CPNI
Centre for the Protection of National Infrastructure

Chapter 11 – Vehicle-borne threats and the principles of hostile vehicle mitigation

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Vehicle-borne threats and the principles of hostile vehicle mitigation

Introduction

Vehicle-borne threats range from vandalism to sophisticated or aggressive attack by determined criminals and terrorists. The payload capacity and mobility of a vehicle can offer a convenient delivery mechanism for a large explosive device. Hostile vehicles can be parked, manoeuvred or rammed into or out of a target location.

The choice of vehicle and driver by those with hostile intent can also assist in it not being challenged en route and, if either or both are familiar to personnel with responsibility for security (e.g. a known delivery driver and their usual vehicle), it can help to deceive surveillance or assist in gaining entry to sites.

Methods employed to gain entry or exit from a site can also involve surreptitious tampering with the barrier systems or their control apparatus, or the targeted placement of small explosive charges to breach the integrity of a barrier structure. Clear definition of the threat and the potential attack *modus operandi* (MO) should be considered when deciding which to defend against and consequently the most commensurate countermeasures.

In order to calculate the blast loading on a structure (whether to design a new structure or to assess the blast effects on an existing structure), two fundamental factors need to be established:

1. mass and type of explosive charge
2. distance to the target (stand-off).

Traditionally, stand-off distance has been defined on the assumption that the detonation will occur at a set distance from the target, e.g. at the site boundary (when typically delineated by a perimeter fence) or at the edge of the kerb in a city centre location.

Previous attacks using a vehicle-borne improvised explosive device (VBIED) have typically involved vehicles parked legally and illegally, or parked in a location where a vehicle would not be completely out of context (e.g. the lorry used in the Manchester city centre bombing in 1996, or the taxi used in the attack of the BBC in London in 2001). However, the MO for terrorist attacks using VBIEDs has changed to include determined terrorists prepared to use the vehicle to deliver the explosive device as close as they can to the target, i.e. either into the building, or as close to the building façade as possible.

Worldwide terrorist action including suicide VBIED (SVBIED) attacks in Iraq, Afghanistan, Pakistan and Bali, and the attack on the British Consulate in Turkey in 2003 illustrate the shift to this penetrative methodology. In June 2007, an attempt was made at Glasgow Airport to ram a vehicle into the terminal building, which although not entirely successful, demonstrated the vulnerability of infrastructure to hostile vehicle penetrative attack.

The assumption must therefore be that a site with a conventionally secure perimeter (i.e. one that is resistant against pedestrian intruders), can no longer be considered to have a perimeter that is enforceable against the full range of vehicle-borne threats. Therefore, the fundamental requirement when commencing the design or the assessment of any structure to resist an external VBIED is to define the minimum stand-off distance required to protect the building against the blast threat, and to ensure that this distance is *enforceable* against hostile vehicles.

If it is considered that the first point of challenge of a VBIED is likely to be the point of detonation, the consequential effects on the protected building(s) and, in some instances, on the surrounding buildings and utilities, should be assessed using the methods set out in the earlier chapters.

The successful deployment of vehicle security barrier (VSB) systems, although seemingly simple, often requires a good degree of negotiation and compromise in design. Security, business and safety needs are not always mutually compatible, and added to this are the engineering constraints that generally materialise during project feasibility, design and implementation stages.

It can be remarkably difficult to mitigate all forms of vehicle-borne threat MO while satisfying other business needs. At the highest level, striking this balance requires consideration of many factors, some of which are illustrated in Box 11.1.

