges (L-ratings) do not apply. Instead, DoS acknowledges that the penetration of any vehicle's cargo bed must not exceed 1 m (39 in.) past the pre-impact inside edge (protected area) of the barrier system to be certified.
2. Regardless of L-rating, DoS certified AVB only perform to the penetration distance standard of 39-inches (1-meter).

3.2 AVB design

AVBs are either passive (static or non-moveable) meaning they have no moveable parts; or active (operator controlled for access), meaning some parts of the barrier are moveable. They are manufactured and rated to resist different levels of kinetic energy and are also available in different design styles, such as flush or surface-mount wedge, plate or bollards; rolling (sliding) gate; and drop-arm designs. Once an agency has selected the performance design, it should see the APTA *Recommended Practice* "Crime Prevention Through Environmental Design (CPTED) at Public Transit Facilities" for additional information.

Typical AVB designs should include the appropriate following support equipment, such as backup power; an emergency cutoff switch; adequate lighting and safety options (i.e., alarms, strobe or rotating beacon lights and safety interlocks to prevent the AVB from being accidentally activated); vehicle sensing loops (on the secure side to prevent activation of the barrier until the vehicle has completely cleared the AVB); safety markings; and signage. All AVB supporting equipment should be located on the secure side of the barrier and should be monitored on a continual basis by CCTV and an intrusion detection system (IDS) to reduce their potential for being sabotaged, as well as for optimum functionality. Additionally, the area surrounding an AVB should be monitored for security.

Passive vehicle barriers are non-moveable systems. Passive barriers include steel or concrete framed or reinforced earthen barriers; plastic (water-filled) or steel-reinforced concrete modular concrete barriers ("Jersey barriers"); planter-styled security barriers; steel "impaler-style" barriers; concrete or metal bollards; and permanently installed concrete, cinder/concrete block or brick wall-type barriers. In contrast, active vehicle barriers are characterized by their ability to move and can be operated manually or automatically.

The bollard is one of the most versatile components in comprehensive integrated design planning and design execution. The breadth of design styles of bollards renders them an easy candidate to complement building architectural and landscaping designs of a broad spectrum. Bollards can be made from any of the following materials: cast iron, stainless steel, steel/cast iron composite, recycled plastic or plastic covers. Bollards can be active or passive as well.

Detailed descriptions of passive and active barriers are given in **Table 3** and **Table 4**.

TABLE 3
Passive (Fixed Installation) Barriers

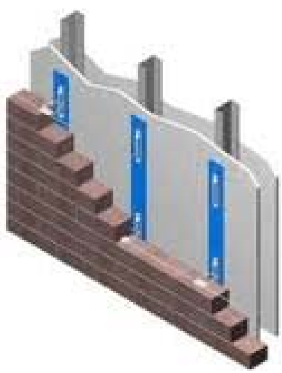
Barrier System	Description	Utilization	Typical Height and Length	Construction (Material)
Steel/concrete framed/ reinforced earthen 	Typical steel concrete framework backfilled with soil, and topped with sod	Striped, flashing lights, sirens, etc. Used in open areas with plenty of space and when cost is an issue. Can be used to route or direct vehicle traffic circulation.	Height and weight vary depending on application and vulnerability of the structure.	Steel or concrete
Plastic (water-filled) barrier 	Available in various styles, lengths, shapes and colors	Placed as protective barriers where needed; can be arranged end-toned, side-by-side, or even stacked for increased security.	Height: 32 to 42 in.	Typically molded plastic (filled with water)
Concrete modular barriers (K-rails or Jersey barriers) 	Available in various styles, lengths, shapes and colors	Used in or along driveways or roads to direct traffic to a checkpoint	Height: 32 to 36 in. Length: 9 to 10 ft	Steel-reinforced concrete

