
Transit Security Design Guidance - Vehicles

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Transit Security Design Considerations

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7.0 Vehicles

The information in this chapter will help increase transit agency awareness and understanding of the relationship between vehicle design and security, and explain how transit policy makers and system designers can use the physical design of heavy rail, light rail (including trolleys), and bus vehicles to help protect their employees and passengers.⁴⁰

The intent is to present a comprehensive set of practical security-oriented design considerations to which transit agencies can refer when preparing their procurement specifications or retrofitting their fleet. Identification of these design considerations is the first step in enabling transit agencies to make informed decisions about improving the security of their vehicle fleets.

Each transit agency is free to determine which of these considerations best suit the current and future needs of its system; some considerations are more relevant for some systems and less so for others. Transit systems with a low level of anticipated threat may not warrant some of the more extreme or expensive measures. Budgetary restrictions may also limit a transit agency's ability to implement ideal solutions.

Transit agencies should remember that vehicle design elements are only one of several tools available to achieve a desired level of protection. An agency may also consider infrastructure design, operational procedures such as training security personnel, or security-oriented policies (such as an Emergency Response Plan). A cohesive security plan interweaves vehicle design strategies, such as those in this chapter, together with other elements. These include balancing system security against other policy goals, such as operational efficiency and passenger convenience; reconciling security-oriented design considerations with existing design codes and standards; and reviewing agency standards in relation to the security considerations in this chapter.

How is this chapter useful?

For **transit managers** it is a resource for:

- Identifying issues relevant to vehicle design
- Identifying potential vulnerabilities of transit vehicles

For **security staff** it is a resource for:

- Exploring potential design solutions to improve security

7.1 Introduction

Vehicles are the foundation of every transit system; they provide the core service on which transit is based and are the primary interface with the public. As the most visible and most accessible elements of a transit system, vehicles are extremely exposed to possible attack. Transit system

⁴⁰ Safety and security regulations for commuter rail services are established by the Federal Railroad Administration (FRA), and are beyond the scope of this report.

designers need to recognize this and determine how best to protect their vehicles against potential threats.

To support system decision makers and vehicle designers in this effort, this chapter presents information on the following aspects of vehicle design and security:

- General security issues for transit staff
- [Potential security threats](#) to transit vehicles
- A comprehensive set of practical [design considerations](#) when preparing procurement specifications or fleet retrofits
- [Vehicle design considerations](#) relevant to security
- [Lessons learned](#) from national and international vehicle security events

7.2 General Considerations

This section presents several issues for transit staff to take into account when considering security during the planning of vehicle design: vehicles in relation to the overall system, vehicle role, accessibility, and vehicle operator protection.

7.2.1 Vehicles in Relation to the Overall System

Vehicles operate as part of larger transit systems that have many components, such as stations, stops, tracks, and roadways. A vehicle's overall design must result in the vehicle being physically and operationally compatible with the other elements of the system. Likewise, the vehicle's security-related design elements must be compatible with facility elements, during both everyday operations and emergency situations.

The security of vehicles affects the security of facilities, and vice versa. While this chapter presents design-oriented considerations specific to transit vehicles, agencies should be aware that attacks on vehicles can have serious consequences for transit facilities and that incidents occurring in transit stations will also impact the vehicles. Security-related design concerns for infrastructure are addressed in [Chapter 6: Infrastructure](#), but it is worthwhile to keep in mind the relationships between transit vehicles and the following types of infrastructure:

- Tunnels and elevated structures
- Stations, including intermodal facilities
- On-street transit stops
- Vehicle maintenance and storage facilities
- Administrative facilities, including operations control and communications centers

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- Signals and track and power
 - Power substations

Transit agencies will benefit if vehicles are designed to promote the security of both the vehicles themselves and the other components of the transit systems.

7.2.2 Vehicle Roles

When transit agencies undertake security planning, they should consider their vehicles from three perspectives:

- **Target.** Transit vehicles are likely targets for terrorist attack because they often carry large numbers of people and are highly visible. Agencies should consider treating vehicles as assets to be guarded at two levels, the vehicles themselves and the people they carry.
- **Weapon.** A transit vehicle provides an excellent means of delivering a terrorist's weapon to a target, because of its public nature and the areas in which it will typically travel. Terrorists can plant a device on board—and then detonate it when the vehicle reaches the intended target, such as a transit station.
- **Means of Response.** After an attack has occurred, transit vehicles can comprise a significant element of emergency response: they can evacuate large numbers of people from dangerous areas, and can move emergency responders and equipment as needed. Accordingly, vehicles need to remain functional after an attack.

7.2.3 Accessibility

By their nature and purpose, transit vehicles are designed to be accessible to many people at a time and are therefore difficult to secure. Their design must facilitate quick boarding and exiting, with few impediments to passenger flow through the vehicle. Vehicles are often accessed from uncontrolled public spaces (especially buses), and it is impractical to pre-screen passengers entering a vehicle.

These factors make it difficult to implement measures that establish strong security on a vehicle. The design must often rely on passive elements to improve on-board security.

7.2.4 Vehicle Operator Protection

In most transit systems, drivers operate vehicles autonomously. For this reason, the safety of the operator and his/her ongoing ability to operate the vehicle are critical; the operator must be able to bring the vehicle safely to a stop after an incident, to remove the vehicle (and its passengers) from the immediate area of a threat, or to use the vehicle to support emergency response activities. All of

this is subject to the operator surviving an attack on the vehicle and the control systems remaining functional.

For this reason, it is helpful to include design elements that will protect the operator in the event of an explosion, fire, and other types of attack.

7.3 Potential Threats to Transit Vehicles

Transit vehicles are an extremely visible element of most cultures, and are easily accessible to potential attackers. For these reasons, they are attractive targets for a terrorist attack intended to inflict civilian injuries, disruption of service, disruption of emergency response capabilities, and general panic. They may be the primary target of an attack, may be damaged in an attack on a transit facility, or may even be used as a means of delivering a weapon to an attack site. While it is acknowledged that transit facilities and vehicles impact the security of one another, this section focuses only on threats to vehicles.

