A Performance Based Design Methodology for Designing Perimeter Vehicle Barriers for Existing Facilities Using the ISC Security Design Criteria

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Introduction

Over the last decade, many of our nation's cities have seen a proliferation of security barriers surrounding many existing Federal and private facilities. These barriers have been installed, rather quickly in some cases, in response to recent terrorist events throughout the country such as the bombing of the Murrah Federal Building in Oklahoma City and the attacks of September 11, 2001. In theory, most of these security barriers have been installed to prevent or mitigate the impacts of a vehicle delivered bomb.

It is a well known and scientifically proven fact that blast loads decrease rapidly with distance. Therefore, setback is one of the first considerations when designing to mitigate blast loads. The setback is the distance between the explosive threat location and the nearest structural element requiring protection. The term standoff is synonymous with setback, and the two terms may be used interchangeably.

Additionally, it is known that the existence of security barriers provides a level of deterrence to potential terrorists. However, it is difficult to quantify how much value they provide as a deterrent, and may just drive terrorists to another nearby target that appears "softer".

The installation of security barriers around existing facilities has taken many different forms. Some security barriers, in the form of planters or jersey barriers, have been installed at available standoff distances as temporary measures; to be removed when the risk has been removed or until more permanent barriers can be designed and constructed. However, in some cases, these temporary measures have been in place for considerable time and may never be removed or replaced in the foreseeable future. Although their value seems to be limited as a permanent measure (no known Federal security criteria suggests their use), they can provide value as a temporary barrier because they can be installed comparatively quickly and inexpensively.

Many Federal and private facilities have designed and/or constructed heavier, more robust barriers around their facilities to protect against the vehicle delivered bomb threat. In some cases these installations have been deemed successful from security, architecture, urban planning and cultural preservation points of view. Many more, however, have been considered unsuccessful by at least one of these groups.

Ultimately, the desire for standoff has resulted in many undesirable effects. Unquestionably, the installation of security barriers has had, generally, a detrimental effect on urban communities. Urban planners and landscape architects consider the installation of unsightly and makeshift security barriers as negatively impacting the historic beauty of cities and the concept of a free and open society. Occasionally, roadways are closed to achieve standoff. The installation of permanent security barriers requires substantial construction and excavation which may also affect city infrastructure such as utilities, trees, and transportation. Finally, the requirements for perimeter standoff, among other measures, may force Federal tenants out of leased facilities that cannot meet the security requirements. This can substantially affect the commerce and livelihood of many urban areas.

The design community has joined forces to address this problem in many ways. Organizations such as The Security Design Coalition have been formed to advocate good design practices and planning into the implementation of security measures. The National Capital Planning Commission (NCPC) has developed the *National Capital Urban Design and Security Plan* to provide guidance for security planning in the nation's capital that enforces good urban planning and design.

Although some in the design and planning communities question the need, at all, of security barriers, most do not. They recognize the threat and true security need for such measures, but question how the need is determined, where the security barriers should go and how they are designed.

Purpose

The purpose of this paper is to propose a risk and performance based methodology to assist decision makers in determining the need for, and the location of, perimeter vehicle barriers. It is intended for facility owners, architects, urban designers, engineers, and security consultants that are planning perimeter vehicle barriers for an existing facility where the risk to that facility justifies the expense of this measure. This methodology can also be used by reviewing agencies to evaluate barrier designs presented to them. This methodology will not make security design decisions for the user, but provide the steps for a thoughtful process and approach to the design of perimeter security barriers. This process will not address the implementation of temporary barriers such as jersey barriers or planters, but only hardened reinforced barriers that are recommended by a comprehensive risk assessment and reputable security design criteria.

Additionally, the following will be discussed:

- Even if a risk assessment recommends security barriers, they may not always adequately mitigate the threat and acceptance of some risk is necessary and allowable.
- A performance based design, rather than prescriptive, is a more secure, reliable, reasonable, and conscientious way of determining security barrier needs and location.
- The mitigation of the impact on architecture, cost, and cultural preservation, as well as risk, must be addressed when planning perimeter vehicle barriers.

Although this methodology is not exclusive to any one standard or criteria, the *Interagency Security Committee Security Design Criteria* will be used as an example of how this methodology may be implemented.

The Interagency Security Committee (ISC) Security Design Criteria for New Federal Office Buildings and Major Modernization Projects

The ISC Security Design Criteria is the leading criteria for the protection of Federal facilities in the United States. This criteria and its predecessor, the General Services Administration (GSA) Security Design Criteria, are significant in that they were the first attempts to truly integrate security into every facet of the design and construction of a facility for non-Department of Defense (DOD) organizations. Prior to these documents, security was generally an afterthought; the last item added and the first item cut from a typical building design. These criteria are required for all new Federal office buildings, Federal courthouses and major modernization projects not under the jurisdiction or control of the DOD. Certain facilities are currently not required to meet the ISC Security Design Criteria including: airports, prisons, hospitals, clinics, border patrol stations, ports of entry, and unique facilities including those classified as Level V by the Department of Justice (DOJ) rating scale. However, the risk management and design principles and approaches presented in the ISC documents may be used in any facility. Over the past several years, many facility owners who are not required to implement the ISC requirements have adapted and adopted the requirements of the criteria. Examples include state government agencies, quasi-Federal agencies such as the Smithsonian Institution, and private developers.

<u>Other Relevant Security Criteria</u>

It is important to understand that other criteria exist specifically to meet the unique requirements of other agencies such as the Department of Defense and Department of State. Other agencies, such as FEMA have provided guidance, rather than standards, to both the public and Federal agencies in their series of risk management publications.

Standoff

Considerable research has been conducted to determine the optimum standoff distance for facilities. For example, Figure 1 illustrates the level of protection offered by conventional construction with a given setback. The green bars in Figure 1 indicate that no significant protection from blast effects is readily attainable at these distances with a conventional building without structural hardening for the bomb sizes indicated. The blue bar is an indication of a low level of protection. At these distances, conventionally constructed buildings will typically sustain moderate to heavy damage. Occupants in exposed structures may suffer temporary hearing loss and injury from the force of the blast wave and building debris fragmentation. Other assets may receive damage from these effects. The pale blue bar is an indication of medium level of protection. At these distances, conventionally constructed buildings will generally sustain light to moderate damage. Occupants of exposed structures may suffer minor injuries from secondary effects such as building debris. The violet bar indicates a high level of protection. At these distances, conventionally constructed buildings will generally sustain only minor damage. Flying debris may also cause superficial injuries and damage to assets.