It is therefore extremely important that a security Operational Requirement [1] is developed, defining the need for the deployment

Box 11.1. Considerations for mitigating vehicle-borne threats

Security
Security risk attitude
Attack MO to be mitigated
Proportionate countermeasures
Potential response to increased threat
Enforceable stand-off distance

Business needs
Lifetime cost (operation and manpower)
Traffic management
Appearance
Internal and external stakeholder requirements
Vulnerabilities due to safety concerns or systems

Engineering constraints
Architectural
Structural
Foundations
Public realm design
Buried services/utilities
Land ownership and available space
Planning consent

of VSBs and the security parameters around which they should be deployed and operated. In conjunction with the security Operational Requirement, a User Requirement Document (URD) should also be developed. This document addresses additional business needs relating to the deployment and may include environmental factors, working conditions, maintenance and service regimes, highway and traffic management issues, liaison with particular stakeholders, planning and design parameters etc. The development of each document requires input from key stakeholders from the outset.

Security, safety, project design and implementation risk assessments should be produced by the stakeholders as early as possible. This early engagement with the stakeholders also facilitates the development of business cases and will help identify potential issues, associated costs and constraints. In doing this earlier, expensive problems can be averted later.

Types of vehicle-borne threat

There are five main types of vehicle-borne threat. All can be deployed with or without the use of suicide operatives.

1. *Parked vehicles*. Parking for unscreened vehicles adjacent to a site or in underground parking facilities can pose a significant problem in terms of reduced confidence and reduced blast stand-off distances. If the same or an identical vehicle has been deployed empty on days prior to the attack in a similar location then familiarity to the guard force surveillance or patrols can lead to a less stringent response and vital evacuation time may be lost should the vehicle be hostile and the device detonate.
2. *Encroachment*. Encroachment is where a hostile vehicle is negotiated through an incomplete barrier line without the need to impact.

   A dilemma exists in the design of barriers where unfettered pedestrian access is required. This is because gaps wide enough to cater for pedestrians and mobility/disability needs will also allow a virtually clear access to very narrow vehicles, such as bicycles and motorcycles. Although there is a reduced payload capacity on such vehicles compared to that carried by four-wheeled vehicles, it may still be a larger device than that deliverable by a pedestrian.

   An alternative form of encroachment attack is exploitation of an active barrier system at a vehicle access control point (VACP) by a hostile vehicle 'tailgating' a legitimate vehicle. The only effective way of countering such attacks is by the use of an interlock system using two lines of barriers. However, this has a consequential adverse effect on legitimate vehicle transit times and flows.
3. *Penetrative attacks*. Penetrative attacks use the front or rear of the hostile vehicle as a ram and have typically been used for criminal activity and, more recently, terrorist attack to breach target premises. The analysis of likely hostile vehicle type in terms of their structure, mass, velocity and manoeuvrability will directly affect the design of suitable countermeasures.
4. *Deception techniques*. Deception techniques prey on human weaknesses. For vehicle-borne threats this may be by using a 'Trojan' vehicle (one whose model, livery or registration is familiar to the site), or by hostile occupants negotiating their way through by pretence, or by using stolen (or cloned) access control or ID passes. Alternative scenarios include an unwitting 'mule', a driver unknowingly delivering an improvised explosive device (IED) surreptitiously planted in their vehicle by an attacker, or an 'insider' bringing an IED in to their own work site.

Traditionally, sites have been designed with the notion that only 'consensual' visitors will arrive at the VACP and errant vehicles have been managed by allowing them to U-turn within the site or by reversing legitimate queuing vehicles back on to a public highway to allow the errant vehicle back from the barrier. The design of a VACP to include a rejection lane can improve traffic management and reduce the necessity to open a barrier and allow access to an errant or potentially hostile vehicle.

5. *Duress techniques*. Duress against the driver of a legitimate vehicle who is forced to carry an IED or duress against a guard controlling a VACP are perhaps the most difficult forms of vehicle-borne threat to mitigate. Risk management strategies can include removing control of the barrier from the guard force at the VACP or designing a site for total vehicle exclusion and adequate enforceable blast stand-off even for staff and delivery vehicles.

Layered attack scenarios

Site design can also accommodate countermeasures for layered attack scenarios using one or more of the above threat types, for instance the use of a first hostile vehicle to create a gap by way of penetrative attack or blast which then allows a second to encroach through.

