CHARACTERISTICS AND COMMON VULNERABILITIES INFRASTRUCTURE CATEGORY: SUBWAYS

Protective Security Division
Department of Homeland Security

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Preventing terrorism and reducing the nation's vulnerability to terrorist acts requires understanding the common vulnerabilities of critical infrastructures, identifying site-specific vulnerabilities, understanding the types of terrorist activities that likely would be successful in exploiting those vulnerabilities, and taking preemptive and protective actions to mitigate vulnerabilities so that terrorists are no longer able to exploit them. This report characterizes and discusses the common vulnerabilities of United States (U.S.) subway systems, which serve large cities and are characterized by high concentrations of people in closed environments that are vulnerable to attack.

SUBWAY CHARACTERISTICS

Common Characteristics

The transportation mode "subway" is sometimes referred to as Heavy Rail or Rapid Transit. Throughout the U.S., there are 14 subway systems consisting of more than 1500 route miles, over 1,000 stations, and approximately 10,500 subway cars. Approximately one-half of these subway stations are located underground. The New York City Transit Agency is the largest subway system in this country (64 percent of one-way trips, 58 percent of passenger miles, and half of the passenger stations), with more than 6,000 scheduled trains per day carrying over 3 million passengers. Transit agencies operating subways in the U.S.are as follows:

1. Atlanta, GA – Metropolitan Atlanta Rapid Transit Agency - MARTA
2. Baltimore, MD – Mass Transit Administration - MTA
3. Boston, MA – Massachusetts Bay Transportation Authority - MBTA
4. Chicago, IL – Chicago Transit Authority - CTA
5. Cleveland, OH – Greater Cleveland Regional Transit Authority
6. Los Angeles, CA – Los Angeles County Metropolitan Transportation Authority
7. Miami, FL – Miami-Dade Transit Agency
8. New York, NY – MTA – New York City Transit
9. New York, NY – MTA – Staten Island Railway
10. New York, NY – Port Authority of New York/New Jersey – PATH
11. Philadelphia, PA – Southeastern Pennsylvania Transportation Authority

12. Lindenwald, NJ – Port Authority Transit Corporation - PATCO
13. San Francisco, CA – San Francisco Bay Area Rapid Transit - BART
14. Washington, DC – Washington Metropolitan Area Transit Authority – WMATA

All subway cars (except those in Cleveland and small sections of a branch in Chicago and Boston, which are powered by overhead catenary) are powered by an electrified "third rail," with a 600-volt capability. The inclusion of this third rail requires that subways be separated from other traffic for safety reasons by an exclusive right-of-way that does not interface with automotive or other passenger or freight cars.

Subway systems are typically only one division of a transit agency. Bus, light rail, and commuter rail often operate as feeders to subway stations. Each agency usually has its own sworn police department or a dedicated unit of local law enforcement. However, contactors such as Wackenhut Corporation can also supplant transit agency security forces. In most instances, these operations are multimodal (subways, buses, commuter rail, light rail, and ferries), so police responsibilities often extend to all modes.

Because subways are located in metropolitan areas, an attack on the physical infrastructure of a subway will also impact other critical physical infrastructure sectors such as power, sewage, and communications. Determining the potential cascading and cross-sector consequences of an attack is difficult because facilities are owned by a variety of public and private entities. For example, a subway's control center might be a tenant in the floor of a building without access control to the floors above and below it.

Previous mass transit security efforts targeted criminal activities such as fare evasion, petty crime, and vandalism. Hardening measures include the use of locks, safes, and physical barriers to provide access control and secure property perimeters. Signage, improved lighting, elevator shaft coverings, piping ducts and vents, and power lines are other physical hardening efforts currently being undertaken. Access Control Systems (ACS) have advanced from manually operated locks to magnetic swipe card readers, employee badge identification systems, and vehicle management systems.

The primary focus of security efforts since September 11, 2001 has been the deployment of additional security personnel and security awareness training of front-line subway employees. Local law enforcement and additional security assets, such as K-9 units and special tactical teams, have been deployed to transit systems (in accordance with elevated national threat levels). Transit systems have consistently requested additional resources, security technology recommendations, and more timely intelligence. They are also conducting emergency drills with scenarios involving terrorist incidents. While security plans are being formulated, there is no verification that these plans are viable.