It is important to note that the information in Figure 1 is for illustration purposes only and applies only to a broad class of "typical, generic conventional construction". Actual results will vary (and can vary greatly) based upon the actual construction. However, this illustration clearly shows that increasing standoff is important. This figure also shows that without structural hardening, even at relatively smaller explosive sizes, a large amount of standoff is required to minimize damage to acceptable levels.

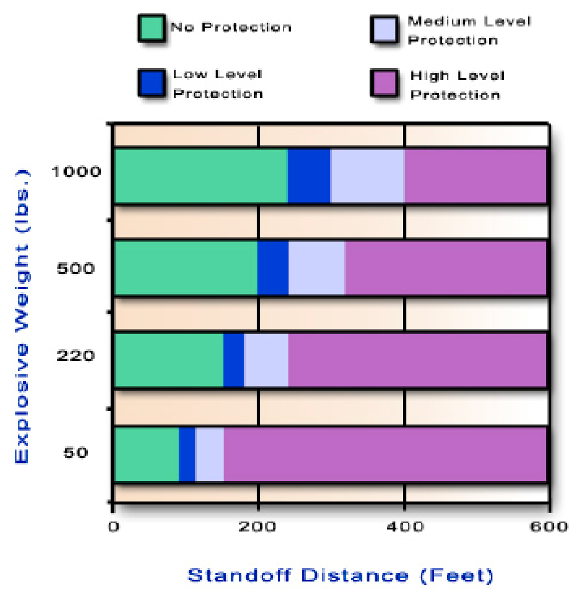


Figure 1. Level of Protection vs. Explosive and Standoff

In addition to exploring standoff as a means of mitigating blasts, studies have been accomplished to explore the maximum financial benefit between structural hardening and standoff.

Figure 2 illustrates how standoff affects various structural and non-structural components of a facility. This figure generally illustrates, at no specific scale, the general trends and relationships between standoff and cost of protection to implement the ISC Security Design Criteria.

A number of the various components of incremental security cost are shown, including structural and non-structural component contributors. The relative magnitude and scale of these relationships vary from project to project.

As one can see the cost associated with hardening the mailroom, loading dock, and lobby to meet the ISC requirements is usually relatively small compared to total project cost, and does not vary with the available standoff to a vehicle delivered bomb. The cost associated with progressive collapse considerations is also constant with standoff, since it is normally treated as threat-independent. There is a point at smaller standoffs where the framing design is further impacted by the blast loading on the frame, resulting in larger framing members and additional cost. This region is illustrated in the close-in regions, particularly within about 50 ft. As the standoff gets very small, costs increase exponentially.

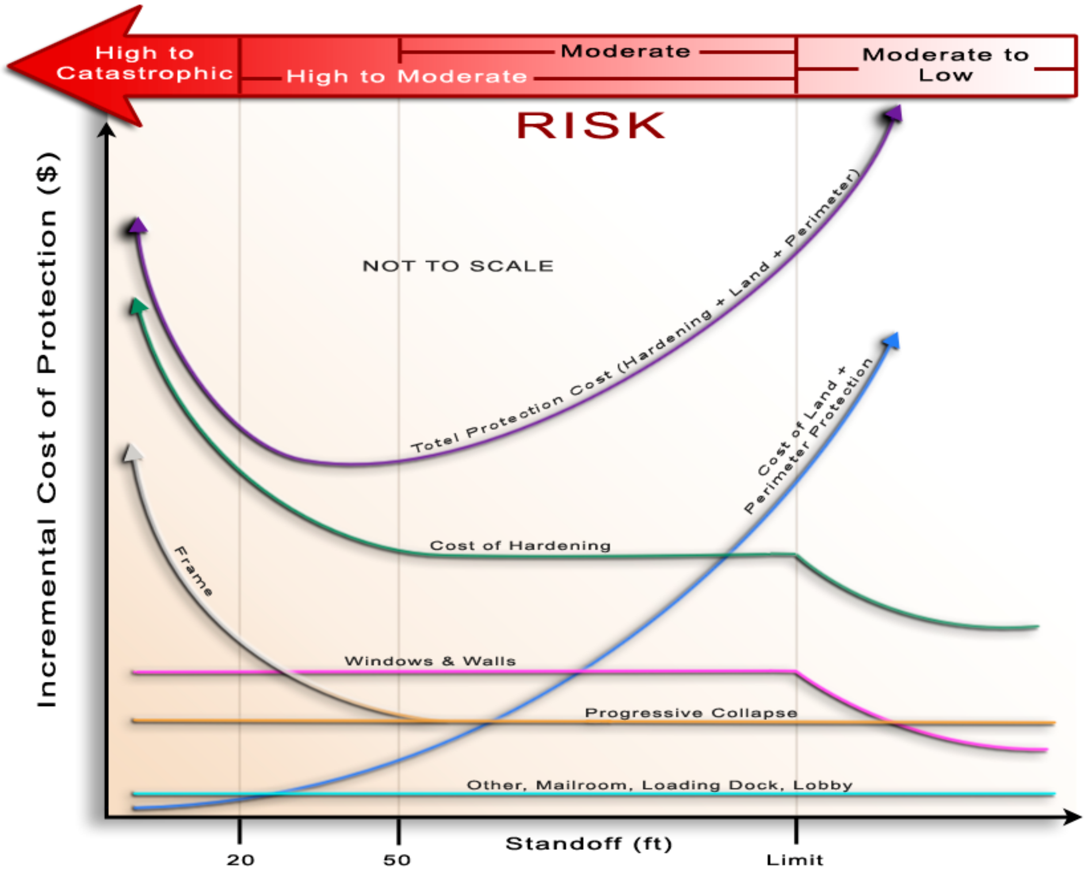


Figure 2. Impact of standoff distance on component costs.

The requirements for walls and windows are a function of standoff, as indicated for larger standoff. However, the ISC Security Design Criteria places limits on the maximum levels for which various components must be designed. The limits placed on the design blast pressure and impulse for the medium and higher levels of protection cap the cost at a particular standoff (limit) such that costs for walls and windows do not increase within this limit. It must be noted that this limitation in blast resistance increases the inherent risk accepted with decreasing standoff.

