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High-Security Fencing for Rail Right-of-way Applications:

Current Use and Best Practices

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The Volpe Center investigated how high-security fencing is used to prevent right-of-way (ROW) trespassing at several urban transit and commuter rail agencies in the United States. Interviews, operations documentation, and site visits were used to gather information for this research, and it was found that the best high security fencing installations do the following: 1) prevent trespassing in all directions, i.e., over, under, and around; 2) are strategically placed in locations determined through rigorous hazard analysis and have community support; and 3) are part of a comprehensive railroad fencing program.

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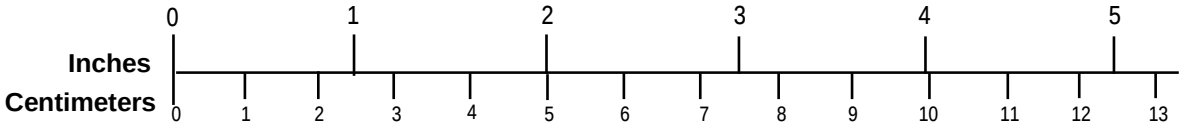

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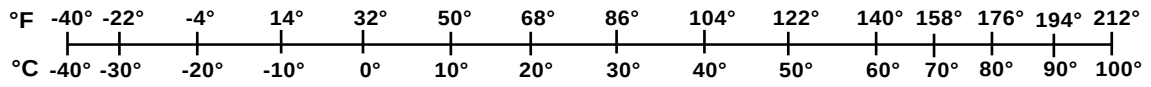

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Executive Summary

The John A. Volpe National Transportation Systems Center (Volpe Center) investigated the current uses of high-security fencing to prevent right-of-way trespassing at several urban transit and commuter rail agencies across the United States.

The best practices for building high-security fencing along right-of-ways can be summarized as follows:

1. The fencing should prevent trespassing from all directions: over, around, under, and through.
2. The fencing should be strategically located. Ideally, the location should be determined by conducting a robust hazard analysis with all relevant sources of trespassing information.
3. Community support can be extremely beneficial to a fencing program as well as trespass-prevention programs in general.
4. The most successful and comprehensive fencing programs have demonstrable support from the railroad.

This report summarizes field observations and operational documentation to relate practical experience that should be taken into account when trespass mitigation strategies and safety solutions are proposed. Also, the best practices listed above are presented and supported by real world examples.

1. Introduction

1.1 Background

The John A. Volpe National Transportation Systems Center (Volpe Center) provides technical support to the U.S. Department of Transportation's Federal Railroad Administration (FRA) Office of Research, Development and Technology on issues involving railroad safety including trespass prevention. The Volpe Center is developing a body of information to assist current and future researchers in their efforts to reduce rail trespassing, the leading cause of rail-related deaths in the U.S.

Railroads have experimented with alternative fencing strategies to deter illegal trespassing. High-security fencing—reinforced fencing used to prevent trespasser incursions or breaches whether from climbing, cutting, or other method of passage—is being used more frequently. Although this solution is more formidable than standard fencing, it tends to be more costly than standard chain link fencing or no fencing.

While cost constraints prevent many agencies from using high-security reinforced fencing, others have begun to use it in limited circumstances. As a result, there is a need for more industry best practices for installing high-security fencing solutions and identifying appropriate applications for them.

At the 2012 Right-of-Way Fatality and Trespass Prevention Workshop[1], which was sponsored by FRA and the Federal Transit Administration (FTA), the attendees (mostly rail and transit safety experts) identified current research needs, including research into fencing design and the use of fences to mitigate rail trespassing. FRA tasked the Volpe Center to conduct this research with a focus on gathering information about the extent and use of high-security fencing.

1.2 Objectives

This report summarizes field observations that highlight the differences and similarities in railroad approaches to select and appropriate effective fencing strategies. As the market for high-security fencing solutions grows based on increased demand and costs become competitive in more balanced market conditions, it is vital to remember "safety first" when measuring safety concerns against associated economic realities.