Passenger service is not offered 24 hours per day on most subway systems. Transit agency activity is eventful during the early morning hours (track work, dispatchers, car maintenance, training, and cleaning). Large track renewal projects are generally undertaken in the spring and summer months.

There are over 300,000 transit employees in the U.S. (not including contractors). The largest labor organization representing these workers is the Amalgamated Transit Union.

Common Components

To deliver power to the subway trains, an electrified third rail (elevated on insulated posts) runs beside the main track. Each traction wheel truck (2 traction wheel trucks per car) picks up electrical power via a set of external power shoes on either side of the truck. The power shoe usually rests on top of the third rail and slides along as the train moves forward. The third rail typically weighs 125 lb with a symmetrical cross section. The web of the rail is filled with aluminum bars to increase current carrying capacity.

Alternating current (AC) operates signals, station and tunnel lighting, ventilation, and miscellaneous line equipment. Direct current (DC) is used to operate trains and such auxiliary equipment as water pumps and emergency lighting. In New York City, the subway system has over 200 electrical-power substations that receive high- and low-voltage electrical current from the New York Power Authority. Those substations may receive about 30,000 volts from the power plants and then convert it for use in the subway.

Tracks run above ground, below ground, and at elevations. Bridges, elevated structures, and tunnels carry the subway cars. Each subway system usually has one tunnel ventilation system that is equipped with thermostats, remote electric surveillance and operations controls that allows the system to be used daily as well as in emergencies. During daily operations, a few fans are used depending on traffic, temperature and other parameters. More fans would be used during an emergency. Most systems are considering the addition of vent shafts placed 1,000 to 1,500 feet apart. These shafts will supplement explosion mitigation already in place by current ventilation shafts and portal openings.

The distance between the two rails is 4' by 8-1/2" inches, which is the standard track gauge for the General Railroad System for freight and commuter railroads. There are exceptions — a line in Philadelphia uses broad rail gauge (5' by 3"). Because of the degree of curvature, grade, and low clearance, specialized equipment must be used for track maintenance. Since subways were built around individual signaling and power configurations unique to each system, there is no interchange of equipment between different systems.

A track is divided into a series of electrically isolated sections. Each section has an insulated feed cable to take the traction current back to the substation, and a voltage is set up across the rails. As trains have metal wheels and axles, the train shorts the voltage — sending an indication that the track section is occupied when a train enters a track section.

Most subway track is welded rail. The rail is insulated in each direction, and there are usually 4 to 8 different frequencies available for train detection ranging from 2,100 Hertz (HZ) to 3,900 HZ. This results in low impedance so that the AC current does not enter adjacent track circuits. Throughout the system, heavy copper cables around the rails ensure low impedance at DC. In addition, a number of small aluminum boxes are centered between the rails. These are passive markers (circuits) that are used to convey the station stop position to the train. The markers are placed at intervals from the center of the station platform. Identical units are also used to convey grade information to the train. On the train, an amplifier couples to the marker and oscillates at the marker's frequency. The receiving antenna for the marker coils is usually located directly under the drawbar that connects the cars.

The length of a subway car ranges from 60 to 85 ft. Approximately 200 people can fit in a car. Two of the largest subway car manufacturers are Kawasaki and Bombardier. Typical subway trains are configured with 2 to 6 car sets, with cabs that are powered by traction motors at each end. The individual cars attach via a "coupler." Subway cars weigh less than their "light" rail counterparts. For example, the newest car used on Portland's light rail system weighs 109,000 lb empty as compared with a San Francisco subway car that weighs 63,000 lb empty. Older subway cars are frequently refurbished and placed in service on lines with less traffic. Components of a subway car are shown in the schematic in Figure 1.