The sum of the varying costs of hardening for the various components results in the "cost of hardening" curve indicated on Figure 2. This function generally has a plateau between about 50 ft. standoff and the limit value for the relevant level of protection. At closer standoff, costs usually increase rapidly due to increased framing requirements. At larger standoff values, costs decrease to a plateau where conventional design requirements may govern.

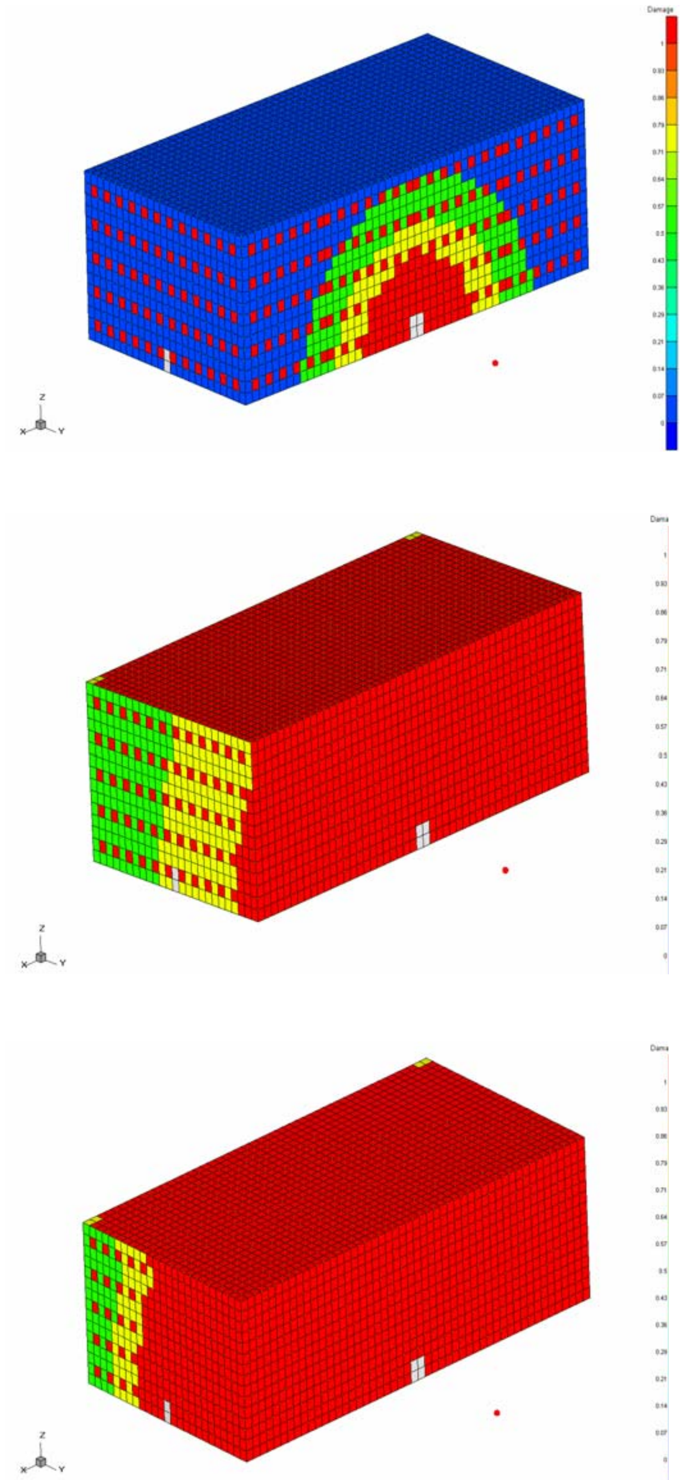
One cost component that increases with increasing standoff is that for land (site area) and perimeter protection. For example, to provide increased standoff, the distance to the defended perimeter must increase, thereby increasing the area of the site and the length of the perimeter that must be protected.

Finally, adding the cost of hardening and the cost of land and perimeter protection results in the general function indicated as "Total Protection Cost". At standoff values within the “limit”, the risk continues to increase with decreasing standoff. Figure 2 illustrates general characteristics of the cost and risk functions. Actual relative magnitudes and significance of individual cost components vary for each case considered, i.e., these relationships will be different for each building and site considered.

As one can see, considerable research has been done to determine the optimal standoff distance that balances a reduction of risk with reasonable cost. This research and information is critical, particularly in the design of new facilities and site selection. However, these figures represent trends for more modern “conventional construction” and the results vary based on the actual design of a facility. It is also important to point out that these figures do not necessarily represent existing construction. Although the general trends may be the same, the optimum standoff distances will vary substantially based upon the myriad types of different construction techniques that have been used on existing facilities.

For example, Figure 3 represents how differing construction materials and techniques can affect the performance of a facility in a blast environment when the threat (blast size and standoff) remains constant. All structures are subject to 500 lb TNT explosion at a standoff of 50 ft. The color coding indicates the level of damage to the facility with blue representing no damage, green and yellow representing various degrees of repairable damage, and red representing total destruction or collapse.

As one can see, there can be dramatic differences in the level of damage based on construction materials and techniques. In Example 1, the facility structure and exterior walls perform well and provide protection of occupants and assets. In Example 2, however, the facility experiences a complete collapse of the roof and exterior walls facing the threat and provides very little protection of staff and occupants. Finally, the facility in Example 3 is almost completely destroyed and provides basically no protection to staff and assets.



Example 1: Cast-in-place concrete structure – 12-inch walls with 0.50% steel. Roof consists of 8-inch slabs with 0.60% steel.

Example 2: Pre-cast concrete structure – 8-inch walls with welded wire mesh (0.13% steel). Roof consists of 1 5/16-inch metal deck over open web steel joists supported by rolled steel beams.

Example 3: 8-inch steel frame wall with CMU infill. Roof consists of 1 5/16-inch metal deck over open web steel joists supported by rolled steel beams.

Figure 3. Impact of Construction Type on Building Performance During a Blast

As demonstrated in Figure 3, different construction types and methods provide varying degrees of performance and levels of protection. Therefore, the standoff distances required to adequately protect these buildings cannot be constant and must also vary. Figure 3 also demonstrates that the only way to determine if the standoff is actually providing adequate protection of a facility is by analyzing the performance of the building in a blast environment.

Unfortunately, not everyone performs a blast analysis when designing and constructing perimeter security barriers for their facility. Many owners may place barriers at the easiest available location and others may follow some form of prescriptive design process by misinterpreting security requirements such as the ISC Security Design Criteria. These criteria apply to new construction or major modernization efforts and are not intended to be used, alone, for determining the requirements of perimeter security barriers.