1.3 Overall Approach

The FRA asked railroad industry representatives to provide information on current and proposed installations of high-security fences along railroad rights-of-way. Where feasible, site visits were made by Volpe Center researchers to visually inspect and photograph examples of fencing that are currently in use. In addition, most of the participating agencies were informally interviewed about issues such as policy implications, community acceptance, site choices, hazard analysis

[1] 2012 ROW Fatality Trespass Prevention Workshop, http://www.fra.dot.gov/conference/trespass2012/ cited on 9/18/2014.

and cost concerns. From this information gathering exercise, a summarized list of best practices has been created and presented in this report.

1.4 Scope

The report's scope is by no means exhaustive and is limited to the specific transportation agencies and localities identified within it, which were chosen through informal outreach and its familiarity with fencing and rail right-of-way (ROW) security.

This research was also limited because some of the information is considered safety-sensitive or confidential by railroads or the public agencies that own or operate rail service. Much of the information that the team received was not available online and was made available to the authors for investigative purposes only.

1.5 Organization of the Report

Chapter 1 – Introduction: Addresses the objectives of this research, defines the intended scope, and presents an outline for organizing the information found within this report.

Chapter 2 – Physical Attributes: Focuses on the physical hardware and installation of high-security fencing designs used to limit access to the railroad ROW. Each agency's fencing solutions are examined; the agency's stated needs and the proposed/implemented solution are briefly discussed.

Chapter 3 – Location-Based Hazard Analysis: Describes some of the standardized methods that transportation agencies use to determine specific locations for high-security fencing.

Chapter 4 – Community Interactions: Highlights situations where with local communities and collaborating with local institutions led to improved high-security fencing solutions.

Chapter 5 - Organizational Prioritization: Briefly discusses why an official (or formal) organizational commitment to a uniform fencing policy plays an important role in implementing useful high-security fencing.

Chapter 6 – Conclusion summarizes best practices developed through interviews, site visits and observation.

2. Physical Attributes

This chapter examines the physical attributes of the high-security fences that are used by each agency to limit access to the ROW. All information contained herein was gathered from document reviews, interviews, and site visits with the respective agencies.

2.1 Long Island Rail Road

The Long Island Rail Road (LIRR) is a significant user of high-security fencing, given the agencies' considerable experience with this approach and its satisfaction with the results. LIRR's fencing structures have the following characteristics:

- Each section consists of expanded metal gratings (galvanized or powder-coated) and has an upstand at the top to discourage climbing
- Eight-foot sections with two 4-foot panels that overlap with bolts
- Posts buried four to six-foot deep with concrete encased poles
- Bolts and clamps connect sections to poles

Figure 1 and Figure 2 below are examples of this type of fencing configuration by the LIRR.

Figure 1. Overlapping Panels of High-Security Fencing at the LIRR

Figure 2. Offset Sections of High-Security Fencing at the LIRR

LIRR has discovered that high-security fencing works very well for its needs. If its fences suffer an impact (for example, by a car), only one section will probably be affected and not cause a replacement of the entire fencing system. Also, by design, expanded metal grating fencing is difficult to climb and cut, making it suitable for ROW trespass deterrence.

The LIRR has been using high-security fencing for over 15 years. Vehicles have struck the fence, but none have yet breached it. LIRR has found only one fence cut. Although expanded metal grating fencing can be cut with a K12 saw (like those used by members of fire departments or emergency rescue crews), this has not proven to be a problem thus far. Even so, individuals have been discovered trying to cut the fence with ineffective tools.

All fencing at LIRR, including fence replacement, is handled by a third-party contractor. The cost to fix each hole in a chain link fence was approximately $800, but now that LIRR is using high-security fencing on a more regular basis, repairs are rare. When the chain link fence needs

to be replaced, it is usually replaced with high-security fencing. The engineering group at the LIRR has begun to include high-security fencing in its designs for substations.

Basically, expanded metal fencing provided LIRR with an anti-cut, anti-climb design which could be installed easily and has both lower maintenance and repair costs. Yet the additional cost per square foot over traditional fencing solutions is still a major concern.