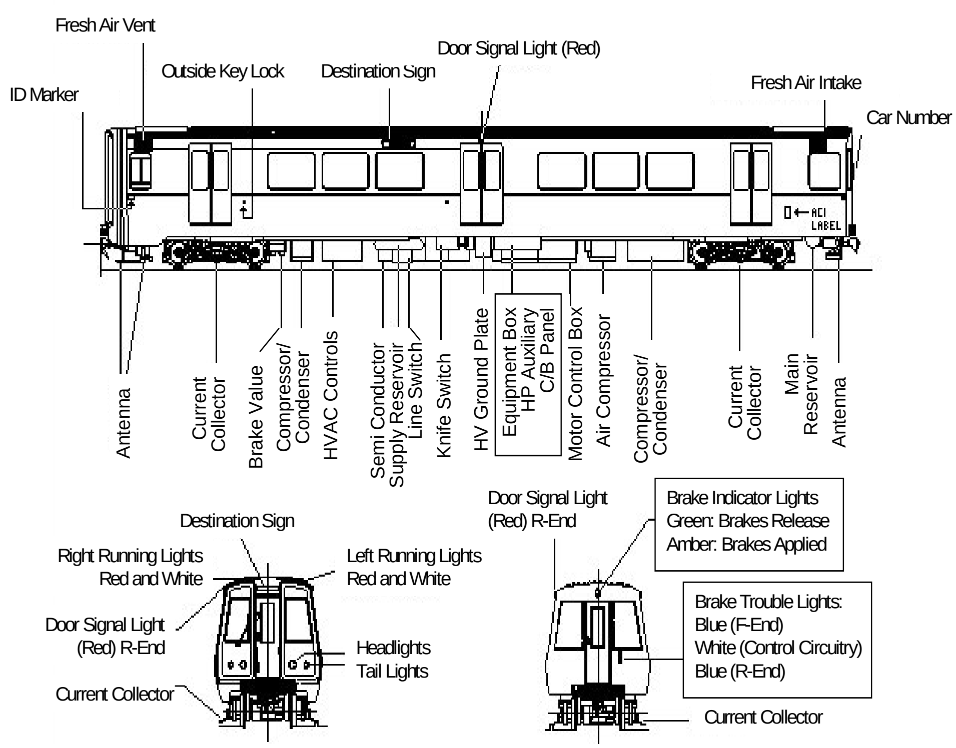
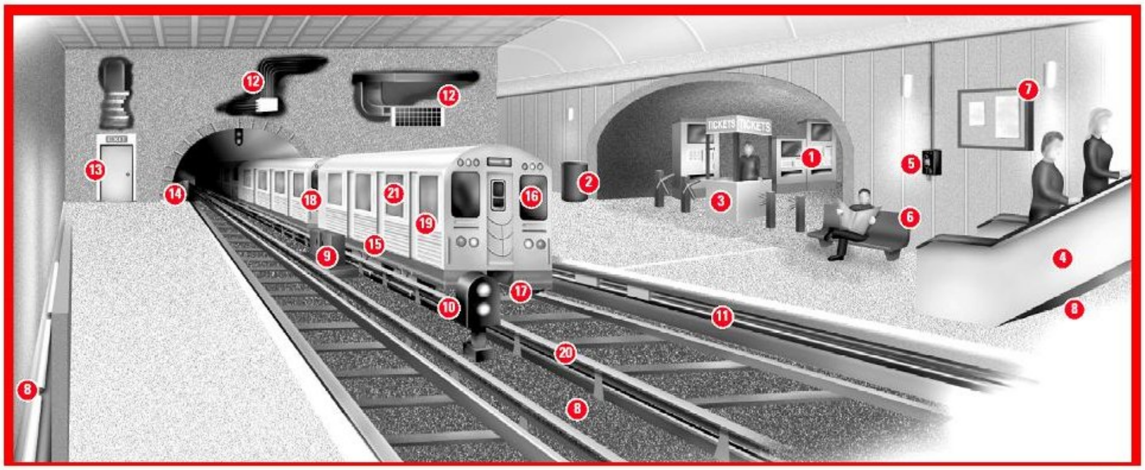


Figure 1 Components of a Subway Car

Each subway system has administrative offices, an operations control center, stations, maintenance facilities, and storage yards. The general layout of a subway station is shown in Figure 2.



STATIONS	RIGHT-OF-WAY	TUNNELS	RAIL CARS
1. Fare vending machines	8. Accessible hidden spaces	12. Cable and pipe chases and ductwork	15. Floors and floor compartments
2. Trash containers	9. Equipment cabinets	13. Exit stairs and ventilation shafts	16. Operator's area
3. Station agent booth	10. Signals, cabinets and lines	14. Passageways and equipment rooms	17. Undercarriage equipment (brake system, trucks, cables)
4. Stairs/escalators	11. Electrical and communication lines		18. Space between cars (couplers and cables)
5. Pay phones			19. Electrical and other compartments
6. Benches			20. Third-rail contact equipment
7. Lights and signs			21. Interior compartments and lights

Figure 2 General Layout of a Subway Station

(Source: NTI Employee Guide to System Security for Heavy Rail Operations, Federal Transit Administration, National Transit Institute, Rutgers University)

The role of signaling is to safely separate trains from each other and to protect specific paths through interlockings (where a section of track joins switches, the surrounding signals, and the control machinery) at junctions and crossovers. Additional functions include automatic train stops should a train run through a stop signal and speed control to protect approaches to junctions, sharp curves, and terminal stations where tracks end at a solid wall. Automatic train control adds further features to the train protection of basic signaling, including automatic driving and train supervision that regulates service.