Balancing enforceable blast stand-off with building resilience

For most new-build designs, there is scope to accommodate either sufficient blast stand-off distance in their layouts or enhanced robustness in their building construction. However, for most existing sites or for some new-build designs on existing constrained sites, building, financial and logistical constraints can compromise the effectiveness of the security measures. Therefore risk management of the vulnerabilities is necessary, and this normally takes the form of enhanced retro-fit protection measures with screening procedures to ensure the legitimacy of staff, pool or routine delivery vehicles etc.

The stand-off distance used as the basis of the design for blast hardening of a building must be enforceable, i.e. no hostile vehicle should be able to gain access beyond the blast stand-off barrier line. Achieving an enforceable stand-off distance is likely to lessen the blast hardening measures required for the building and associated costs. It should be noted that the costs associated with hardening a building due to lack of enforceable blast stand-off can be significantly greater than installing hostile vehicle mitigation (HVM) measures at a suitable distance, and therefore that stand-off is the single biggest beneficial factor in protecting against vehicle-borne IEDs. This is particularly the case for new or refurbished builds. Each site should be assessed on a case-by-case basis as land costs, ownership and the other factors highlighted in Box 11.1 will affect this balance between stand-off, blast hardening and business needs.

Site assessment for vehicle-borne threats

Each site will require a specific assessment before HVM measures can be recommended. The assessment requires the normal 'rules of the road' to be ignored and must be based simply on whether the adjoining land is traversable and, if so, by what vehicles. Congestion, signage and lining should be ignored in such an assessment – tactics by accomplices can relatively easily ensure an empty route to a hostile vehicle. There is unlikely to be hesitation by someone with hostile intent to travel the wrong way along a one-way street or across pedestrianised areas.

Part of the assessment should focus on the calculation of maximum speeds and angles of attack achievable by potentially hostile vehicles. This process is a vehicle dynamics assessment (VDA), which effectively profiles the vulnerabilities to penetrative impact along each approach route. This enables the HVM measures to be designed to an appropriate level, preferably neither over-engineered (for cost-effectiveness) nor under-engineered.

The site assessment should be regarded as a living document. Following installation of HVM measures, it should be reviewed on a regular basis to note changes to the local environs. For instance, demolition of a neighbouring building or changes in the landscape could open up an approach route that did not previously exist or may then allow a fast straight approach that, for certain threat vehicle types, could exceed the capability of the original HVM measures. Equally, neighbouring site activity, security measures and ownership should also be monitored in case these factors affect the performance of the HVM measures and vulnerability of the asset.

Practical site assessment

The enforceable perimeter must be defined and the following considered:

- Ensure that the full extent of the area to be protected is identified.

- How the enforceable perimeter might affect the surrounding buildings in terms of collateral damage in the event of an attack.
- The location of any existing site infrastructure that might suffer collateral damage (e.g. sewers, communication networks, electricity, water and gas services).

It is important to understand the day-to-day operation of the secure site in order to minimise any inconvenience to legitimate vehicles and personnel, including those illustrated in Box 11.2.

Hold and search areas should be designed to have sufficient space for waiting vehicles, vehicle turning movements and rejection lanes. It is

Box 11.2. Issues to consider in practical site assessment

Access
Vehicle access control points
Emergency access points

Types of legitimate vehicle
Cycle
Motorcycle
Car
Van
Vehicle with trailer
Large goods vehicle
Bus
Plant or construction equipment including special loads

Legitimacy of driver, occupant or organisation
Staff, visitors, contractors and disabled users
Delivery/courier services
Refuse collection
Emergency services
Utilities, building, site maintenance or construction companies
Number, flow and travel patterns of vehicles

Operation and procedures
Security manning requirements
Operational procedures
Response procedures
Facilities
Equipment

important to consider whether or not the proposed mitigation measures increase the risk to those with legitimate and authorised access.