2.2 New Jersey Transit

New Jersey Transit (NJT) is another railroad agency that uses high-security fencing. Over the last ten years, it has been installing fencing along the ROW. For the first time, NJT installed high security fencing in 2002; the fencing was added to a line with a single track ROW that experienced high levels of trespassing. In 2003, NJT installed an additional 20,000 ft. of high-security fencing. The agency's high-security fencing has a tight weave that cannot be cut by standard tools (Figure 3). Figure 4 shows how this fencing can be joined with existing infrastructure.

Figure 3. High-security Fencing on NJT's ROW

Figure 4. Interfacing High-security Fencing with Existing Infrastructure at NJT

In NJT's *Policy on Right of Way Signage and Fencing*[2], its choice for security fencing is specific, naming a manufacturer and stating that the "Mesh Fence Fabric shall be made from a sheet of steel that is simultaneously slit and stretched into a rigid, open mesh diamond making one continuous sheet that cannot unravel. The finished shape of the mesh openings shall be diamond. Conventional expanded metal not manufactured specifically for security purposes is NOT permitted for this use". This type of fencing has successfully prevented trespass and typically it stays undamaged. The only known breach was in one location where trespassers stacked pallets in order to scale the fence.

The policy states that "the standard fencing application to deter unauthorized access to NJ Transit Rail Right-of-Way is chain-link fence". However, the policy specifically mentions security and ornamental fencing, stating that either will be used "upon specific recommendation during the Hazard Identification and Resolution process".

Expanded metal fencing provided NJT with an anti-cut, anti-climb solution that is easy to install and has both lower maintenance and repair costs. However, the additional cost of high-security fencing can be prohibitive when an agency chooses a fencing solution.

[2] New Jersey Transit Policy on Right of Way Signage and Fencing (Number: SAF-027), effective date revision 02/01/2012.

2.3 Capital Metro

In its *Guidelines for Fencing*[3], the Capital Metropolitan Transportation Authority (Capital Metro) of Texas lists four possible types of fencing that can be used based on need. Although the types of fencing in these guidelines are mainly traditional chain link (and thus not typically regarded as "high-security"), the existence of a policy that recommends fencing choices based on situation is noteworthy.

Fencing choices and designated purposes, as taken from Capital Metro's Guidelines, are listed below:

- Eight foot industrial grade uncoated chain link fencing with top cable
    - Most suitable for areas where trains travel at moderate to high speeds with perhaps less opportunity for warning. Most suitable for areas having few pedestrian/bicycle crossings as a result of land use. Close proximity to schools raises trespass risk and makes this fencing the preferred choice.
- Six foot industrial grade uncoated chain link fencing with top cable
    - Most suitable for areas where trains travel at moderate to high speeds with perhaps less opportunity for warning. Most suitable for areas having few pedestrian/bicycle crossings as a result of land use.
- Four foot fence black vinyl coated chain link with top rail
    - Most suitable where separation from the rail ROW is needed to avoid unintentional trespass, and for pedestrian/bicyclist channelization to optimize safe circulation in the area and promote safety at legal crossings.
- Four foot bollards with triple strung cables
    - Most suitable for areas parallel to pedestrian/bicyclist travel-ways, where separation/channelization is needed within a minimum, confined space, and/or as a boundary marker to avoid the encroachment of motorized vehicles.
- No fencing
    - Most suitable for areas that have an existing natural or structural barrier and/or a clearly marked area that includes a defined designated legal crossing, and/or is considered to have a sufficient line of sight so that the functional value of installing a fence is negligible.

To date, Capital Metro does not specify any high-security fencing solutions in its policies. However, the agency has addressed the issue of fencing along the railroad ROW by creating a formal policy on the subject that spells out, in detail, the suitability for different fencing choices based upon situational assessments. Having a policy available not only acts to shed light on the serious nature of security, but also limits confusion and serves as a basis upon which the policy can be reviewed and expanded.

[3] Purpose, Standards, and Guidelines for Fencing and Associated Designated Pedestrian/Bicycle Crossings Along MetroRail Right of Way as Approved by the Capital Metro Board of Directors on September 29, 2008.