In a fixed block system, trains are detected by the wheels and axles shorting a low-voltage current into the rails. The rails are electrically divided into blocks. The signaling system only knows the position of a train by the simple measure of block occupancy, and trains proceed according to signal aspect configurations.

Cab signaling uses codes inserted into each track circuit and detected by an antenna on each train. The code specifies the maximum allowable speed for an occupied block. This speed is displayed in the driver's cab.

Moving-block signaling systems are also called transmission-based or communication-based signaling systems. They have neither blocks nor aspects. This system requires continuous or frequent two-way communications with each train and a precise knowledge of a train's locations, speed, and length; and fixed details of the line – curves, grades, interlockings, and stations. The computers that calculate and control a moving-block signaling system can be located on each train, at an operations control center, dispersed along the wayside, or any combination of these. Most subways use some hybrid of cab signaling and moving-block signaling system because it is impractical or uneconomical to equip machinery such as track maintenance equipment with the moving-block signaling system.

Automatic Train Operation (ATO) provides basic over-speed protection. It is usually supplemented with automatic speed regulation and station stopping technologies. The operation throughout a certain section is controlled by the train operator who is supposed to be operating at restricted speeds (prepared to stop within some range of vision short of an obstruction). To allow manual operation after system failure, track circuits and signals may be retained at major interlockings with either a local or remote control panel. The question of whether to operate manually after the failure of any type of signaling is difficult. Many systems err on the side of caution and establish bus service (bus bridges). Most safety accidents do not involve trains using ATO, but stem from atypical operations (e.g., a maintenance-of-way crew working on a section of track).

Standards

Subways are currently excluded from the regulatory authority of the Federal Railroad Administration (FRA). In 1995, the Federal Transit Administration (FTA) established a State Safety Oversight Program for those states with fixed-rail guideway systems that are not under the regulatory authority of the FRA. As a grant-making agency, FTA has delegated oversight to the state level to establish lines of authority and levels of responsibility and accountability. Unlike the Federal Aviation Administration (FAA) that controls and regulates the nation's aviation system, FTA has no direct control over transit operations. <u>There is no federal regulatory agency that performs mechanical, signal, track, or operation inspections on subways.</u>

The National Fire Protection Association (NFPA) has issued a model standard for Fixed Guideway Transit and Passenger Rail Systems – NFPA 130. It covers fire protection requirements for underground, surface, and elevated fixed-guideway transit systems, including trainways, vehicles, transit stations, and vehicle maintenance and storage areas. This standard is currently being modified. There is no assurance of compliance with these standards.

Subways have operating rules that place the responsibility of passenger safety on the employees. The ultimate responsibility for the safety of passengers on a particular train rests with a train operator. Train operators are supposed to bring their vehicles to a safe stop if instructed by any person to take any action that would adversely affect the safety of the passengers (such as someone violently waving any object on or near the track). Train operators should then report the incident immediately to the Operations Control Center, which has the full authority, jurisdiction, and control over all activities on the subway's main line.

The Federal Transit Administration has prepared guidelines for managing security incidents involving surface transit vehicles (Ref. 7). It has also prepared guidelines for managing suspected chemical and biological agent incidents in rail tunnel systems (Ref. 8).

CONSEQUENCE OF EVENT

General

Subways stand at or near the top of terrorists' targets. The network of a subway system, with its tunnels, moving trains, and ventilation shafts can distribute a chemical or biological agent throughout many stations and tunnels below ground as well as up through ventilation shafts and station egresses above ground to an entire city. A terrorist can attack a subway system by releasing a chemical/biological weapon in a station, subway car, tunnel, or through a ventilation shaft.