Scenarios of potential threats to transit vehicles include:

- Explosives placed on or under a vehicle
- Armed assault on board a vehicle
- Chemical, biological, or radiological release on a vehicle
- Attack by another vehicle
- Derailment (rail vehicles only)

7.3.1 Explosives Placed on or Under a Vehicle

This scenario involves the detonation of an explosive device on board a vehicle while it is in service. Recent terrorist attacks abroad on buses and trains have used this type of attack to harm both passengers and non-passengers, as the explosions sent shrapnel throughout the surrounding area.

In these attacks someone brings the explosives on board or plants the explosives on or under the vehicle, either while the vehicle is in operation or when it is parked at a maintenance/storage facility. The on-board explosive device might be conventional, or could be a 'dirty bomb' designed to spread contaminants (see Section [7.3.3](#)). In a subway system, an explosion in an underground tunnel could have catastrophic impacts on both the riders and the ongoing operation of the system.

7.3.2 Armed Assault On Board a Vehicle

This scenario involves a passenger attacking fellow passengers or the operator on the bus or train, either when the vehicle is stationary or underway.

There are several recent examples of this type of attack occurring on buses, including an assault on a Greyhound bus driver while the vehicle was in service. Most of these attacks have been crime-related rather than terrorist-related.

This type of situation could develop into a more serious incident involving the attackers barricading themselves on the vehicle, possibly with hostages. Attackers may even hijack the transit vehicle with the operator and passengers on board.

7.3.3 Chemical, Biological, or Radiological Release on a Vehicle

The release of a chemical, biological, or radiological substance on a vehicle could cause significant casualties. The impacts from such an event might be limited to on board the vehicle, or could disperse to the surrounding area, depending on the ventilation of both the vehicle and the area in which the release occurs.

In addition to the injuries incurred, these attacks also disrupt service for extended periods while the vehicles and immediate areas are contained and decontaminated to prevent further consequences. The release of sarin gas in the [Tokyo](#) subway in 1995 is an example of this type of attack. A substance can be released surreptitiously, either in person or via a remote device, or through the use of a “dirty bomb” that spreads contaminants in an explosion.

7.3.4 Attack by Another Vehicle

This scenario involves the intentional crashing of another vehicle into a bus or train to cause physical damage, injuries, an explosion, or fire. An alternate scenario would be for a terrorist to pull up next to the target in a vehicle carrying explosives and then detonate the explosives.

This type of attack has occurred several times in [Israel](#). It is virtually impossible to prevent this type of attack on a bus because they travel on public roadways; rail vehicles whose rights-of-way are parallel to roadways or run beneath overpasses are also at risk.

7.3.5 Derailment (Rail Vehicles Only)

One of the biggest dangers for rail vehicles, short of an explosion, is from derailments or rollovers. By sabotaging either the vehicle itself or a section of track, a terrorist can initiate a chain reaction along a train of cars, pulling them all from the tracks. These incidents often result in numerous casualties, and require specialized equipment to clear the accident site and enable transit service to resume.

7.4 Design Issues

Many of the design issues discussed in this chapter will be more effective when combined with operational actions that are needed to ensure a robust integrated system of security. For details on operational improvements and recommendations related to safety and security, refer to the FTA Web site at www.transit-safety.volpe.dot.gov.

Security-oriented design considerations for transit agencies to take into account when preparing their procurement specifications or retrofitting their fleet include the following:

- CPTED
- Competing concerns
- Life-cycle timing of technology improvements
- Existing safety and security standards
- Vehicle design trends

7.4.1 CPTED

In many cases, measures taken to improve the day-to-day safety of the transit system against crime can result in improved security against larger threats, such as terrorism. The FTA is promoting the use of CPTED principles to help transit agencies reduce the incident of crime. CPTED is based on the idea that proper design and the effective use of the built environment can lead to a reduction in the number of crimes committed against passengers and the transit agency. For additional information on CPTED refer to [5.1.5.1](#) and to www.cpted.com.au or www.cpted-watch.com.

Other improvements being incorporated into vehicle designs to help reduce or mitigate criminal acts, such as the installation of CCTV or driver shields, may also help to reduce or mitigate the effects of a terrorist attack, or to preemptively discourage attacks.

7.4.2 Competing Concerns

A number of major variables should be addressed during the vehicle design process; balancing these competing concerns presents a challenge. Proposed design considerations that may improve one variable may have a negative effect on other variables. Transit vehicle designers need to decide which factors take priority and where compromises need to be made. These variables include:

- Safety
- Reliability
- Accessibility
- Purchase cost of the vehicle

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- Maintenance cost over the life of the vehicle
 - Weight of the vehicle

Safety, Reliability, and Accessibility

Safety of the vehicle passengers and operators is the paramount consideration for vehicle designers. A transit agency will be reluctant to include a feature that reduces vehicle safety. Unfortunately, safety and security sometimes conflict with each other in terms of their design requirements. For example, security might benefit from locked windows, but such windows might prevent passengers from evacuating a vehicle quickly during an emergency.

A transit vehicle must be designed so that it can operate in various urban and rural environments, make frequent stops, move large numbers of people, and provide accessibility to all. The nature of transit may limit the use of some security features that have proved effective in stationary facilities such as airport terminals.

Purchase and Maintenance Costs

Cost effectiveness is key to suggesting design considerations that are security oriented. Transit agencies are faced with difficult choices—between reducing the total cost of a vehicle, and adding technology or design features that contribute to the safety and security of a vehicle. It would be unrealistic to expect that transit agencies will be able to incorporate new design modifications unless they are affordable and multi-faceted. One key to ensuring that security systems are more widely used in vehicles is to make them serve additional functions, such as improving safety and crime prevention, or reducing maintenance costs.

Features should also be easy and inexpensive to maintain. Components that have high ongoing maintenance costs will be more difficult to justify.

Weight

Another trade-off involves the total weight of a vehicle. It is crucial to keep the weight of a vehicle within certain limits to minimize stress on the axles and wheels, as well as on streets or rail beds. Since 1982, the U.S. federal government has imposed a weight limit of 20,000 pounds for a single axle and 34,000 pounds for a tandem axle for buses, although federal legislation in 1992 allowed states to exempt certain classes of transit buses from these weight limits.