2.4 Amtrak

To determine what kinds of fencing will be used at a target location, Amtrak uses a site specific security planning and review process.[4] The various stakeholders participate in a design review which ensures that the scope of the design and the type of fencing meets the security needs for each location. Fencing is one component of an overall "tool kit" approach and Amtrak typically installs fences as a compliment to other security measures such as lighting, closed-circuit television (CCTV), security guards, and so on. Amtrak generally uses the following fencing choices for each location type:

- High Value Stations - Expanded metal, or tight weave chain link
- Historical Locations - High security decorative fence
- Medium Stations - Combination of tight weave chain link and regular chain link
- Significant Bridges/Tunnels - Combination of tight weave chain link and regular chain link
- Facilities, Yards - Combination of tight weave chain link and regular chain link

Though it may seem that Amtrak's fencing decisions are defined by the above list, Amtrak's approach to using high-security fencing is not that simple. Fencing type, design, appearance and considered level of security are components of an overall comprehensive site review, and are not merely menu-driven choices. As in other agencies, Amtrak's fencing options are similar in type, spanning from low security chain link fence to high security expanded metal mesh fencing, and they are selected when there is a demonstrated need for stronger security.

2.5 TriMet

TriMet plans to install high-security fencing on a new line that is scheduled to open in the fall of 2014.[5] At this stage of planning, they are considering a welded-wire type of fencing solution, as pictured in Figure 5 below. The design has prongs on the top of the panels to prevent breeches over the fence. The physical make-up of this fencing consists of a heavier gauge wire material than chain link that is welded together vertically. There are horizontal members, but the gaps are not wide enough to easily establish a foothold for climbing. This choice is more difficult to cut than chain link, yet not as tough as expanded metal: a determined trespasser would need specialty bolt-cutters or lock-cutters to breach through the fence. If damaged, this particular type of fencing would be easier to fix than typical chain link, yet, more expensive, as a whole panel would need replacement.

[4] Email from Michail Grizkewitsch, FRA Transportation Specialist, regarding Amtrak's Emergency Management and Corporate Security (EMCS) approach to selection of security fencing.

[5] Interview with Kurt Wilkinson, TriMet – March 2014.

Figure 5. Welded-wire Fence Proposed for a new Rail Line at TriMet

2.6 SEPTA

A distinct class of fencing not typically included in the "high-security" category, yet worthy to mention in this work, is referred to as intertrack fencing. In practice, intertrack fencing is primarily standard chain link, perhaps even shorter than normal, placed between tracks to discourage crossing. Although potential trespassers still have access to the ROW, once they cross one track, they would have to walk along the ROW for some distance to find a way around the intertrack fencing to get to the other side.

The Southeastern Pennsylvania Transportation Authority (SEPTA), which uses intertrack fencing exclusively on commuter lines between stations, notes that this fencing choice is not meant to stop the determined trespasser but rather "the middle-aged adult who doesn't feel like walking around the fence". In some locations they've extended the intertrack fencing into the station area, particularly at stations that have at-grade parking facilities, so that people won't cross the tracks on its way to the parking lots. This type of fencing has worked well for SEPTA, as it cannot fence on the outsides of the ROW for a number of reasons, including roadway worker protection. SEPTA property lines are often close to the ROW, ultimately prohibiting fencing on the outside of the tracks that would not leave enough room for workers to shelter from an oncoming train.

2.7 Physical Attributes Summary

From interviews conducted and observations made during site visits, we can provide a summary of some of the most commonly used options for fencing choices. Table 1 below presents a listing of the fencing systems observed in current use or proposed future use by surveyed agencies. By no means is this summary to be considered exhaustive.

Table 1. Fencing Systems Observed

Fencing System	Strengths	Weaknesses
Standard Chain Link	Low to medium cost, Ease of configuration	Easily cut, easily scaled
Intertrack	Low to medium cost, Ease of configuration	Easily cut, easily scaled
Welded-Wire	Medium to higher cost, Ease of configuration, Smaller mesh makes scaling difficult	Easily cut
Expanded Metal	Difficult to cut, Difficult to scale, Low maintenance costs	Higher initial cost

The range of options observed in practice spanned from basic fencing solutions, such as standard chain link fence which is not typically considered a high-security option, to bollard enforced expanded metal fencing. The choices made were based upon a myriad of factors, including cost, existing policy, community impact, needs assessment and potential for success.