For example, Chapter 2, Site Planning and Landscape Design, of the ISC Security Design Criteria provides designers with guidance for planning perimeter security barriers. This chapter provides recommended standoff distances (based on level of protection) found in Part II of ISC Security Design Criteria. Many security consultants, building owners, designers and reviewing agencies view this as the only requirement for determining standoff location of barriers. As Figure 3 demonstrates, without a blast analysis of the facility, following a prescriptive process for locating a barrier system may lead to an ineffective system. The following is a quote from Chapter 2 of the ISC Security Design Criteria:

> *The minimum distance from a building to unscreened vehicles or parking is ______ (project-specific information to be provided). On any given site, the recommended distance may not be available. In that case, address the identified threat by using countermeasures such as perimeter barriers and street furniture (see below), structural hardening (see Chapter 4), and parking restrictions (see Chapter 9); relocation of vulnerable functions within or away from the building; and operational procedures, such as tighter access control.*

Note that the ISC Security Design Criteria requires a combination of measures to mitigate the impacts of a bomb blast in addition to a "recommended" standoff distance because the criteria recognizes the reality that the recommended standoff may not always be available. Additionally, the ISC Security Design Criteria, and the recommended distances provided, are intended for new construction, when a combination of measures are more easily applied. Ultimately, without analyzing the performance of the facility to be protected, designers may be designing barrier systems that are ineffective or inadequate to protect the facility.

Performance Based Design

The remainder of this paper is dedicated to the decision process and techniques required to design useful and effective perimeter security barriers for existing facilities. The methodology will be broken into five steps that take a planner through analysis, decision-making, and design:

Step # 1: The Risk Assessment
Step # 2: The Blast Analysis
Step # 3: Develop Minimum Standoff
Step # 4: Compare to Available Standoff
Step # 5: The Design

The "performance" of the facility in a blast environment will be the foundation of this process. Although the process is not dependent upon any specific criteria, it will be shown that the ISC Security Design Criteria, though intended for new construction or major modernization, can be used to adequately and effectively design perimeter security barriers for existing facilities.

It is important to note that complete blast mitigation for adequate protection will rarely be achievable solely through the use of perimeter security barriers and standoff. Some level of facility hardening, glass hazard mitigation at a minimum, will be necessary to adequately achieve facility and staff protection. This process assumes some level of hardening and is intended to minimize damage to a facility's structure and exterior wall systems. This process will examine:

- The value or need of a security barrier system.
- The minimum standoff required for adequate protection of a facility's structure and exterior wall systems and to minimize facility hardening.
- The optimum location for a barrier system to minimize the impact on cost, architecture, public space, and historic and cultural preservation.

Step 1, The Risk Assessment

Before determining the need for any security measure for a facility, a risk assessment should be performed to determine the threats against the facility, the consequences of a successful attack or incident, and the vulnerability of the facility to the threats and their tactics. Specifically, the ISC Security Design Criteria requires two outputs from the risk assessment:

1. Design Basis Tactics: These are the particular criminal or terrorist tactics or acts, such as vehicle delivered bombs, to which the facility must be designed.

2. Level of Protection Designation: This designation quantifies such aspects as target attractiveness of the facility, consequences of a successful attack, and collateral damage potential and determines the performance requirements of security countermeasures (to include whether they are even required) to protect the facility. For the ISC Security Design Criteria, the designations are Minimum, Low, Medium, or High.

These two products together determine whether perimeter security barriers are justified as an appropriate countermeasure (against the threat of vehicle delivered bombs) for a particular facility. However, they do not quantify the effects of blast on a facility, nor do they establish the vulnerability or consequences of a successful attack against the facility. To complete the risk assessment process a blast analysis (based on the threat charge size) of the facility must be performed to quantify the consequences of an attack and determine if perimeter security barriers, or other measures like facility hardening, can improve the performance of the building.

Step 2, The Blast Analysis

NOTE: This is the most critical step of this process and it is important that it be performed by qualified personnel. The ISC Security Design Criteria states that if blast protection is required, then a blast consultant must be included as a member of the design team. He/she will have formal training in structural dynamics, and demonstrated experience with accepted design practices for blast resistant design and with referenced technical manuals.

For the purposes of perimeter security barrier design, the level of protection designation from the risk assessment determines the appropriate blast charge sizes (found in Part II of the ISC Security Design Criteria) to which the facility must be analyzed, and the allowable level of damage to a facility's structure and exterior wall systems. However, the ISC does not require that the same level of protection designation be used for both the charge size and the facility performance. The facility risk assessment should identify the appropriate level(s) of protection for each.

Working with the advice and guidance of a blast consultant, facility owners must determine the appropriate protection level (for allowable damage) for each portion of the facility. This determination is the essence of the "performance" based design process and is the key input of the owner of the facility. It may be difficult for some owners to determine "how much damage is allowable" for the facility. Owners should realize that total protection is likely not possible for existing facilities, and some acceptance of risk is unavoidable. Although this process may be difficult, owners should realize that this process is a more thoughtful and conscientious way of designing perimeter security barriers, rather than blindly following a prescriptive standoff distance that may, or may not, be appropriate for their facility.

The following are the protection level definitions from the ISC Security Design Criteria:

Major damage. The facility or protected space will sustain a high level of damage without progressive collapse. Casualties will occur and assets will be damaged. Building components, including structural members, will require replacement, or the building may be completely unrepairable, requiring demolition and replacement.

Moderate damage, repairable. The facility or protected space will sustain a significant degree of damage, but the structure should be reusable. Some casualties may occur and assets may be damaged. Building elements other than major structural members may require replacement.

Minor damage, repairable. The facility or protected space may globally sustain minor damage with some local significant damage possible. Occupants may incur some injury, and assets may receive minor damage.

It is important to note that the protection level (for allowable damage) does not have to be the same for the entire facility. The facility risk assessment should identify those portions of the facility that require higher (or lower) protection levels based on staff location, facility mission, and assets.

One of the most effective methods of blast analysis requires the blast consultant to develop a computer model of the facility on which to perform the analysis. A detailed survey of the facility and its structure is required to gather this information in order to build this model.