Given that many transit buses already exceed U.S. federal axle weight limits, any security design elements that add to the total weight of the vehicle must be evaluated against the need to keep the total weight of the vehicle below a certain threshold, or the need to compensate by reducing the weight of other vehicle components.

7.4.3 Life Cycle Timing of Technology Improvements

There are at least three points in the life of a transit vehicle when new technology can be incorporated into the vehicle to help improve security:

- New vehicle purchase
- Major overhaul
- Minor overhaul

New Vehicle Purchase

The ideal time for incorporating security design features is during the new vehicle design and purchase process. The technical specifications for a new procurement can incorporate design features that enhance security, and can be included in the overall design of a new vehicle fleet purchase. Other vehicle design elements can be modified to accommodate or even support security-oriented features.

Unfortunately, the life cycles of transit vehicles make these opportunities infrequent. According to the American Public Transportation Association (APTA), the typical lifespan of heavy rail and light rail vehicles is between 20 to 40 years, and buses have an average lifespan of 12 to 18 years. The lifespan of rail cars is significant because the likelihood that existing transit systems will change out an entire rail fleet is improbable. The most common approach is to replace a portion of the fleet with a new purchase and retire the oldest or most mechanically unreliable of the existing fleet. This means that relatively easy and inexpensive retrofits on existing rail car fleets are most feasible for transit agencies in the United States today.

Major Overhaul

The main purpose of a major overhaul is to address reliability issues and safety of operations activities, but security measures can also be incorporated. On average, rail vehicles receive a general overhaul (complete, heavy) approximately every 12 years, and buses receive one after 7-10 years. There are, however, different time and mileage criteria applied to each vehicle system and its related components and sub-components, so schedules may vary. There is also a great deal of variation among transit agencies on their major overhaul schedules.

Major overhauls provide an opportunity for extensive improvements to be made, including those intended to promote security. Large portions of the vehicle can be disassembled or modified, as needed.

Minor Overhaul

Minor overhauls occur on a more frequent interval and are often related to a specific component. At some agencies, these are called service and inspection cycles. Small-scale security design features can be incorporated during these maintenance functions, and minor safety modifications can also be made when cars are brought in for a particular cycle of maintenance. Industry experts advise that

safety aboard existing vehicles can be enhanced significantly by performing simple tasks during a minor overhaul, such as properly securing equipment cabinets in walls and under seats.

7.4.4 Existing Safety and Security Standards

When evaluating potential design improvements to a vehicle, it is important to recognize that standards already exist that address the material composition of the car interior, including walls, floor, ceiling materials, seats, lighting fixtures, and windows. Many guidelines that agencies might consider have already been established as standards within the industry by Standards Development Organizations (SDO).⁴¹

APTA representatives have noted that historically the focus of standards development for transit vehicles has been on maintenance and inspection issues rather than on design criteria. For example, a review of recent literature on flammability and toxicity of materials used in rail vehicle construction indicates that room for improvement or at least for consistency across the industry exists.⁴² Across the United States, there is inconsistency among rail vehicle procurement specifications and their testing. In general, European standards may be more stringent than U.S. standards for flammability and toxicity.⁴³

Organizations that have produced standards and guidelines that are applicable to transit vehicle design and procurement include the following:

- The United States government issues regulations that are listed in the Code of Federal Regulations (CFR). These regulations are developed to comply with the legislative mandates passed by Congress and signed into law by the President. The federal government also issues recommended practices, which are non-regulatory, but provide an awareness of issues and tools to address them.
- APTA facilitates the development of standards for both rail and bus vehicles. A chapter on vehicle design criteria is included in the 1981 APTA Guidelines for the Design of Rapid Transit Facilities, and APTA also produced the Standard Bus Procurement Guidelines. For more information, refer to www.apta.com.
- American National Standards Institute (ANSI) is a private non-profit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system.

⁴¹ Regulations and rules (that have been promulgated) are the only requirements that can be and usually are legally enforceable.

⁴² *Fire Safety Analysis for Rolling Stock*, Mark A. Davis; *Material Toxicity Test Issues in Rolling Stock Procurements*, Mark Davis, Balaji Krishnamurthy, Peter Katsumata.

⁴³ *Comparisons of American, British, French and German Standards for Flame, Smoke and Toxicity of Elastomeric Materials*, Rick Hopf, Carol Stream, Emily Witthaus.

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- Institute of Electrical and Electronics Engineers, Inc. (IEEE) is a technical professional association that develops standards applicable to rail vehicles, in addition to other engineering areas.
 - American Society for Testing Materials (ASTM) is a non-profit organization that provides a forum for the development and publication of voluntary consensus standards for materials, products, systems, and services.
 - American Society of Mechanical Engineers (ASME) is an educational and technical organization setting many industrial and manufacturing standards.
 - National Fire Protection Association (NFPA) develops consensus codes and standards intended to minimize the possibility and effects of fire and other life safety risks. NFPA 130 covers fixed guideway transit fire safety from a systems approach, including provisions for the fire and life safety of trainways and stations, as well as vehicles.
 - FTA Recommended Fire Safety Practices Rail Transit Vehicle Material Selection specifies certain flammability and smoke emission tests and performance criteria. This has provided a tool for rail transit agencies to screen out particularly hazardous materials, which could rapidly ignite and spread fire or emit large quantities of smoke. FRA issued passenger rail equipment fire safety regulations in 1999 and 2002.
 - Society of Automotive Engineers (SAE) develops engineering design and safety standards for the motor vehicle industry, including buses.

In addition, many transit properties supplement published standards with more stringent requirements, based on their experience and determined needs. For additional information about specific standards, refer to Appendix F2, “Codes Standards, Regulations: Bus Vehicles.”