3. Location-Based Hazard Analysis

Determining the type of fencing to install is only one part of a high-security fencing policy decision. Most robust high-security fencing programs have standardized methods for determining where to install the fencing. These methods are essential, as sentiments were reiterated several times over by safety professionals stating that "you can't fence the entire ROW!"

In order to efficiently allocate fencing resources and maximize safety benefits, many agencies are using risk methodologies to differing degrees; generally, a tailored location-based hazard analysis is used to support the decision-making process. This section describes some standardized methods being used by associated agencies to determine where high-security fencing should be installed.

3.1 Long Island Rail Road

The LIRR uses a very detailed hazard analysis system for prioritizing locations in need of a fencing solution. Its prioritization algorithm takes into account accidents and suicides within a four-year time period, as well as trespass incident reports and debris strikes. The trespass incidents and debris strikes are reported by both engineers and train crews as they occur. This type of reporting is made possible with the use of hazardous condition report forms that are distributed to all "boots on the ground" departments, including transportation and engineering. Submittals are encouraged from everyone in any department. In addition, reports are also received from the Public Affairs office and New York's Metropolitan Transportation Authority (MTA) police. Finally, all received reports are loaded into a database that can then be queried by county, date, and time.

The next step involves a methodology to prioritize segments for fencing. Each segment is broken into four mile increments that are ultimately rated. The rating system uses the following assignments:

- Accidental fatality = 10 points
- Suicide = 5 points
- Debris strike = 2 points
- Trespass incident report = 1 point

Using these assignments, the number of accidents is multiplied by the point value per accident to produce an overall rating for each segment. Once an overall rating is calculated, the segments are filtered by point values and assigned to groupings or levels, with level 1 being considered most serious and level 4 being considered the least serious. Level ratings are assigned according to the following point system:

- Level 1 (most serious) = greater than 60 points
- Level 2 = 41-60 points
- Level 3 = 21-40 points

- Level 4 (least serious) = 0-20 points

After level ratings are calculated, a qualitative evaluation of the area is conducted to see if there exist additional risk factors, such as the presence of a school, known hang-out locations for children or adolescents, the existence of a discernable homeless population, or an existing fence/barrier that is continually being breached.

3.2 New Jersey Transit

According to the "Policy on Right of Way Signage and Fencing"[2], locations suitable for fencing, signage or other barriers are identified using the "Hazard Identification/Resolution Process". As part of this process, a "Priority Trespasser Location Analysis" is conducted using data from hazard analysis evaluation documents. In addition, information gathered from engineers, supervisory employees and the NJT Police Department is considered in the decision making process.

The methodology used is largely based on one presented by the American Public Transportation Association (APTA). NJT uses a standard hazard analysis worksheet which focuses on both the frequency and severity of impending hazards. The results are ultimately ranked, with those locations considered most critical considered for remediation.

A copy of the Hazard Analysis Worksheet used by NJT can be found in Appendix A. Similar to the procedures followed at LIRR, after identification of locational information, hazard severity is classified into categories, with Category 1 being most severe in nature and Category 4 classified as negligible. The following bulleted list is used in this determination:

- Category 1, Catastrophic, death or system loss
- Category 2, Critical severe injury, illness or system damage
- Category 3, Marginal, minor injury, illness or system damage
- Category 4, Negligible, less than minor injury, illness or system damage.

Subsequently, hazard probability is addressed based upon a determined frequency of occurrence of the considered hazard. Table 2 is used in this determination:

Table 2. New Jersey Transit Hazard Analysis Probability Ratings

Hazard Probability	Level	Individual Item	Fleet or Inventory
Frequent:	A	likely to occur frequently	continuously experienced
Probable:	B	will occur several times in the life of an item	will occur eventually
Occasional:	C	likely to occur sometime in the life of an item	will occur occasionally
Remote:	D	unlikely but possible to occur in the life of an item	unlikely, but may occur
Improbable:	E	so unlikely it can be assumed the occurrence may not be experienced	unlikely to occur

Finally, a hazard resolution matrix is used to aid in making the determination as to whether or not a proposed mitigation strategy should be undertaken or abandoned.