Using this computer model, the required performance level(s), and the test charge sizes a qualified blast consultant can simulate various blast scenarios around the perimeter of the facility. The number of blast scenarios will vary based on the size and shape of the facility. However, for a simple rectangular shaped facility, a minimum of four scenarios should be developed; one for each side of the facility. In essence, the blast consultant simulates an explosion, at the furthest available location from the facility (available standoff), to determine the effects of the blast on the facility. This simulates the value a perimeter barrier system may have in defending the available standoff. Owners may also want to evaluate the performance of the building with no standoff to further quantify the value of perimeter vehicle barriers. After the blast scenarios have been completed, the blast consultant can compare the results to the required performance levels determined earlier.

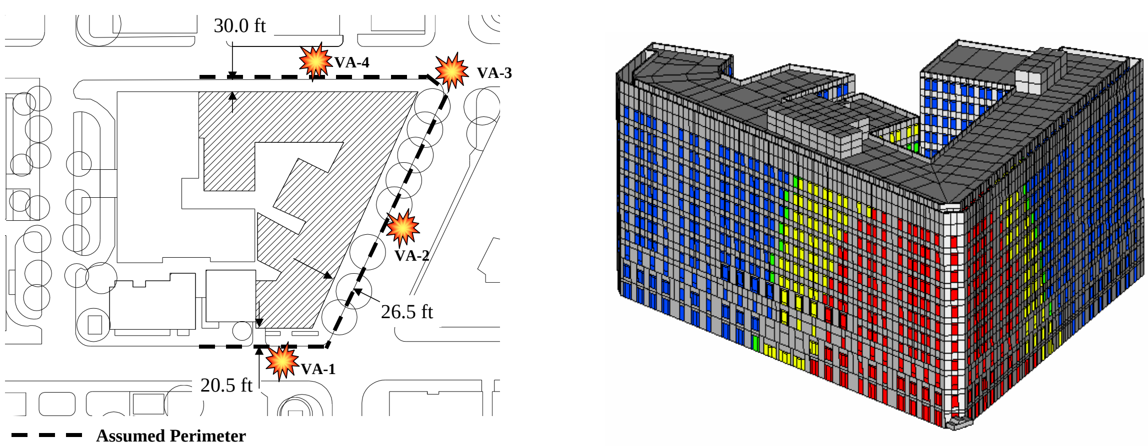


Figure 4. Example of a Blast Analysis

Ultimately, the goal of the perimeter barrier system is to minimize the need for substantial structural hardening of the facility. As was shown earlier in Figure 2, the cost of structural hardening, particularly at smaller standoffs, is substantially higher than that of perimeter barriers. However, complete protection with just standoff is not likely on existing facilities. Therefore, owners should maximize the use of standoff and perimeter security barriers to protect the facility's structure and exterior wall systems while trying to limit facility hardening to measures such as glass hazard mitigation. Although, mitigating the dangers of flying glass can be costly (particularly in historic structures), these measures are substantially less intrusive and less expensive than hardening of a facility's framing or exterior wall systems.

As the blast consultant compares the blast analysis results to the desired performance levels, facility owners should keep these factors in mind and ask their consultant to frame their results accordingly. Ultimately, the comparison will result in one of several situations:

1. The available standoff is inadequate to achieve the desired performance level of the facility without additional substantial facility hardening. Major renovation and hardening of the facility is required.
2. The available standoff allows portions of the facility to achieve the desired performance level of the facility, while other portions cannot without a major renovation. Partial hardening is required.
3. The available standoff is adequate to achieve the desired performance level of the facility without substantial facility hardening. No substantial structural hardening is required.

At this point, the risk assessment (in regard to the threat of vehicle delivered bombs) can be completed because the vulnerability and consequences of a successful attack have been quantified. A wide variety of potential countermeasures such as vehicle screening, facility hardening, staffing additions, and perimeter vehicle barriers should have been identified (with estimated costs) for owners to evaluate risk and the expense of mitigating the risk. Owners should begin managing this risk through a combination of short term mitigation measures, risk acceptance, and long term risk mitigation measure planning. Generally, perimeter vehicle barriers would fall into the latter category if owners feel that the threat justifies the expense of the mitigation measure and do not wish to accept the risk. If owners feel they want to pursue a perimeter vehicle barrier mitigation strategy, then further analysis is necessary to support their design.

Step # 3, Develop Minimum Standoff

The first part of the design process begins with further analysis of the facility. In this case the goal is to develop a minimum standoff that is necessary to achieve the desired facility performance. Using the same computer model, required performance level(s), and the test charge sizes identified earlier a qualified blast consultant can develop minimum standoff locations for a barrier system that can achieve the desired level of performance.

When all analyses have been completed, minimum standoffs (at least one for each side of the facility) shall have been determined. It is possible, and very likely for some facilities, that the minimum standoff may vary as one moves around the perimeter of the facility. The shape and construction techniques in various portions of the facility can affect the performance, and therefore minimum standoff, of the facility. Additionally, if different protection levels were identified, one would also find various minimum standoff distances around the facility.

Step # 4, Compare to the Available Standoff

Situation 1: One can already assume that for Situation 1 in Step # 2, that the minimum standoff will exceed the available standoff for the site. In this undesirable situation, some owners may have, because of their location, the flexibility to improve performance. In essence, these options all involve the attempt to gain more standoff and include:

- Purchasing more land or adjacent facilities
- Closing adjacent roadways
- Moving adjacent roadways

In all cases, these options will likely involve some additional expense in construction cost, public right-away, transportation impact, or cultural preservation that will substantially reduce the value of perimeter security barriers or make them impractical to implement. Owners must consider these factors and costs when analyzing the risk to their facilities. Generally, except for very high risk facilities, these will not be options (especially in urban environments) and facility owners must consider that installing perimeter security (by themselves) will not substantively reduce the risk to their facility. This performance based process determines the minimum standoff needed to achieve the desired performance of the facilities and assumes a certain charge size when doing so. In reality, a larger standoff distance is always desirable because an actual direct threat against the facility can easily carry a larger charge size than the one used for the analysis. The ISC Security Design Criteria has adopted a rational and prudent approach to concentrate protection against collateral damage and to mitigate the adverse effects of a direct attack while recognizing that some damage will occur and some level of risk is to be accepted. In other words, if owners cannot achieve the required performance by using the charge sizes referenced in the ISC Security Design Criteria, then that performance is likely unachievable without a major renovation of the facility to improve the performance of the structure and exterior wall system.