7.4.5 Vehicle Design Trends

There are several recent trends influencing transit vehicle design. While none is directly related to security, all influence the security of vehicles indirectly. These include:

- Modular components
- Accommodations for riders with disabilities
- Alternative bus fuels

7.4.5.1 Modular Components

To reduce the initial purchase price of a vehicle and the eventual maintenance costs, transit agencies are working with vehicle manufacturers to design the major vehicle components using modular components. This approach allows for the quick removal and replacement of modules and reduces repair and maintenance costs.

Modularization also provides a safety benefit. For example, modular seats have fewer small parts, which have the potential to become shrapnel and injure passengers and bystanders in the event of an explosion. A modular design also facilitates the replacement of certain components of a vehicle with new components that are more security-supportive.

7.4.5.2 Accommodations for Riders with Disabilities

The Americans with Disabilities Act (ADA)⁴⁴ and accompanying regulations (49 CFR Parts 27, 37, and 38) require that transit vehicles provide certain features to assist people with disabilities. A major focus of these regulations is to provide people who have ambulatory restrictions with access to vehicles, so that they are able to enter and exit a vehicle via a low floor or mechanical lift. Another key focus is to provide audible announcements of stops for the visually impaired.

ADA regulations have resulted in transit agencies moving toward vehicle designs that use low floors and designs that incorporate automated stop announcements using some type of automated vehicle locator system, usually based on the global positioning system (GPS) or transmitters embedded in the rail bed.

Public address systems help security by improving the vehicle operator's ability to communicate with passengers. The physical design elements intended to assist passengers with limited mobility, however, may preclude the installation of some security-oriented design features.

7.4.5.3 Alternative Bus Fuels

Different types of fuels are used to power buses in the mass transit fleets. Since the 1950s, diesel has been the predominant fuel for public transit buses that are 30 feet in length or longer, making up approximately 88 percent of the existing national transit bus fleet.

While diesel is the predominant power source, transit agencies have been increasing their purchases of alternative fuel vehicles, typically because of air quality concerns. According to APTA,⁴⁵ in previous years, compressed natural gas (CNG) -powered vehicles made up the greatest percentage increase in the vehicle fleet. In 2002, CNG-powered buses made up almost 10 percent of the overall transit bus fleet, as shown in Figure 7-1.

⁴⁴ <http://www.usdoj.gov/crt/ada/adahom1.htm>.

⁴⁵ APTA 2001. APTA Table 79, New Bus and Trolleybus Market by Power Source. For current data, see <http://www.apta.com/research/stats/bus/busmktpower.cfm>.

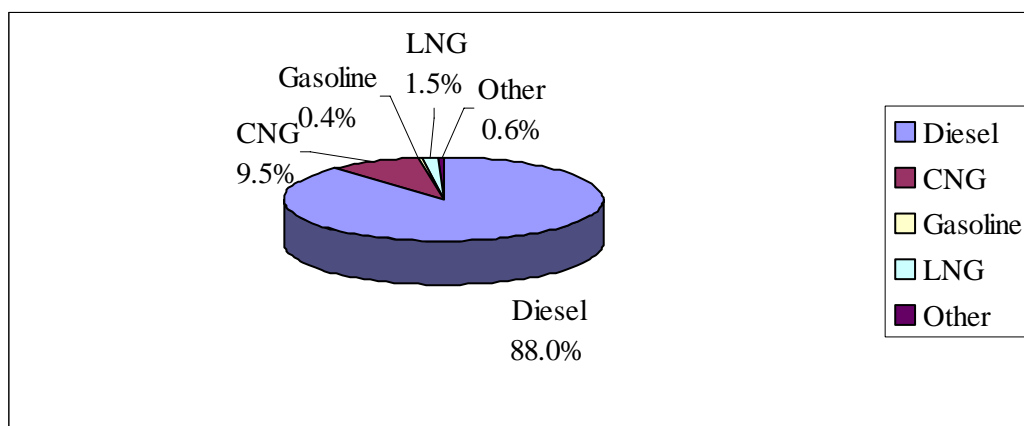


Figure 7-1. Percent of 2002 Transit Bus Fleet By Power Source

The trend moving away from diesel because of environmental air quality concerns appears to be continuing (APTA 2001). For buses either delivered or on order for the years 2001-2002, diesel-powered buses made up only 73 percent of the total market, with CNG-powered buses increasing to around 18 percent of the market. According to an APTA report, CNG-powered buses made up approximately 21% of potential orders for new buses that identified a fuel source for the years 2003 through 2008.⁴⁶

This trend is significant for safety reasons. The two types of fuels react very differently to explosions and fire. While diesel fuel is more likely to spread into a pool and burn for a longer period of time, a CNG-powered system has a higher propensity for combustion when exposed to flame because of the high pressure in the system and the gaseous state of its contents. More recently, however, several operators have adopted or considered hybrid vehicles, which introduce fewer air pollutants and offer more versatility than vehicles powered solely by diesel fuel.

However, use of diesel hybrid power is beginning to rise. APTA reports indicate that dual-powered vehicles make up approximately 17% of orders in January 2004. Potential orders, though small, nearly double the amount of vehicles built in 2003. Such vehicles improve many of the environmental concerns posed by vehicles powered solely by diesel fuel, and do not carry the safety concerns associated with CNG-powered vehicles.

7.5 Suggested Security Strategies for Vehicle Design

In considering how to protect their vehicle fleets, transit agencies can incorporate a number of physical features and design elements to hinder a potential attack or to reduce the consequences of a

⁴⁶ APTA 2001. APTA Table 79, New Bus and Trolleybus Market by Power Source. For current data, see <http://www.apta.com/research/stats/bus/busmktpower.cfm>.

successful one. Agencies are reminded that these are suggested strategies only and each agency should determine which best suit the current and future needs of its system.

Lessons learned from prior events suggest that the following security strategies will help protect the vehicle fleet:

- Limit the ability to place or hide explosives on or under vehicle
- Improve the ability to see into and out of vehicle
- Reduce the damage that would result from an explosion
- Reduce the damage that would result from a fire
- Reduce the damage that would result from contaminants
- Enhance emergency egress through doors and windows
- Protect the driver from physical threat
- Network the vehicle with the OCC
- Enable communications between the vehicle operator and passengers
- Secure the vehicle from theft/unauthorized operations

Each strategy is summarized in the following subsections.