Vehicle dynamics assessment (VDA)

The primary assessment for the agreed areas at risk should determine:

- the perceived threat vehicle type(s)
- the normal approach
- the surface of the approach
- the speed that a threat vehicle could achieve
- whether an angled attack can occur
- alternative vehicle approaches
- other surfaces that are traversable.

Determination of the perceived threat vehicle types, potential approaches and traversable speeds should take the following factors into account:

- the road geometry
- camber
- gradient
- corner severity
- clear approach lines and distance
- traversable surfaces (e.g. road, verge, footway)
- ditches (not along barriers)
- ground conditions including seasonal variations
- surface characteristics (e.g. ruts, potholes, loose chippings)
- location of existing objects (e.g. street furniture, trees)
- buildings and retaining walls
- neighbours' adjoining accesses.

Principles of hostile vehicle mitigation (HVM)

Once the vulnerabilities of a site have been assessed, appropriate HVM measures can be proposed by the combination of one or more of traffic management, traffic calming, passive vehicle security barriers or active vehicle security barriers. These measures are discussed further in the subsections below.

Traffic management

For retrofit to a site, designers typically try to accommodate the existing traffic patterns of staff, deliveries and visitors. By doing this the security solutions are usually less effective and more expensive. In practice, a good starting-point should be to manage traffic in such a way that enforceable blast stand-off is created and less traffic has to negotiate VACPs. If pass check personnel are in situ at a VACP then the design of the area should also be such that they are not put under undue pressure or distracted by traffic management requirements. The design of the VACP should incorporate a rejection lane.

There are four main options for traffic management. In order of preference for security against vehicle-borne threats:

(a) *Total traffic exclusion* should be a starting-point in terms of ambitious and effective protection. Car parking remote from the site or asset for both visitors and staff can bring extra confidence. Covered walkways through the car park, or a 'park and ride' facility (depending on relative distances) may ameliorate staff concerns.
(b) *Traffic exclusion coupled with screening* of all vehicles that are allowed into the cordon is the next best option. Less than 100% screening, or a random screening strategy, increases risk. Naturally, if traffic management or guard force activity allows a hostile vehicle through a secure cordon and no internal/secondary protection is provided around critical assets/sub-sites then this would be a risk. Off-site consolidation and screening facilities can offer multiple security benefits by reducing the number of vehicles that need to access a site, increasing confidence in vehicles that arrive at the site, releasing valuable space and moving the first point of challenge of any hostile vehicle to a more remote location. Other benefits in terms of environmental, safety and cost factors may also ensue from off-site screening facilities.
(c) *Traffic inclusion* on a large site is an option, but typically would need to be coupled with individual protection around vulnerable and/or critical assets, thus reducing enforceable stand-off distances.
(d) *Temporary barriers* may be used at times of heightened threat. Although an option for some sites, temporary barriers have a number of drawbacks such as the following:
    - Deployment may be intelligence based.
    - An intelligence-led deployment may indicate to adversaries that there is intelligence about their plans.
    - They may be deployed too late if this is the first attack.
    - The barrier systems require specialist equipment and time to deploy.
    - Unless stored locally, they would normally need to be transported to site.

- They are sometimes less effective against penetrative impact than permanent alternatives.
- Their modular and wall-like nature does not always lend their effective use to undulating or unmade ground.
- Their appearance may preclude their application in certain environments.
- Their mass may preclude their use on elevated slabs.
- Few systems incorporate integral active barrier elements.
- Effective designs tend not to lend themselves to use at sites at which pedestrian routes are not clearly demarcated.
- The need for them to be pedestrian permeable such as at transport interchanges or shopping centres may reduce their structural effectiveness.

The preferred traffic calming and vehicle security barrier solution is highly dependent on location and in most cases will need to be aesthetically adjusted to meet the aspirations of the architect and planning authorities.