TABLE 3

Passive (Fixed Installation) Barriers

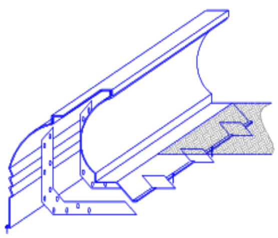
Barrier System	Description	Utilization	Typical Height and Length	Construction (Material)
Planter-styled security barriers 	Concrete “shell” backfilled with soil for added protective weight	Prevents vehicle intrusion; protects walkways, fences, guard booths, important equipment and prevents driving around other barriers; can be used to route or direct vehicle or pedestrian traffic.	Height and weight vary depending on application and vulnerability of the structure.	Steel reinforced concrete “shell”
Steel “impaler-style” barriers 	Designed to roll backward upon impact, impaling the vehicle on the underside, subsequently acting as an extreme friction anchor.	Placed wherever needed, installed slightly below grade, and backfilled in place with concrete; barriers can be interconnected for extended length.	Height: 32 to 42 in. Length: 10 to 12 in.	Steel
Concrete or metal bollards 	Vertically installed metal (preferably steel) “crash tube” with the lower base extending into the ground; in use in numerous military and commercial applications	Inhibits vehicle intrusion, protects walkways, fences, guard booths, important equipment and prevents driving around other barriers; can be used to route or direct vehicle or pedestrian traffic.	Height: 18 to 60 in. or more Diameter: Varies depending on application; typically 8 to 24 in.	Solid steel, or hollow tube filled with reinforced concrete
Permanently installed concrete, cinder/concrete block, or brick wall-type barriers 	A vertically constructed and installed reinforced concrete, cinder/ concrete block, or brick wall	Installed around a security zone or high-value asset requiring protection	Height and weight vary depending on application and vulnerability of the structure.	Concrete, cinder/ concrete block, or brick

TABLE 4
Active (Deployable) Barriers

Barrier System	Description	Use	Height and Length	Construction (Material)
Permanently installed "recessed-mounted" (in ground) ramp-style vehicle barriers with chain reinforcements 	These ramp systems weigh between 2,500 and 12,000 lbs and are installed sub-grade and flush-mounted in the surface of the road. The ramp barrier system is raised or lowered either manually or automatically (based on access being granted) through use of computer-controlled electrical or hydraulic systems.	As a barrier for the perimeter boundary to stop and/or disable unauthorized vehicle penetration	Width: 1 to 24 ft Height: ~3 ft	Steel
Ramp-style vehicle barriers (with chain reinforcements) 	27° lift angle facing the opponent's direction of approach. Temporary or permanently installed; mounted at-grade. These ramp systems weigh between 2,500 to 12,000 lbs. The ramp barrier system is raised or lowered either manually or automatically (based on access being granted) through use of computer-controlled electrical or hydraulic systems.	As a barrier for the perimeter boundary to stop and/or to disable unauthorized vehicle penetration	Width: 1 to 24 ft Height: 3 ft	Steel

TABLE 4
Active (Deployable) Barriers

Barrier System	Description	Use	Height and Length	Construction (Material)
Hydraulically deployable metal bollards 	Subsurface vertically installed metal "crash tube." Once deployed, part of tube is above surface with the lower part extending into the ground; in use in numerous military and commercial applications.	Inhibits vehicle intrusion; protects walkways, fences, guard booths, and important equipment; prevents driving around other barriers; can be used to route or direct vehicle or pedestrian traffic.	Height: 18 to 36 in. or more Diameter: Varies depending on application; typically 12 to 24 in.	Constructed of solid tubular steel, can be filled for added strength.
Traffic controllers ("tire teeth") 	Metal teeth used to cut/shred vehicle tire; metal teeth that are either spring mounted to allow safe one-way travel or retractable to allow two-way travel	Prevention of wrong-way traffic flow (parking applications) and deployable to flatten tires if vehicles cross security access point	Approximately 1 in. wide by 4 in. long teeth are used.	