For more details on security strategies for buses, refer to [Table 7-1](#); for rail vehicles, see [Table 7-2](#). Each table includes information about design features, as well as the cost, timing, and difficulty of installing such features. These tables should help transit agencies make informed decisions about which measures are appropriate or feasible for their particular circumstances. Note that each table was prepared by separate panels of industry experts from the bus and rail vehicle industries, and while they contain similar data, there are slight differences in the types of information presented.

7.5.1 Limit the Ability to Place or Hide Explosives

One function of transit vehicles is to allow passengers easy access into and within the vehicle and to provide space for passengers to carry and store packages during their ride, but agencies must balance these needs against safety concerns when designing a vehicle.

Compartments

Compartments both inside and outside the vehicle should be lockable and designed to prevent unauthorized access to on-board systems and mechanical components.

Many older vehicles have no locking devices for compartments, but several large transit agencies are now specifying that their new vehicles must include locks for their major compartments, including those for fueling, storage, engine, electrical wiring, and HVAC. One solution is to equip the major access doors with locks requiring a specialized tool to open. A more secure method would require the use of a key to open the compartments, but this can present operational and maintenance

problems. The interior of a vehicle should also be designed to reduce sheltered spaces where a package containing an explosive device or contaminants could be hidden from public view.

Detection Systems

Sensor/pager systems can be installed to detect dangerous substances, such as radioactive or bio-hazardous material, and alert the operator when the vehicle has been contaminated. The FTA is currently working on a prototype of a stationary detection system under the PROTECT program. PROTECT is intended to provide timely and accurate information about airborne chemical attacks in a station or tunnel. Adapting such systems to operate in vehicles presents significant technological challenges, and the cost of these systems is currently too high for most transit agencies.

7.5.2 Improve Visibility Into and Out of Vehicle

In the event of an incident on board a transit vehicle, responding law enforcement and emergency response agencies need to be able to assess the situation as quickly and as easily as possible. Their ability to see what has taken place in the vehicle, or what is currently happening, will enable them to respond in a manner that helps protect both their own safety and that of the transit passengers.

Similarly, improving a vehicle operator's ability to see what is taking place around the vehicle enables the operator to respond more quickly to impending threats and developing situations. While buses are often equipped with side view mirrors (and sometimes CCTV) to enable the driver to see all four sides of the vehicle, most rail transit vehicles do not have this feature and it may be difficult for an operator to assess what is taking place near the rear of the train.

Techniques for improving visibility into and out of transit vehicles include:

- Maximizing window coverage to the most reasonable extent (subject to conflicting structural and safety requirements).
- Locating windows strategically to provide important fields of view, and eliminating "advertising wraps" on the exteriors of windows that prevent people from seeing into the vehicle.
- Including on-board CCTVs; some buses already have CCTV installed to provide rear-facing views of the vehicle's exterior; adding these to additional vehicles would improve operators' ability to assess potential threats and operate the vehicles more safely.
- Design and selection of materials that minimize reflection/glare.

7.5.3 Reduce Damage from an Explosion

While it may be unrealistic to think that a vehicle can be made "bomb proof" or "bomb resistant," several design elements can improve a vehicle's ability to reduce the damage that results from an on-

board or nearby explosion. This may even enable the vehicle to maintain at least basic operating capacity in order to evacuate the area being attacked (assuming the device was not on board the bus), and may protect the passengers on board.

Reinforcing key elements of the vehicle is a logical first step in improving blast resistance. Stronger elements may enable a vehicle to maintain structural integrity and prevent catastrophic collapse of the vehicle body. Stronger body components are less likely to fragment in an explosion, and can shield occupants from flying debris. Selection of structural materials such as stainless steel may also increase strength and temperature of phase change (i.e. melting temperature).

Windows

One of the biggest concerns is windows, because glass shatters more easily than other materials and shards can injure nearby people. Transit agencies can consider selecting windows constructed of safer materials that are more resilient and shatter into fewer pieces.

Modular Seating

Modular seating can also offer safety benefits; it is constructed of larger components, with fewer small pieces to become potential shrapnel in a blast.

Fuel Tank

On buses, the fuel tank is one of the most dangerous components because of the large volume of fuel stored in it. Fuel tanks for natural gas are usually placed on the top of a vehicle where they are less vulnerable; pressure-release devices have been designed to release the fuel at the top of the vehicle to direct it away from any possible ignition sources on the bus.

Current standards for alternative fuel containers are covered in ANSI standard NGV2. Transit agencies can consider strengthening fuel storage compartments against punctures, although this would likely add to the overall vehicle weight.

7.5.4 Reduce Damage From a Fire

In the event of a fire, there are a number of design measures that can minimize the damage and assist with response efforts. This can be critical to protecting vehicle occupants from flames and providing them with enough time to evacuate the vehicle. Note that many of the measures used to reduce blast damage assist with mitigating fire damage as well.

Vehicle Materials

While there is no completely non-combustible, non-toxic material in existence, certain materials will hinder fire spread, smoke emission, and the release of toxic gases. These types of materials should be used throughout the vehicle to the greatest practical extent, balancing their benefits against other criteria such as durability and cost. All materials in the passenger area should comply with existing

fire safety standards (ASTME162 and E662). Vinyl seat coverings and foam seat padding should meet Federal Specifications CCC-A 680a. Seating upholstery should meet the requirements for textiles specified in Federal Aviation Regulations 25.853(b).

Firewall Barrier

A firewall barrier to prevent any flame propagation into the passenger area should separate the passenger area from major mechanical elements and fuel storage compartments. On rail vehicles, for example, ply metal floors are commonly used to isolate the passenger area from equipment beneath the floor. The 1984 FTA Recommended Fire Safety Practices require that the vehicle floor stay intact for a nominal time period of not less than 15 minutes, and most rail operators have their own performance criteria that exceed this specification.

7.5.5 Reduce Damage from Contaminants

In the event of a chemical/biological/radiological attack in which contaminants are intentionally released, the vehicle should be designed to limit the effects of those materials. This approach needs to take into account that such substances can be in solid, liquid, or gaseous form.