If facility owners feel that a major modernization, based solely on the need for mitigating the risk of a vehicle bomb, is warranted, then the perimeter security barriers should be designed and planned in conjunction with a facility modernization project to optimize the blast design. Except for very high risk facilities, this expense is usually not justified. However, if a facility has a renovation planned (for other reasons), then adding the requirements of blast hardening and perimeter security barriers, to this planned renovation project, may be financially prudent.

Owners may still feel that installing perimeter security barriers may provide a deterrent to potential attacks. As previously mentioned, it is difficult to quantify the security value of deterrence. However, if owners still feel that deterrence is justified, then they may wish to consider installing less robust, non-rated barriers to minimize the substantial construction costs of rated (to meet certain performance criteria like the ISC Security Design Criteria) systems. Most security experts would not recommend constructing barriers solely for the purpose of deterrence, nor would they recommend constructing non-rated systems. In any event, whether the barriers are rated or not, owners would still be spending a substantial amount of money on a measure that is just a deterrent.

Finally, owners may still be concerned with vehicles driving into vulnerable portions of the facility such as underground parking and lobbies (or other areas with large ground floor windows). Generally, these vulnerabilities can be reduced more efficiently than ringing an entire facility with a vehicle barrier system. It is important to keep in mind that in this situation the blast analysis already has proven attackers do not even have to enter the building to produce an unacceptable level of damage.

Ultimately, most facility owners who find that the minimum required standoff is unavailable must face either accepting the risk of vehicle delivered bombs or moving their operations because perimeter vehicle barriers offer no real protection.

<u>Situation 2</u>: For Situation 2 in Step # 2, owners will find that in some cases the available standoff exceeds the minimum standoff for some sides of the facility, but does not for other sides of the facility. Owners must decide, with the advice and guidance of their blast consultant, if enough of the building performs adequately to justify the expense of a barrier system.

If the building, in general, performs adequately, owners should proceed to Step # 5 and proceed with design. If the building does not, in general, provide the necessary safety to the staff and mission of the facility, then owners should consider the options in Situation 1, (i.e., accept the risk or move their operations).

<u>Situation 3:</u> For Situation 3 in Step # 2, the available standoff will be greater than the minimum standoff and this performance based process has proven that perimeter vehicle barriers can successfully be deployed to reduce the risk of vehicle delivered bombs at the facility. At this time, owners should proceed to the design phase to develop their perimeter vehicle barrier systems.

NOTE: If the minimum required standoff is equal (or very close) to the available standoff, facility owners should continue with the planning and design of their perimeter security barriers for the minimum standoff location (available standoff in this case). Although, the blast analysis process is scientific, certain assumptions are made when constructing the facility model. Additionally, assumptions are made in the development of the test charge sizes that result in a certain level of tolerance on either side of the minimum standoff location. However, designers and reviewing officials must be warned that any substantial deviance, during the design process, that reduces the standoff of the facility may result in an unacceptable performance of the facility and create a situation similar to that of Situation # 1. Owners, designers and reviewing officials must consult their blast consultant to determine the impact of such decisions. A revised blast analysis may be required.

Step # 5, The Design

This process has, by and large, been intended to support decision makers in determining the need for, and the location of, perimeter vehicle barrier systems. It will not address any specific architectural or engineering requirements of the barrier systems themselves. However, during the design process there are several issues, as the design develops, that could influence the location of the barriers and the success of the design.

The Design Team: As previously mentioned, the installation of perimeter vehicle barriers can be considered to have a detrimental effect on urban communities. Therefore, it is important owners select architects and team members that have considerable experience in urban design, historic preservation, and landscape architecture. Additionally, a key member of the design team should be a blast consultant who can advise, throughout the design process, on various barrier locations and the location's potential impact in regard to the performance of the protected facility from a vehicle delivered bomb.

The Design Process: The purpose of establishing a minimum standoff distance(s) for the facility was to provide a ***range of distances***, between the minimum standoff and the available standoff, in which the barrier system could be placed and attain the performance goals of the owners. By providing this ***range of distances***, it is possible to give the design team some flexibility in implementing an appropriate, conscientious design that mitigates the risk to the facility, but also minimizes impact of the barrier system on its environment. Having said that, the blast assessment is based on "assumed" charge sizes that are products of the risk assessment and application of the ISC Security Design Criteria and it is altogether possible, in the event of a direct attack, larger charges could be used. Simply put, every foot counts and the design team is strongly encouraged to begin the design process by locating the barrier system at the available standoff location. By taking advantage of the available standoff, the risk to the facility will have been mitigated as much as possible. However, there are other issues that require mitigation, as well as risk, when planning a barrier system:

- Cost: A very real aspect of every design and construction project is cost. It is particularly important when managing risk. As the cost of a particular countermeasure (i.e., perimeter vehicle barriers) increases, the value of the measure decreases. Mitigating the most risk for the minimum amount of money is one of the basic principles of risk management. Therefore, designers must always consider ways to mitigate cost when designing a vehicle barrier system. Some items to think about include:

    - Perimeter Length: As shown earlier in Figure 2, as standoff increases, the area of the site and the length of the perimeter that must be protected also increases, thereby driving up the cost of the barrier system.

    - Use of Existing Features: Taking advantage of existing landscape elements or features that can perform as perimeter vehicle barriers, and fall within the acceptable ***range of distances*** can substantially reduce the cost of construction. However, it is important to note that this would be acceptable only after a detailed analysis by structural engineers to determine the landscape element's ability to defend against the threat size vehicle. Owners must consider how much risk they are willing to accept by using existing, unrated systems.

- Utilities and Underground Elements: The very robust underground structure of perimeter vehicle barriers often conflicts, particularly in an urban setting, with underground utilities and tree roots. The cost impact of relocating utilities is usually quite prohibitive and the barrier system may need to be located to minimize the impact. Additionally, the limited amount of green space in cities makes damaging tree root systems particularly unattractive to facility owners and city residents.

- Public Space: The design team must be aware of the importance of protecting public space from the potential adverse impacts of perimeter vehicle barriers on a community's need for mobility, mixed use development and activated street level activity to protect and enhance its economic vitality. It is important to strike a balance between physical perimeter security for buildings and the vitality of the public realm. If the ***range of distances*** allows, designers should consider placing the barrier system within the facility yard, rather in public space.