3.3 TriMet

TriMet, as part of a future installation of high-security fencing on a new line in late 2014[5], is focusing installations at places where there is most likely to be intrusion. These include, but are not limited to, the following locations and situations:

- Locations with a history of transients
- Locations where existing fencing has been breached in the past.

TriMet uses a less formal approach to locational hazard analysis than both LIRR and NJT. An important note of relevance is that the railroad owner, on whose tracks TriMet operates, prefers to install only standard chain link fencing. Thus, as a matter of practice, TriMet has installed standard chain link fencing on railroad property and welded-wire fencing on its own property. Faced with these limited choices, a more formal approach to location-based hazard analysis may not be warranted.

3.4 Location-Based Hazard Analysis Summary

As the need for tighter security evolves and the desire to combat illegal trespass along the railroad ROW grows, more and more sophisticated hazard analysis methodologies will be examined, employed and refined. Currently, two of the methods surveyed use rigorous step-by-step classification algorithms to determine priority for securing a location. The other method reviewed employs a more informal methodology based primarily upon conditions and observations, yet is considered sufficient by those in charge of carrying out a comprehensive hazard analysis.

It should be noted that a recent study conducted by Volpe Center researchers adapted the hazard analysis methodology first developed by LIRR and NJT and developed a risk-based prioritization algorithm to identify and rank high-risk trespass areas within a transit ROW. The methodology and results of its implementation within that project is detailed in a 2013 FRA technical report entitled *Trespass Prevention Research Study – West Palm Beach, FL*[6].

The choice of tool for performing a location-based hazard analysis depends on many environmental factors. A broad perspective must be embraced with focus on agency policy, problem scope, and likelihood of success given available resources and options.

[6] Trespass Prevention Research Study, http://www.fra.dot.gov/Elib/Document/3943 cited on 9/18/2014.

4. Community Interactions

Cooperating with local communities seems natural to building a robust fencing program, high-security or otherwise. Indeed, it is essential to any safety and security program that attempts to limit ROW trespassing. This section illustrates instances where working with local communities has led to informed, successful implementations of high-security fencing solutions while managing to control the incidence of trespass.

4.1 Long Island Rail Road and a Youth Baseball Field

The LIRR worked with local officials and parents to install high-security fencing between the ROW and a community baseball field's outfield that abutted the railroad property. Historically, whenever a home run or long foul ball was hit, a player would access the ROW to retrieve the ball. Since the installation, access is restricted and safety is ensured. The fencing configuration is shown in Figure 6 and Figure 7.

Figure 6. High-security Fencing Installed by LIRR Behind Community Baseball Field

Figure 7. High-security Fencing Installed by LIRR Behind Community Baseball Field

4.2 Chico, CA, and the Union Pacific Railroad

In 1999, the Union Pacific Railroad (UP) and the City of Chico, California entered into a partnership where UP gave the city part of its ROW next to a well-traveled footpath while the City of Chico agreed, in return, to build and maintain fencing along the ROW. As recently as 2009, there was evidence that the fencing was regularly being breached (Figure 8). As part of a comprehensive plan, the City of Chico worked to actively engage the community's cooperation in realizing a solution.

Along with technological and physical improvements that were introduced to improve security (in the form of cameras to catch fencing breeches and higher quality fencing materials), the city worked to educate landlords about the program to eliminate breeches in fences near apartments. The city also actively interfaced with the large local student body to educate on the dangers of trespassing and to shine a spotlight on the camera installation.

Figure 8. A Fencing Violation in Chico, CA

4.3 SEPTA and the University of Pennsylvania

SEPTA has partnered with graduate students from the University of Pennsylvania to develop a database for housing reported trespass incidents. Upon completion, incident information gathered from SEPTA's customer service database, train engineer reports, police reports and anecdotal information from roadway workers will be available for mining in one consistent format. Currently, the data is received in multiple formats making it difficult to examine, compare and derive trespassing patterns from. SEPTA highly values working with the local university talent and looks forward to having access to better, more comprehensive data as a result of community interactions and cooperation.