Contaminant Spreading

The first consideration is how to limit the spread of the dangerous substances. For example, aerosol contaminants can be circulated by the vehicle's HVAC system. The HVAC may also vent outside the vehicle, spreading the substance and contaminating surrounding areas. Providing a manual HVAC "shut down" button may enable the vehicle operator or emergency responders to deactivate the system in time to limit contamination to a certain section of the vehicle or to the interior of the vehicle.

Cleanup/Decontamination

Vehicles can also be designed to facilitate the required cleanup and decontamination process that follows this type of attack. An interior design with smooth surfaces is easier to clean and disinfect. Where possible, non-porous materials can be used to reduce the absorption of toxic substances, making it easier to ensure that all contaminants have been removed.

7.5.6 Enhance Emergency Egress

In an emergency, vehicle operators and passengers should be able to exit a transit vehicle quickly and easily. This can be critical to preventing further casualties in the aftermath of an attack.

Door Releases

Manually operated emergency door releases should be considered for all vehicle doors, with the door release interconnected to the braking system and the accelerator to bring the vehicle to a stop when the door release is activated. The emergency door release device should be visible to passengers, but secured behind a protective cover to prevent accidental activation.

Passenger Windows

The passenger windows, particularly on buses, should be designed to allow for emergency exit, in compliance with FMVSS 217. Currently, some rail transit professionals consider it very difficult for an average person to push out a rail transit vehicle window. The redesign of emergency windows might be considered to ensure that quick removal is possible by an average-sized person under duress.

7.5.7 Protect the Driver from Physical Threat

The vehicle operator is a transit agency's front line of defense against attack and for conducting emergency response activities. The safety of the operator and his/her ongoing ability to operate the vehicle are critical; the operator must be able to bring the vehicle safely to a stop after an incident, to remove the vehicle (and its passengers) from the immediate area of a threat, or to use the vehicle to support emergency response activities. All of this is subject to the operator surviving an attack on the vehicle.

On heavy rail vehicles, the driver is usually isolated from passengers in a secured compartment. In buses and light rail vehicles, however, the driver typically sits in the main body of the vehicle. While these operators need to be able to interact with passengers, threats against the driver can be minimized through vehicle design.

Compartment Barrier

Some transit agencies are incorporating a barrier around the bus driver's compartment, similar to those found in light rail vehicles, into the design of new vehicles. The barrier can extend from below seat level to near the ceiling and can be made of metal or polycarbonate material. This barrier is hinged so the vehicle can be operated with the barrier either closed or open, at the discretion of the driver.

Compartment Shielding

Shielding around the operator's compartment can also protect him/her from the effects of a bomb blast or other form of attack on the vehicle. This would help the operator retain the ability to move the vehicle to a safer location and to activate any on-board emergency systems after an attack.

7.5.8 Network the Vehicle with the OCC

A crucial element in detecting, delaying and responding to a crisis involving a transit vehicle is a reliable communications link between the vehicle and the OCC, which can enable vehicle operators and operations staff to share accurate information and make well-informed decisions.

Current communications technology on most transit fleets consists of a radio connection between the vehicle and operations, but there are additional possibilities.

Automatic Vehicle Locator (AVL)

An automatic vehicle locator (AVL) system allows the OCC to remotely track and monitor the position of a vehicle. AVLs are more relevant for buses than rail transit systems. In addition to security considerations, AVLs can improve a transit agency's operational capabilities. When linked with a GPS system, a transit agency can track vehicle on-time performance in real time and make on-board stop and location announcements, as required by ADA.

Mobile Data Terminals (MDTs)

Mobile data terminals (MDTs) installed in conjunction with an AVL system enable the OCC to communicate electronically with the vehicle driver. An OCC can send messages electronically to the fleet about an in-progress incident, or contact individual drivers to alert them to a specific problem. Currently, MDTs are used primarily by agencies operating paratransit services to schedule real-time assignments of trips.

Silent Alarm Systems

A silent alarm system can be as simple as a panic button that flashes lights on the front of the vehicle or as complex as a link with the AVL system to allow for the remote tracking of a vehicle by the OCC or the police. Another option is CCTV systems. Where these systems have been installed on vehicle fleets, they have been primarily intended as part of a safety program to help deter crime. However, a CCTV system can be set up to perform a variety of functions, such as recording an incident for later viewing, sending images to a control center, and streaming live video from a vehicle.

7.5.9 Enable Communications between Vehicle Operator and Passengers

During an emergency, it is extremely helpful for transit agencies to be able to keep their passengers up to date on the current situation and to provide instructions as needed. Likewise, transit vehicle passengers can inform transit staff of emergency situations taking place on the vehicle; this is particularly relevant for heavy rail systems, where large portions of the interior are not directly viewable by on-board staff.

On-Board Public Address Systems

On-board public address (PA) systems can be used to inform riders about service status. More importantly, during an emergency operators can use the PA system to provide instructions to passengers such as when evacuating a vehicle. Many transit systems already have this type of system in place, but not necessarily on all types of vehicles.

Emergency Call Boxes

Emergency call boxes in vehicles enable passengers to inform transit staff of security-related incidents taking place. This greatly improves security by involving riders in passive surveillance and enabling them to report incidents to transit staff quickly without leaving the site.

7.5.10 Secure the Vehicle from Theft/Unauthorized Operation

Traditionally, transit vehicles do not require any type of key to operate. For most transit buses, a driver simply activates the master run switch and then activates the engine start button.

“Smart” Card

To prevent the operation of a vehicle by an unauthorized person, installation of a key system or a “smart” card system can reduce the threat of vehicle theft. If a key system is used, a transit agency often uses one master key that operates a specific series of vehicles in a fleet. The smart card system could also provide a higher level of security by integrating the ability to start and operate a vehicle into a transit agency’s credentialing program for its employees.

Vehicle Design

Vehicle design can also help to prevent unauthorized access to the operator compartment. Lockable doors and, in the case of buses and some light rail vehicles, partitions keep attackers from gaining access to the control system, while also helping to protect the vehicle operator. These also reduce the likelihood of vandalism or sabotage to the control systems.