AVBs should be designed and deployed to restrict entry of unauthorized vehicles into specific facility areas, especially during heightened National Terror Advisory System (NTAS) conditions. AVBs may be significantly damaged after absorbing the full impact of a moving vehicle. The barrier may not be fully functional or operational after impact and may fail if kept in service. To determine AVB serviceability, any AVB sustaining an impact should be inspected. It may require repair, restoration or replacement to remain in service and to maintain its respective agency certification.

3.3 AVB selection

When selecting a barrier, it is important to begin with a site survey. The site survey should include the relative locations, major dimensions and descriptions of buildings and structures, roads, terrain and landscaping, existing security features, and the property perimeter. Based on the analysis of the aforementioned factors, the proper levels of protection will be determined. Other things to consider as part of the terrain include:

- whether the structure that is going to be protected is downhill;
- whether the road leading to it is straight or curved; and
- whether the building is accessible to an unauthorized vehicle through other means.

It may be necessary to install more than one set of barriers to counter the effects of the momentum of an unauthorized vehicle attempting to breach the perimeter.

There are also other important factors to consider when choosing a barrier system. Those factors include the requirement for barrier system type, installation plans, the required number and placement, aesthetic requirements, and local codes. The chosen barrier system should also be compatible with the other security components in place. For example, an active barrier system should not be installed adjacent to an unhardened chain-link fence, because then the fence would become the weakest path.

In addition to a site survey, other factors must be considered during the selection process of an AVB. For example, the likelihood of unintended vehicles entering the designated protected area and the possible risks associated with your chosen style of barrier. Annex A provides a checklist that incorporates the selection process and the vehicle barrier design and installation requirements.

3.4 Location of anti-vehicle barriers

The location of vehicle barriers can vary based on their design as active or passive and the area they are protecting. Active vehicle barriers are most often placed at facility entrances. They can also be placed at selected interior locations. The exact location of active barriers may vary among installations; in each case they should be placed as far from the critical structure as practical to minimize damage due to possible intrusion explosion. Passive barriers should be located at entry points to restrict or manage if traffic flow is restricted or periodic. Passive barriers are most often used for protection of perimeter boundaries. The agency's risk assessment will determine its adequate standoff distance for the proper placement of barriers.

3.5 Anti-vehicle barrier access control

Methods of access control are managed by the use of active barriers. Access control can be accomplished with a staffed guard or remotely through the use of a card or biometric access control devices that will automatically activate the barrier. The barrier can also be operated from a protected location other than the entry control point.

3.6 Barrier alternatives

There are several alternatives to AVB systems. These alternatives can include the following:

- ditches
- heavy equipment tires
- tire shredders
- non-reinforced concrete blocks

3.7 Fencing systems

Fences should not be considered as protection against moving vehicle attacks. Most fences can be easily penetrated by a moving vehicle and will resist impact only if reinforcement is added. Fences are used primarily to provide a boundary by defining the outermost limit of a facility and to assist in controlling and screening authorized vehicle entries into a secured area by deterring overt entry elsewhere along the boundary. Fences also support detection, assessment and other security functions by providing a "clear zone" for installing lighting, intrusion detection equipment, and CCTV. For additional information, see the APTA *Recommended Practice* "Fencing Systems to Control Access to Transit Facilities."

4. Training considerations

Most manufacturers recommend operator training for active barrier systems. Operator training prevents serious injury and legal liability, as well as equipment damage caused by improper operations. If a manufacturer does not provide a thorough program for operator training, the user should develop the appropriate checklist for normal and emergency operating procedures.

5. Maintenance considerations

Many manufacturers provide wiring and hydraulic diagrams, maintenance schedules and procedures for their systems. They should also have spare parts available to keep barriers in continuous operation. The manufacturer should provide barrier maintenance support in the form of training and operation and maintenance manuals. Maintenance contracts are available from most manufacturers. Reliability and maintainability data are available from most manufacturers. Maintenance should include inspection, adjustment, cleaning, pressure checks on operational systems, and replacement of worn parts.

Check with the manufacturer for a list of current customers deploying their products, and then consider speaking with those agencies to ascertain performance and other service data about the product your agency is considering.