Traffic calming

The slowing of traffic has a number of benefits. It gives drivers the ability to better comprehend what is expected of them approaching a VSB, e.g. an active barrier system at a VACP which provides the hard stop to a hostile vehicle penetrative attack. It provides the guard force with more time to assess approaching vehicles and their occupants and affords more scope to react appropriately. Since the vehicle approach speed will be reduced accordingly, this reduced speed can then be used to design an appropriate 'threat matched' VSB. This leads to the possibility of reducing infrastructural and engineering impact costs as well as potentially allowing for more visually acceptable VSB to be deployed.

Traffic calming can be achieved by way of vertical deflections (typically road humps) or horizontal deflections (typically bends or chicanes). The former is typically deployed for safety engineering reasons and relies on the driver consenting to slow down. The latter is more effective for security applications, but such traffic calming has to include non-traversable or anti-ram measures for greatest effectiveness. Horizontal deflections can preclude vehicles with poor turning circles or large swept paths, although parts of the chicane can be designed as retractable or removable for occasional access by such vehicles.

When designing chicanes the key factors to consider are:

- the maximum sizes and swept paths of legitimate vehicles which need to negotiate the chicane
- the dimensions of the road and number of lanes
- the planned exit speed
- the road layout (including any footpath or verge as these may be used by a hostile vehicle unless blocked off)
- the space available for turning/diverting of rejected vehicles.

Definitions used in the design of chicane geometry are given in Figure 11.1. The free view width is the clear gap between the opposing chicane barriers as seen from the approaching driver. (This dimension can be negative if the kerblines appear to overlap.)

The final impact speed at a VSB after the traffic calming is dependent on the chicane design and exit speed, and the vehicle acceleration over the distance to the stand-off measure.

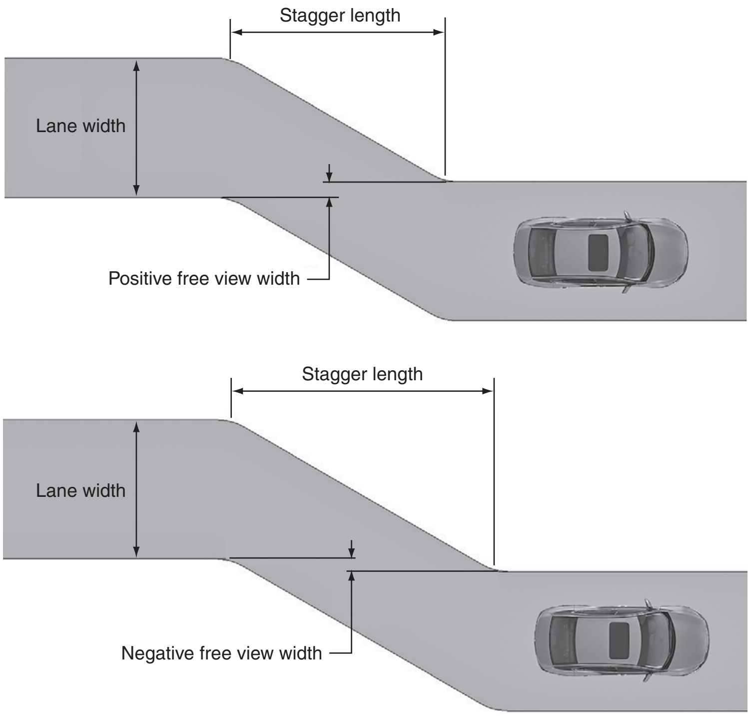

Figure 11.1. Design of chicanes–definitions

Vehicle security barriers (VSBs)

A VSB provides the hard stop for penetrative vehicle attack. VSBs are structural in nature and can be either active (powered or manual) or passive. The development of security barrier systems is ongoing and encompasses a wide range of products. These include:

1. Passive measures (Figure 11.2):
   - static bollards
   - architectural solutions (planters and strengthened street scene furniture)
   - bunds (mounds) and ditches
   - wire rope perimeter systems