- Architecture and Historic Preservation: "Good Architecture", particularly when designing security elements can be a very subjective term. Like works of art, not everyone appreciates the same forms. Although the relatively limited number of rated barrier designs does present a challenge to a design team, the introduction of perimeter security barriers, in some cases, can be viewed as an opportunity to improve or bring character to an otherwise barren landscape. Having said that, a popular architectural concept when designing perimeter security barriers is to minimize the elements and/or make them as "invisible" as possible. This is particularly desirable when dealing with historic facilities and landscapes. It is important to consult with experts in historic preservation and public space to minimize or eliminate any detrimental effects a barrier system may have on a historic facility or landscape. In the Federal facilities community this is accomplished through the National Historic Preservation Act's Section 106 review process.

  One potential strategy for achieving this "invisible" character for a barrier system is to use existing features as the barrier system. This concept was mentioned earlier as a possible cost savings measure. However, even if the existing feature is not robust enough to stop the threat size vehicle, this concept can help to mitigate architectural or historic preservation impacts. Existing features such as walls, planters, fountains, and others can be improved or replaced to meet the performance requirements of a rated system. Even making an existing feature larger is often better than adding an entirely new element to a landscape.

However, in lieu of any overriding public space, architecture, or historic preservation concerns, and no existing features within the range of distances, the barrier system should be placed at the available standoff distance to minimize the risk to the facility and staff within.

- <u>Approach Angle and Speed:</u> The speed of a vehicle, and its angle of approach, at the point of impact on a vehicle barrier is a major parameter in determining the required performance of the barrier. Although this paper is not specifically addressing the design of the barriers themselves, controlling the speed and angle of approach of a vehicle is an important concept in a performance based design and should be fully explored by the design team. Designing obstacles that control speed (or analyzing the possible attainable speeds on the existing site) can allow the design team to develop smaller, lighter barriers within the ***range of distances***. More importantly, for the purposes of this paper, this approach can have a significant impact on the location of the barrier system. A "layered" approach to the barrier design can potentially increase the opportunity to use existing landscape elements either as the barrier system or an obstacle to control speed.

Figure 5a and 5b show how the design process may be applied to an existing facility. Figure 5a shows an example building where the ***range of distances*** has been developed from a blast analysis. The available standoff is located at the street/sidewalk border and the minimum standoff (to achieve the desired facility performance) is indicated by the dashed red line. One should note that the standoff is not the same around the entire facility. In this example the owners desired a higher level of performance for the Child Care Center located on the east side of the facility. Additionally, there are an existing retaining wall (on the west side of the site) and a low planter wall (on the south side of the site). Both elements have been extensively analyzed by a structural engineer and the existing retaining wall on the west side was found to be adequate to protect the site from the threat vehicle size while the planter wall on the south side was not.

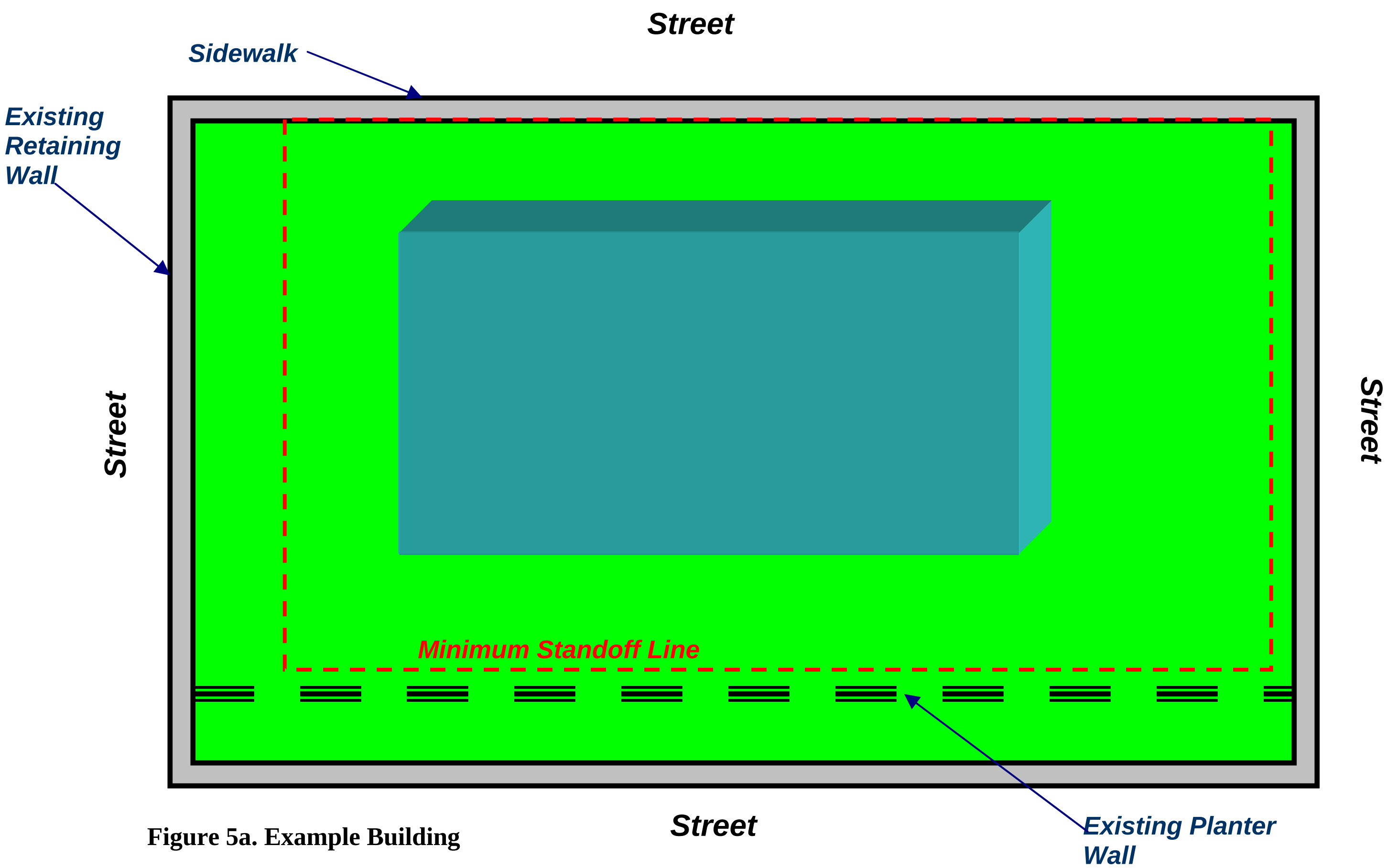


Figure 5a. Example Building

The white dashed line in Figure 5b demonstrates where the perimeter barrier location may be located using the performance based design methodology. On the north side of the facility the barriers were located at the minimum standoff location, yet within the available standoff distance to minimize the impact on the public right-of-way. On the east side, where there are no existing landscape elements, the barrier is located at the furthest location from the facility that is not in the public right-of-way. On the south side, the barrier is located at the location of the existing planter wall. The planter wall will have to be reinforced (or replaced) to protect against the threat vehicle size, but this location minimizes the impact on the architecture and historical preservation of the site. On the west side, the barrier is located at the existing retaining wall to minimize the construction cost, impact on architecture, and impact on historical preservation. However, the barrier does cross the public sidewalk at two locations to make this possible.