Because there is no national inventory of critical subway infrastructure (i.e., exits, locations of subways, numbers of rail tunnels, elevated structures, maintenance facilities, operation and security facilities, communication protocols, etc.), it is difficult to quantify and qualify the consequences of a terrorist event. Integration of security technologies such as access control systems with building management systems (heating, ventilation, and lighting), along with fire detection and suppression systems (alarms and emergency access doors), and closed circuit television systems is challenging.

Since all subways are located within metropolitan areas, alternate modes of transportation (buses) can be utilized in an emergency. Subway operations and passengers have been acclimated to station closures due to construction or special events. The economic impact of system-wide subway closures needs to be evaluated. The decision to suspend subway service because of a threat should be tempered with the reality that subways are used to evacuate persons in the area without increasing other vehicular traffic. Subway stations can serve as shelters should there be above-ground environmental contamination or as a location for quarantined people. However, subways, or any portion thereof, can be permanently closed as a result of a terrorist attack.

Chemical or Biological Attack

It is generally the policy to shut down trains and station and emergency tunnel ventilation (if operating) in case of a chemical attack (guidelines have been prepared for particular types of incidents [Ref. 8]). For subway cars, keeping the HVAC operating in the train with an attack is recommended to help exhaust the attack agent; however, it is recommended to shut down the HVAC in all trains nearby to avoid having the agent enter those nearby trains. Because the effects of a biological attack take one or more days to discern, biological detection is not able to provide immediate notice for mitigation (detector to mitigate) but would be helpful for public health departments in gaining advance warning (detector to treat) in treating potential victims. Reducing the routine cost of biodetection is a challenge with practical solutions possible in the near term. Practical chemical-detection, early-warning systems are now possible (e.g., in

Washington D.C. and Boston subways), if properly set up and monitored. Reducing cost in future years is a challenge to make these systems useful in places other than key, high-threat hot spots.

While components of chemical and biological agents are not difficult to obtain or to produce, there is a degree of sophistication and variables (weather) that are required for the weaponization and delivery of these substances. While there has been only one successful chemical, biological, and radiological (CBR) attack on a public transportation attack (the 1995 release of sarin gas in a Tokyo subway resulting in 12 deaths and 5000 seeking medical attention), there have been other attempts and plans for such attacks. Even though the likelihood of a conventional attack is far greater than a non-conventional attack, the concern for the direct and indirect effects of a CBR weapon on a subway system is primarily based on the unknown and the recognition that restoration service for a CBR attack would be very time consuming and costly. CBR weapons are intended to cause mass casualties and to instill fear.

One countermeasure that can be deployed is a decontamination system that can be activated quickly to reduce the airborne concentration of chemical, radiological, and biological agents in a subway station. There are non-toxic and non-corrosive products that can be sprayed into affected areas that will eliminate over 90% of the airborne threat in a terminal. The activation of the system facilitates subsequent surface decontamination operations and restoration of service. When properly deployed, these decontamination units can reduce the impact of chemical, biological, or radiological attacks, such as the Tokyo subway attack in 1995. However, there are a number of issues that remain unsettled, including the best decontamination agent for different surfaces and the standard to which the surfaces should be cleaned.

Bomb or Explosives Attack

Another threat of a terrorist incident involving a subway is by placing a vehicle bomb near a station or a lower-yield explosive device in a station, or by laying explosives on a track. Deploying conventional explosives in a subway will probably result in scores of casualties. Terrorists choose high-visibility targets, high casualty potentialities, and the opportunity for a good photo opportunity (planes crashing into the World Trade Centers versus a crushed subway car buried underneath rubble). Since subways run underground, the power will be cut off, and the majority of media can be cordoned off the site. The major threat from a terrorist incident on a subway train resides in the damage to nearby critical infrastructure (e.g., flooding of a tunnel). Since subways are located at some of the lowest elevations in a city, an explosion in a subway tunnel could prove disastrous to a city. Many buildings and infrastructures have been built around subway systems, increasing the likelihood that subway systems will be affected during any incident in a city.

The primary objective of an explosive device is to detonate at the proper time. The present countermeasures for explosive devices are the following: evacuation, bomb squad, and refraining from using cell phones or radios within a certain distance of the suspected bomb area. Functional failure of any one of the components of a bomb results in a dud. The challenge in creating explosive device countermeasures is to intentionally induce duds. Subways have large amounts of power needed to drive directed energy devices. By using high levels of electromagnetic energy with radio frequency-directed energy weapons systems, an explosive device can be neutralized without detonation and harm to personnel in the area.