Table 7-1. Bus Vehicle Design Solutions

Design Consideration	State of Technology Maturity Scale of 1 (least mature) to 5 (most mature)	Cost Scale of 1 (low) to 10 (high)	Retrofit: New Buses / Overhaul / All
1. Networking of bus to operations control center			
Install automatic vehicle locator (AVL) system to allow bus operations to monitor bus location	3 – Has been deployed to various degrees widely. Multiple technologies used to determine location and transmit messages	Range of 6 to 10 – Requires significant investment and support infrastructure. High increment of system maintenance required	All
Install mobile data terminals (MDT) to allow for electronic transmission of messages	3 – Can be integrated into AVL systems. Wide variety of commercial technologies	Range of 4 to 8 – Wide variety of commercial technologies available. Less infrastructure and management	All
Utilize GPS to allow bus operations to track the vehicle location	4 – GPS is widely used and commercially viable. Communication technologies for data transfer must be integrated for command and control	Range of 3 to 10 – Varies based on functionality requirements. From stand-alone units to full system integration	All
Install silent alarm system (panic button) with connection to bus operations, bus destination sign, and police department	5 – Silent alarm features triggered manually are incorporated in most transit system radio systems. Typically linked to on-board exterior signage for emergency alert	Range of 1 to 5 – Has been done in a variety of ways. Simple to do on vehicle; compatible with most communication systems	All
Install CCTV cameras. Cameras can either record for later viewing or broadcasting of sample images live to a control center	5 – Mature technology widely available. Real time transmission of video information is not widely available. Concerns are data management and evidence chain of custody	Range of 3 to 5 – CCTV technology has a relatively low cost if information does not require wireless communication	All
Real time transmission of CCTV data	2 – Currently a number of communication approaches are being used to provide real time transmission of on-board video images to command and security personnel	Range of 8 to 10 – Cost is high since technology is new and firm commercial processes are still under development	All

Design Consideration	State of Technology Maturity Scale of 1 (least mature) to 5 (most mature)	Cost Scale of 1 (low) to 10 (high)	Retrofit: New Buses / Overhaul / All
2. Limiting ability to place or hide explosives/Securing compartment doors			
Design compartments (fuel, storage areas, engine, and others) to be protected against unauthorized access	5 – Mature; already available for most applications	Range of 1 to 3 – Various technologies and solutions can be employed	New
Design compartments to be locked by specialized wrench	5 – Commonly used in current production vehicles	Range of 1 to 2 – Cost is nominally different than standard hardware	All
Design compartments to be locked by key	5 – Can be specified on production vehicles	Range of 1 to 3 – Minimal cost differential	All
Reduce or fill spaces that could be used to hide foreign objects	5 – Traditionally included in bus	1 – No cost	New, Overhaul
Install radiological, biological or chemical detector pagers inside bus to detect presence of these materials. The pager could be connected with the OCC	1 to 3 –New technology for this application. Not widely deployed; however, a number of projects and field evaluations are underway	Range of 5 to 10 – Acquisition cost of ownership for these technologies will be significant	All
3. Reducing the damage resulting from a threat (explosion, hijacking, fire, etc.)			
Review fire resistant and fire retardant standards (ASTM E162-02a and E662-03) for interior fixtures	3 – Can be done easily in new vehicles	Range of 1 to 4 – Materials meeting these standards generally have moderate cost increase vs. non-compliant materials	New
Harden exposed wiring and fuel lines	4 – Requires very little development investment	Range of 2 to 6 – Wide range of cost based on various strategies to limit access	New, Overhaul
Install silent alarm system (panic button) with connection to bus operations, bus destination sign, and police department	See item below	See item below	All
Design so that external destination signs and lights are integrated with silent alarm to issue alert of an emergency situation	5 – Already incorporated in base design of electronic signage	1	N/A
Place vehicle number on roof of vehicle to enhance identification from above	5 – Commonly done	1	All

Design Consideration	State of Technology Maturity Scale of 1 (least mature) to 5 (most mature)	Cost Scale of 1 (low) to 10 (high)	Retrofit: New Buses / Overhaul / All
Harden windows to prevent shattering	5 – Typical bus glazing is safety glass or polycarbonate	Range of 1 to 3	New
Provide video surveillance system	4 – Widely available	Range of 6 to 10 – Systems without wireless communications are in wide use; integration with communication system adds significant cost	All
Ensure windows are free from any coverings and provide clear view in/out	5 – Many agencies have banned covering windows with advertising wraps	1– Low	All
4. Isolating the driver from physical threats			
Enclose driver compartment	3 – Deployed to varying degrees	5	All
Provide operator shield	3 – Deployed to varying degrees	5	All
5. Hardening fuel storage compartments			
Harden fuel tanks of alternative fuel vehicles against intentional attack	4 – Most gaseous fuels are contained in roof-mounted storage vessels with limited access	3	New
6. Enhancing emergency egress through doors and windows			
Install emergency door release to allow for manual operation of doors	4	1	All
Improve window release to facilitate easier emergency egress	5	1	New
Strengthen window to be more shatterproof in case of onboard explosion	5	3	New
7. Securing the vehicle from unauthorized operation			
Design ignition system to require a keyed switch in addition to master run switch to start bus	5	1	All
Design ignition system to operate with a smart card technology that only allows permitted users to start and operate bus	5	Range of 3 to 5 – Easily integrated in current vehicle designs	All