6. Cost-effectiveness

Tradeoffs on protective measures may include the following:

- locating the vehicle barrier to provide optimum separation distance
- slowing down vehicles approaching the barrier, using obstructions or redesign of the access route
- barrier open to permit access vs. closed to prevent access
- active vs. passive barriers
- system-activating options: manual vs. automatic, local vs. remote, electrical vs. hydraulic
- safety, reliability, availability, and maintainability characteristics

7. Liability

Possible legal issues may arise from accidents (death/injuries). The agency should consult with legal representation when considering the installation of an active vehicle barrier system to ensure it is complying with all local, state and federal laws.

8. Additional design considerations

The following actions are also to be considered when selecting and installing barrier systems:

- If the location of a vehicle barrier is in an area of high water table, consider using a surface-mounted or shallow profile barrier system. Below-ground barriers can be installed if the required installation depth is above the water table. If the excavation cannot be drained, water collection could cause corrosion, and freezing weather may incapacitate the system.
- When barriers are installed at entrance and exit gates, also consider installing passive barrier systems along the remaining accessible perimeter of the protected area.
- Protection of individual buildings or zones within the perimeter is generally more cost-effective than extensive protection of a large facility perimeter. For example, passive barriers installed in areas where vehicles cannot reach, just to complete a perimeter barrier system, are not effective use of security funding.
- Since most types of active barriers can be easily sabotaged, consider installing active barriers only in areas where they can be under continuous observation.
- Barriers should be used to divert traffic or prevent entry or exit. Installation of barriers immediately adjacent to guard posts is not desirable because the possibility of injury should be minimized. Consider keeping vehicle barriers as far from guard posts as possible.
- Barriers should be installed on the exit side of an access control point, as well as the entrance.

- Long, straight paths to a crash-resistant barrier can result in increased vehicle speed and greater kinetic energy upon possible impact. Where this cannot be avoided, installation of a passive-type barrier maze should be considered to slow the vehicle.

Design passive barrier systems to comply with the requirements of the Deputy Secretary of Defense memorandum "Access for People with Disabilities" dated October 31, 2008. The memorandum updates the DoD standards for making facilities accessible to people with disabilities.

Annex A: Understanding crash test rating classifications

Overview

AVBs are classified according to their crash test rating results (Department of State Standard SD-STD-02.01, Revision A, March 2003). AVBs are tested to resist the kinetic energy (K-rating) of the test vehicle's speed and limit the penetration distance (L-rating) of the test vehicle beyond the front line (protected side) of the AVB. The test rating results are based on the distance a 15,000 lb vehicle traveling at different designated speeds penetrate past the protected side of the barrier. K-ratings are categorized from highest to lowest vehicle impact speeds. When applied, L-ratings are listed from the shortest to farthest penetration distances past the protected area of AVB.

American Society for Testing and Materials (ASTM)

When the DoS published the standard SD-STD-02.01, Revision A, March 2003 "Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates," the penetration distance of a vehicle into a barrier was limited to 1 m. The DoS list of certified barriers was developed under Revision A, and all barriers allowing penetration in excess of 1 m were removed from the list. Most DoD components have sufficient standoff and can utilize barriers that allow penetration distances in excess of 1 m. Due to this and other needs, the requirement for a national standard for crash testing of perimeter was established.

ASTM F 2656-07, "Standard Test Method for Vehicle Crash Testing of Perimeter Barriers," has been published and is being adopted by both DoD and DoS for certification/approval of vehicle barriers. This standard includes more vehicle types and differing penetration depths. The ASTM test vehicles, overall test protocol, instrumentation, measurements and report requirements are standardized to provide consistent procedures and requirements for barrier manufacturers and accredited testing facilities.