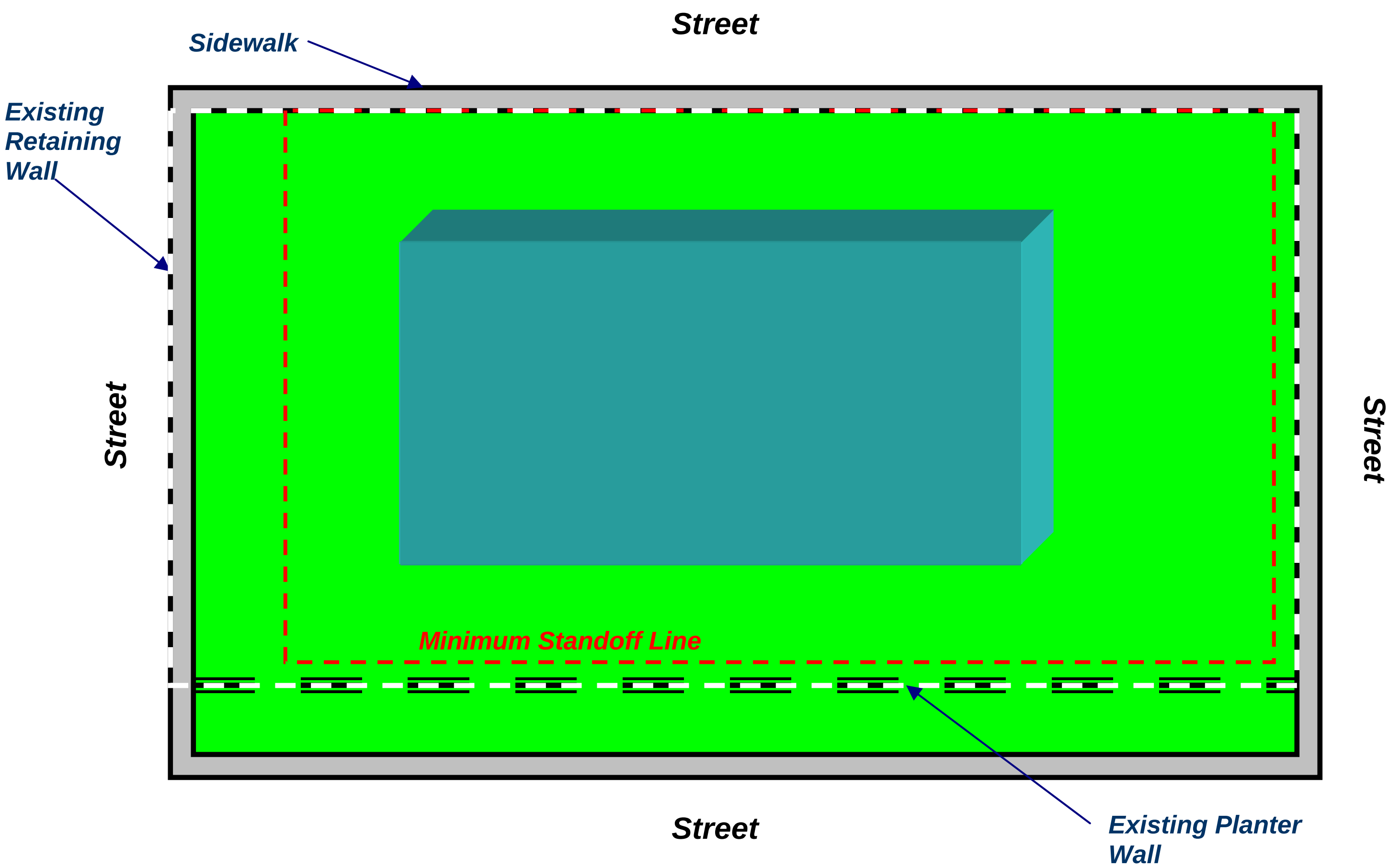


Figure 5b. Example Building with Barrier Locations

As demonstrated in Figures 5a. and 5b., balancing the many issues and requirements (often conflicting) of a perimeter barrier system design can be very difficult. It has been shown that there are several justifiable reasons for moving the barrier system within the available standoff distance. However, every foot of standoff is important and reducing the standoff should not be done lightly. Additionally, it is imperative that the barrier system stay within the ***range of distances*** calculated and never broach the minimum standoff distance. In essence, this would render the barrier system ineffective in a performance based process.

Conclusion

When all is said and done in the design process, the facility owners should have all of the information necessary to complete a cost versus benefit analysis that compares the risk to the facility (and residents) to the cost of the perimeter barrier system. In addition to the financial cost of construction of a system, there can be a significant cost to architecture, historic preservation and the public right of way. The design process should have helped quantify these costs to the owners. Owners must then determine if the risk to the facility justifies the expense of building the perimeter barrier system. Ultimately, owners should seek to strike a balance among the many conflicting issues and tradeoffs.

It has been demonstrated that analyzing a facility's performance in a blast environment is the only way to quantify the value of a vehicle barrier system and justify its need to budget offices, facility owners, and reviewing agencies. Additionally, it has been shown that every facility is not alike and cannot be treated alike when dealing with risk mitigating issues. Even within the same facility there can be differences in performances (both existing and desired) that can drive varying standoffs around a facility. Finally, it has been shown that a performance based decision and design process is really the only way to determine where a vehicle barrier system should be located and if it really can reduce the risk to a facility.

The process outlined in this paper is theoretical in nature. In real perimeter barrier design projects, the existing circumstances may not require all of the steps outlined here, or may require more steps to supplement the decision making and design process. Additionally, forms of blast analysis (other than computer modeling) exist that could support this process.

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