Table 7-2. Rail Vehicle Design Solutions

Asset Components	Design Solution	Level of Difficulty	Best for New Vehicle	Feasible as Minor Retrofit
Passenger Compartment				
Seats/Wall and Ceiling Panels/Flooring	Fire resistant material that is easy to disinfect	Medium		
	Widen aisles to allow easier emergency egress	High	X	
	Lock compartment containing under-seat electronics	Low		X
	Eliminate hiding places in car or on roof	Medium/High	X	
	Modularization of components	Medium/High	X	
	Fire extinguishers in all cars	Low		X
	Fire protective sealant applied to voids where wiring or piping penetrates the floor – arrests spread of fire and smoke through openings	Low/Medium		X (for smaller fleets)
Doors	Clearly indicate emergency-release mechanism*	Low/Medium		
Windows	Harden any glass to prevent shattering – window glazing	Low/Medium		X
	Pressure panels for blast dissipation/mitigation	High	X	
	Ability to open from inside or outside	Medium		
Lighting/Signs	Battery backup*	Low		
	Emergency lighting in every car*	Low		
	Light diffusers and photo-luminescent signs made of fire resistant material*	Low		
Emergency Response Systems/ Equipment	Install silent alarms and covert microphones	Medium/High		
	Install on-board cameras	Low/Medium		
	Enable remote OCC control of on-board cameras (with proper cyber security precautions)	High		
Public Address System	Battery backup	Medium		
	Intercom in each car that allows passengers to communicate with the train crew	Low/Medium		X

Asset Components	Design Solution	Level of Difficulty	Best for New Vehicle	Feasible as Minor Retrofit
Operator Compartment				
Train Control Equipment	Key to operate	Medium		
	Kill switch for power*	Low		
	System to track train location	Medium/High		
	HVAC shut-down if outside air is contaminated	Medium		X
	Include interior mirrors for driver to see activity in the vehicle	Low		X
	OCC remote control of train functions such as power (with proper cyber security precautions)	High		
	Ability to disable unused operator compartment when the other is in use*	Low/Medium		
Communications System, including Internal/External Message Sign Control	Channel fixed radios	Low/Medium		
	Hand-held radios	Low		X
	Panic button to signal OCC, possibly with covert mike for OCC to hear activities in the vehicle	Low/Medium		
	On-board PAs and passenger assistance link	Medium		
	Vehicle-to-OCC link not only radio-based where there are tunnels	Medium/High		
	Computerized automatic communications from train-to-wayside and train-to-OCC	High		
Door Controls	Door locks*	Low		
	OCC remote control of door control (with proper cyber security precautions)	High		
	Ability to release passenger doors in an emergency when loss of power occurs*	Medium		

Asset Components	Design Solution	Level of Difficulty	Best for New Vehicle	Feasible as Minor Retrofit
Car Body/Car Control				
Car body Design	Conduct blast analysis – design implications	High	X	
	Install radiological pagers on vehicle bodies (roofs)	Medium		X
	Barriers between cars that can contain blast resistance and fire from adjacent cars	High	X	
	Paint car number on roof to facilitate identification of railcar by police and others	Low		X
	Secure any equipment compartments, interior or exterior, to prevent tampering	Medium		X
HVAC	Install smoke-clearing ventilators	Medium		
	Install radiological pagers on cars	Medium		X
	Enable OCC remote control of HVAC system (with proper cyber security precautions)	High		
Emergency Sys.	Conduct blast analysis – design implications	High	X	
Misc. Electrical	Standards for lighting in the event of loss of power that specify auxiliary backup capability	Low		

* Indicates solutions that are already prevalent in most rail vehicles.

7.6 Lessons Learned from Past Events

The security of transit vehicles is a worldwide concern. These brief descriptions of events involving vehicles can provide some insight into the issues faced by transit designers and system administrators.

7.6.1 Jerusalem, Israel

Over the past three years, there have been 15 attacks on Israeli buses, killing over 130 passengers. On February 24, 2004, the Israeli Transportation Ministry began an in-service test of components of a new security system to better protect buses from on-board terrorist attacks. Israeli Transportation Minister Avigdor Lieberman stated, “This system will help us impede the wave of terrorist attacks. It is clear that no solution affords 100 percent security.”

In March 2004, five city buses in Jerusalem were equipped with portions of the system for a month-long evaluation period. The price of a turnstile, the most basic component, is approximately \$2,000. A more complete set of components may cost between \$20,000 and \$30,000 for each bus.

The system consists of several components that can be installed individually or as part of an integrated system. The components include:

- Turnstile at the entrance to the bus: the driver is able to lock the turnstile, preventing entry to the bus, until he is satisfied that the passenger poses no threat.
- Two-way intercom: the intercom allows the driver to question a passenger before boarding.
- One-way barrier at the rear door: the barrier allows a passenger to exit through the rear door but prevents anyone from entering.
- Armor-plated glass: the glass is installed in the front of the bus shielding the driver and front row passengers.
- Sensors at the front door of the bus to detect explosives: the sensor will set off an alarm near the driver when it detects explosives within one meter of the sensor.

The FTA is monitoring the evaluation (results have not yet been provided) of this bus security system experiment and will incorporate any relevant findings into future revisions of the bus security design program.

7.6.2 Daegu, South Korea

In 2003, a fire erupted in the subway system of Daegu, South Korea. This event tragically demonstrated the value of some safety precautions that are standard elsewhere. Semi-permanent

openings between cars in Daegu enabled fire to travel rapidly from car to car (barriers between cars are common in the United States). In addition, the doors in Daegu were not capable of manual operation from inside the vehicle, so that passengers inside could not open them, after the train crew closed and locked them.

7.6.3 Tokyo, Japan

In 1995, a terrorist group released sarin gas, a nerve agent, in multiple Tokyo subway trains during rush hour. Several passengers died, and over 1,000 people reportedly suffered symptoms from the attack.

As a result of the attack, one U.S. rail transit agency contacted during research for this report is now including a HVAC access button in their latest vehicle specifications. If the outside is contaminated, the HVAC can be shut down with the special button. In the case of bio-terrorism, the smoother the interior of a car, the fewer the components, and the simpler the design of the HVAC systems, the easier it will be to clean and secure the car after an attack.

7.6.4 New York, United States

Although not considered a terrorist attack, a widespread power outage in August 2003 enabled transit agencies in New York City and elsewhere to test their emergency preparedness. For example, when power was lost, low-voltage batteries maintained the emergency lighting, public address, radio, and intercom systems in NYC Transit (NYCT) vehicles. Manual override of door controls enabled the evacuation of vehicles during the power outage.