4.4 Decorative Fencing and associated communities

Several railroad agencies mentioned its willingness to work with local property owners, abutters, and officials to install fencing that is both aesthetic and acceptable to the community. As a result, the increased community involvement regarding the local safety infrastructure may help to lower breaches, as the community experiences a sense of pride in ownership. The following agencies have official guidelines and/or policies regarding the use of decorative fencing:

- Capital Metro's Guidelines for Fencing mentions that it will install better-looking galvanized steel fencing upon request[3]
- Amtrak's official approach to the selection of security fencing considers decorative fencing, especially in historical locations[4]

- NJT gives towns the choice of standard chain link and ornamental fencing. In at least one case there was town push-back against chain link and NJT responded by installing ornamental fencing. Its official company fencing policy suggests ornamental fencing in towns and/or historical locations[2].

4.5 Community Interactions Summary

Community involvement can prove to be beneficial in achieving effective results. These examples help to demonstrate that cooperation between transit agencies and local communities results in a better flow of information in two directions: information from locally concerned stakeholders flows to transit agencies for consideration in designing solutions, and conversely, information, in the form of proposals, outreach, and education, flows back into the community. The end result is a more tailored resolution that is a smarter fit for the affected community.

5. Organizational Prioritization

It was stressed to the authors that in order for a fencing policy to actually foster improvements in safety, the policy itself must be healthy in scope, made available throughout the organization and supported by a dedicated and educated staff. Possessing an official policy on high-security fencing eliminates uncertainty in choices, specifies methodologies to be used in performing location-based hazard analyses and contributes to greater efficiency in reaching a resolution. Additionally, these results are more easily achieved when a level of priority is attached to the implementation of the policy.

5.1 Long Island Rail Road

The LIRR has managed to institutionalize its fencing policy. The LIRR Department of Program Management has produced a document containing not only detailed fencing specifications, but also a recommended site prioritization process, described by the LIRR as a formalized, "legally defensible" algorithm for determining the best locations to put the best fencing. The Corporate Policy and Procedure[7] spells out the responsibilities of all involved with regards to fencing, and reflects on an official corporate approach to fencing.

The LIRR stressed that having a dedicated team, consisting of one police officer and one system safety official, made fencing upkeep, proper location choice, and the anti-trespassing program possible. By design, the team can quickly respond to calls concerning breached fencing and oversee temporary repairs, follow "rabbit trails" to find the root cause(s) of trespassing in a certain location, and perform thorough examinations of locations with trespassing activity before reacting.

5.2 New Jersey Transit

NJT has also institutionalized its fencing efforts with an official company "Policy on Right of Way Signage and Fencing"[2]. The document, as expected, outlines standard procedures for fencing and signage, including specifying the types of fencing that may be considered. In addition, the policy discusses the methodology to be followed in choosing locations for change, by way of a standardized hazard analysis. By combining the fencing and signage policies into one document, the agency aims to ensure the efficient use of and concern for all available resources used in deterring trespassing.

In recent years, NJT has received increased support from the commissioner of the New Jersey Department of Transportation. This support has led to more improvements in fencing. For transit agencies like NJT, governmental and civic support have proven to be extremely helpful in bringing awareness to the safety issue at hand and to ultimately reduce the potential for risk.

5.3 Organizational Prioritization Summary

Efforts to establish, implement, and emphasize organizational policy concerning (high-security) fencing strategies have demonstrated practical benefits. Documented policy on methodologies,

[7] LIRR internal communication materials reviewed in May 2013.

e.g. location-based hazard analysis, helps to eliminate bias from the process, yielding uniform, scientifically-based results. Limits on fencing types and configurations reduce confusion, saving time and resources. A healthy, visible policy, supported by both the organization and staff, will ultimately serve to support the staff in its roles and responsibilities as safety and security professionals.