The ASTM is the primary testing standard for vehicle crash testing and in 2007 revised the "Standard Test Method for Vehicle Crash Testing of Perimeter Barriers" testing method. However, to date, DoD continues to certify AVBs based on Department of State Standard SD-STD-02.01, Revision A, March 2003, with the exception of penetration distances, which have been evaluated for conformance with SD-STD-02.01, April 1985 testing method; while, DoS continues to certify its AVBs based on the standard test methods of Department of State Standard SD-STD-02.01, Revision A, March 2003.

Annex B: AVB selection checklist

The following list incorporates the selection process for anti-vehicle barrier design and installation requirements. Agencies in the process of selecting an AVB should consider review of the information contained in it, answering each question based on the results of its TVA.

AVB selection checklist

1. Describe the design basis threat as determined by the agency's risk assessment.
2. What is the type, weight, maximum velocity, contents and calculated kinetic energy of the threat vehicle? What type of attack? Single vehicle or multiple vehicles?
3. Is there sufficient standoff distance between the planned barrier and the protected structure?
4. What is the expected speed of the vehicle?
5. Can the speed of the vehicle be reduced (via speed bumps, serpentine approach, etc.)?
6. What is the calculated kinetic energy developed by the moving vehicle?
7. Have all impact points along the perimeter been identified?
8. Have the number of access points requiring vehicle barrier installation been minimized?
9. What is the most cost-effective active barrier available that will absorb the kinetic energy developed by the threat vehicle?
10. How many barriers are required at each entry point to meet throughput requirements?
11. What is the most cost-effective passive barrier that will absorb the kinetic energy developed by the threat vehicle?
12. Will the use of aesthetic barriers at some locations be necessary?
13. Is penetration into the site a factor?
14. If penetration into the site is a factor, is the standoff distance adequate after impact?
15. Will traffic flow be affected by the barrier's normal cycle rate? What is the active barrier's maximum throughput rate per day/hour? What is the number of available traffic lanes: one-way only; reversible; width; and separation? Is the roadway flat/sloping/crowned, islands, etc.?
16. Will the active barrier need to be activated at a rate higher than the normal rate?
17. Will the barrier be required to be normally open (allow traffic to pass) or normally closed (stop traffic flow)?
18. If normally open (allowing traffic flow), is adequate distance available between the guard post and the barrier to allow activation and operation of the barrier?
19. Will the barrier be subject to severe environmental conditions? Consider high/low temperatures, rainfall, drainage, snow and frost. Survey the site for sub-surface conditions, berms, landscaping, buried utilities, drainage, frost line and water table height. Also consider zoning laws.
20. Do passive barriers installed along the perimeter provide equivalent protection to the active barriers?
21. Do passive barriers interfere with established clear zone requirements?
22. In case of power failure, will the barrier fail open or close? Is there an emergency backup power source? Are there warning/safety signs/signals/strobes/horns to warn of the barriers ahead? Are there semaphore gate arms? Are they in sync with the barrier deployment?
23. Is this a temporary or permanent installation?
24. Consider CPTED principles (see the APTA *Recommended Practice* "Crime Prevention Through Environmental Design (CPTED) at Public Transit Facilities").

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Definitions

See aptastandards.com for a complete glossary.

barrier: A natural or manmade obstacle to the movement of people, animals, vehicles or materials.

maintenance: The continued care and upkeep of a space for its intended purpose. It also serves as an expression of ownership.

risk assessment: A formal methodical process used to evaluate risks to a transit system. The security portion of the risk assessment identifies security threats (both terrorism and crime) to the transit system; evaluates system vulnerabilities to those threats; and determines the consequences to people, equipment and property.

standoff distance: The distance maintained between an asset or portion thereof and the potential location for an explosive detonation or other threat.

Abbreviations and acronyms

AVB	anti-vehicle barrier
ASTM	American Society for Testing and Materials
CCTV	closed-circuit television
CPTED	crime prevention through environmental design
DoD	Department of Defense
DoS	Department of State
IDS	intrusion detection system
K-rating	kinetic energy rating for AVBs
L-rating	penetration distance rating for AVBs
NTAS	National Terror Advisory System
TVA	threat and vulnerability assessment