Blast-hardening techniques as shown below (Figure 3) are another countermeasure being developed for subway stations. Physical infrastructural hardening measures that have been used for natural events (such as earthquakes, gale-force winds, heavy rain, and snow) include slope protection, avalanche fences, wind barriers, and seismic reinforcement. Such measures can also be used for blast-mitigation techniques. These measures are the most effective possible but would be prohibitively expensive if applied to every section of every track, explaining why priority is given to track sections that are at most risk of natural disasters.

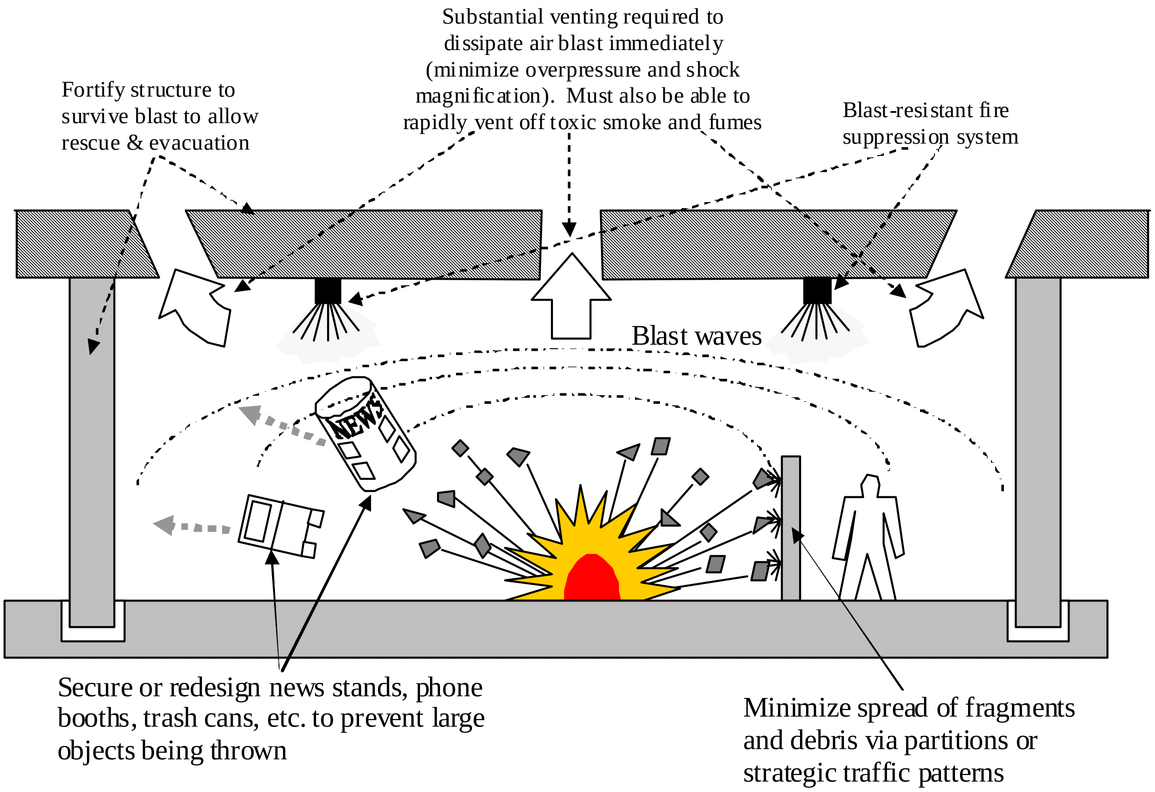


Figure 3 General Blast Mitigation Improvements for a Subway Station

Control Center Attack

Additionally, should an adversary gain control of a subway control room, train signaling, detection, automatic train operations, and other safety devices could be disabled or altered. This could cause subway train crashes (into other trains or terminal stations) throughout the subway system, resulting in numerous injuries or even death to passengers and subway employees. Emergency response to the resulting injuries would be overwhelming if crash victims have to be extricated from tunnels and subway platforms through the urban area.

COMMON VULNERABILITIES

Critical infrastructures and key assets vary in many characteristics and practices relevant to specifying vulnerabilities. There is no universal list of vulnerabilities that applies to all assets of a particular type within an infrastructure category. Instead, a list of common vulnerabilities has been prepared, based on experience and observation. These vulnerabilities should be interpreted as possible vulnerabilities and not as applying to each and every individual facility or asset.