6. Conclusion

Most successful high security fencing solutions along rail rights-of-way are robust in design, preventing trespassing from all directions, i.e., over, under, through and around. These solutions begin with a location-based procedural methodology designed to pinpoint locations where trespassing and ROW encroachment or incursions are frequent, requiring further examination and remediation. Community outreach and stakeholder engagement are encouraged to improve communication, generate goodwill and foster cooperation. Finally, a comprehensive railroad fencing program includes official policy and procedures concerning fencing choices and methodologies that is strongly supported by the organization.

Best practices for high-security fencing can be summarized in the following four themes:

1. The fencing should be thoroughly designed and engineered to prevent trespassing from all directions: over, around, under, and through.
2. The fencing should be strategically located, ideally using a robust hazard analysis that includes all relevant sources of trespassing information.
3. Positive community engagement can be extremely beneficial to a fencing program and a successful localized trespass-prevention program in general.
4. The most successful and comprehensive fencing programs are demonstrably supported by the railroad organization.

The scope of this investigation is limited to the specific railroads and transportation agencies that shared information with the research team, and are identified within the body of this report. Even with this limitation, the authors were able to identify several areas in need of further research. Specifically, additional research is recommended on:

- Analyzing high-security fencing costs,
- Developing a trespass hazard analysis framework (possibly built on existing work by NJT and LIRR), and
- Conducting fencing effectiveness studies through review of trespass activities before/after implementation of high-security fencing.

These additional research efforts would provide the information needed for railroads and local communities to better justify the use of high-security fencing to prevent trespassing on the rail ROW, and allow for a more optimal allocation of limited resources, resulting in greater safety benefits for the community.

Appendix A.
NJT Hazard Analysis Worksheet

<table>
<tr><th colspan="3">HAZARD ANALYSIS WORKSHEET</th></tr>
<tr><td colspan="2">Location / Activity Description:</td><td>Date of Analysis:</td></tr>
<tr><td>Division:</td><td>Line:</td><td>Mile Post or Street Address:</td></tr>
<tr><td colspan="2">Current Status or Activity:</td><td>New Status or Activity:</td></tr>
<tr><td colspan="3">Other Safety Related Items to Consider:</td></tr>
<tr><td colspan="3">Considerations:</td></tr>
</table>

HAZARD ANALYSIS:

Hazard Severity:	**Hazard Severity Rating:**
Category 1, Catastrophic, death or system loss. Category 2, Critical severe injury, illness or system damage. Category 3, Marginal, minor injury, illness or system damage. Category 4, Negligible, less than minor injury, illness or system damage.	

Hazard Probability:	**Level**	**Individual Item**	**Fleet or Inventory**	**Hazard Probability Rating:**
Frequent:	A	likely to occur frequently	continuously experienced	
Probable:	B	will occur several times in the life of an item	will occur eventually	
Occasional:	C	likely to occur sometime in the life of an item	will occur occasionally	
Remote:	D	unlikely but possible to occur in the life of an item	unlikely, but may occur	
Improbable:	E	so unlikely it can be assumed the occurrence may not be experienced	unlikely to occur	

HAZARD RESOLUTION MATRIX:

	1	2	3	4	**Hazard Resolution:**
A	UN	UN	UN	AC/WR	
B	UN	UN	UD	AC/WR	
C	UN	UD	UD	AC	
D	UD	UD	AC/WR	AC	
E	AC/WR	AC/WR	AC/WR	AC	

UN = UNACCEPTABLE **UD** = UNDESIRABLE **AC** = ACCEPTABLE **AC/WR** = ACCEPTABLE WITH REVIEW BY MANAGEMENT

RECOMMENDATIONS:	
Analysis and Recommended by:	**Date:**

Abbreviations and Acronyms

Amtrak	The National Railroad Passenger Corporation
APTA	American Public Transportation Association
Capital Metro	Capital Metropolitan Transportation Authority
CCTV	Closed Circuit Television
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
LIRR	Long Island Rail Road
MBTA	Massachusetts Bay Transportation Authority
MTA	Metropolitan Transportation Authority (New York)
NJT	New Jersey Transit
ROW	Right-of-way
SEPTA	Southeastern Pennsylvania Transportation Authority
UP	Union Pacific
Volpe Center	John A. Volpe National Transportation Systems Center