The following is a list of common vulnerabilities found at subways.

Exhibit 1 Economic and Institutional Vulnerabilities	
Economic and institutional vulnerabilities are those that would have extensive national, regional, and industry-wide consequences if exploited by a terrorist attack.	
1	Most transit authorities that possess rail tunnel systems (subways) have large volumes of riders (e.g., New York City Transit Subway accommodates over 4 million passengers per business day). A loss of service to any of the lines that serve a large metropolitan area could have economic consequences on the transit authority. This kind of loss of service may be exacerbated for subway systems that do not possess multiple lines to allow rerouting of rider traffic. Centralized transit crossover stations, as well as transit nexuses and hubs, may be vulnerable, since their disruption could potentially impact multiple subway lines, or other forms of transit.
2	Since subway lines serve metropolitan and economic centers, a loss in commuter access could result in a significant burden to commuters. Subsequently, this loss could have an associated financial impact to companies whose workers no longer can commute to work on the disabled subway lines.
3	Subway rail cars are extremely expensive. Replacement of damaged or destroyed rail cars could result in a financial burden for a transit authority.

Exhibit 2 Site-Related Vulnerabilities	
Site-related vulnerabilities are conditions or situations existing at a particular site or facility, that could be exploited by a terrorist or terrorist group to do economic, physical, or bodily harm, or to disable or disrupt facility operations or other critical infrastructures.	
General	
1	The enclosed nature of subways (concomitant with large volumes of confined patrons) could make them vulnerable to certain types of attack.
Access and Access Control	
2	Public transportation, by definition and necessity, are open to the public. Access limitations are generally confined to right of way areas, operations and control rooms, signal and electronic equipment, and track beds.
3	Critical assets, such as signal boxes and communications may be accessible (surreptitiously) resulting in disruption of service.
4	Some systems may be subject to access control issues due to their geographic size and large employee/contractor population (e.g., identifying authorized personnel/contractors and enforcing appropriate identification may be difficult).
5	Access to control rooms may not be adequately secured, especially those located in urban office buildings rather than at the active subway system facilities.
Operational Security	
6	Known (and openly accessible) operating schedules and timetables are required by patrons in order to plan travel.
7	Background checks on employees and contractor personnel may be limited. Some states or even union contracts may limit the use of background investigations.
8	Websites may provide detailed information on subway locations, critical assets, maps, and operational data.
9	Hacking may provide adversaries with additional information.
10	Transit personnel may not be trained in the protection of critical information and/or operational security.
Emergency Planning and Preparedness	
11	Contingency plans, emergency response, and incident command may not be formally coordinated or exercised with all the entities that support subway system assets located within their geographic areas of jurisdiction.
12	Back-up emergency operation centers may be limited.
13	A subway infrastructure involves enormous amounts of electric current. Emergency personnel must make sure that a subway employee verifies that power has been cut off before attempting any response efforts near subway infrastructure.

Exhibit 3 Interdependent Vulnerabilities	
Interdependency is the relationship between two or more infrastructures by which the condition or functionality of each infrastructure is affected by the condition or functionality of each other. Interdependencies can be physical, geographic, logical, or information-based.	
General	
1	Subways traditionally serve inner-city economic corridors. Loss of transit service to these areas may have economic effects on corporate, entertainment, and tourist entities, which their operations around access to subways. Additionally, multimodal interdependencies may exist for certain transit system assets (e.g., a major disruption at Grand Central Station may impact for service of the New York City Subway System, the Metro North Rail Road, as well as the New York City Bus System).
2	Link/transfer trips exist between various transit systems (i.e., subway to commuter surface rail system, commuter surface rail system to bus depot, etc.). A service disruption in any of these links may have ramifications for the other systems (as well as for the patrons).
Electric Power	
3	Subway systems rely on substantial electric power grids (e.g., the New York City subway system has over 200 electric power substations that may receive up to 30,000 volts) to energize the third track, as well as to operate auxiliary equipment and telecommunication systems.
Telecommunications	
4	Subway systems rely on sophisticated telecommunication and control systems to operate the trains, provide signaling, and even allow for automatic train operation. Subway system telecommunications would be essential during emergency situations within the tunnels.

USEFUL REFERENCE MATERIAL

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12. Massachusetts Bay Transportation Authority, http://www.mbta.com/
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