Figure 11.2. Example passive vehicle security barriers

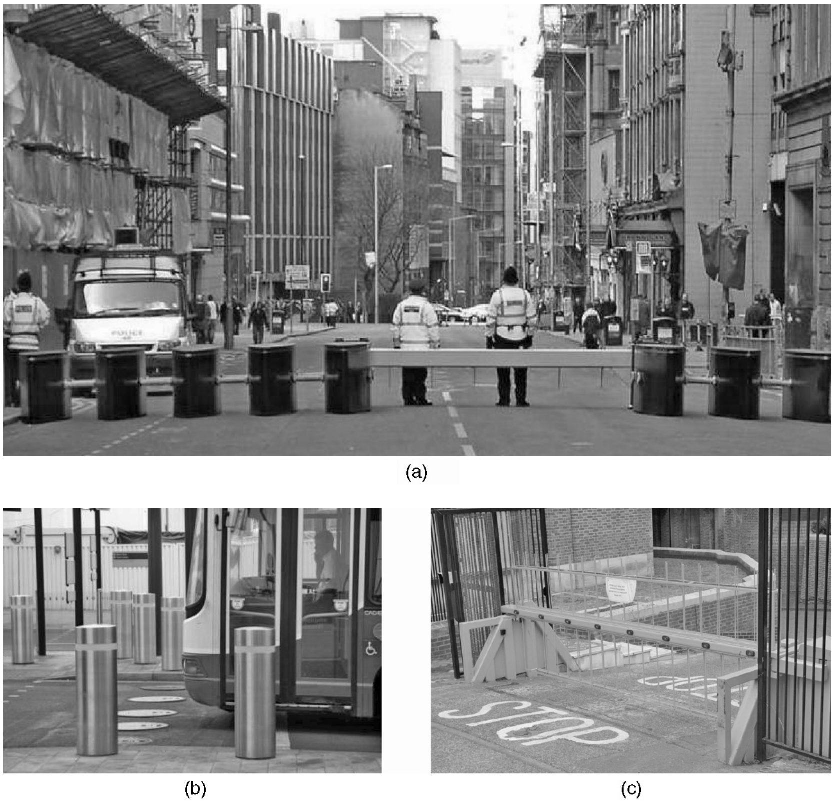

Figure 11.3. Example active vehicle security barriers. (a) Temporary deployment of a modular hinge gate and linked surface-mounted barriers. (b) Retracting bollards with static bollards at kerb edge. (c) Rising arm barrier

- trees of sufficient girth
- buildings or large structural components.

2. Active measures (Figure 11.3):
    - retracting and rising bollards and road blockers
    - rising and dropping arm barriers
    - sliding and hinge gates.

Passive vehicle security barriers

In order to complement and enhance the urban environment, architecturally aesthetic products have been developed to provide stand-off measures. The impact tested architectural solution generally comprises planters and other strengthened street furniture. Planters are typically reinforced concrete structures which are either reliant on gravity, keyed-in to the surface or have a buried foundation, or steel sub-frame structures surface-mounted and located by dowels or resin anchors. Both types of planter are usually finished with an architectural cladding (Figure 11.2(a) and (b)).

Earthworks and environmental features, if well designed, can form part of a protective security strategy. Ditches need to be dug and maintained sufficiently wide to be able to deal effectively with the dynamic characteristics of the approaching vehicle. Bunds (typically mounds of earth) need to be sufficiently high and steep on the attack face to prevent slow speed encroachment typically by four-wheel drive vehicles. Designers need to ensure that profiles account for local material stability, compaction, slump and erosion – the use of geo-textile materials inside the bund may assist with this stabilisation. If reliant on earthworks as a defence measure, good guard force surveillance is still required to ensure that plates are not used by hostiles to bridge a ditch or make a bund face less steep.

Trees of sufficient girth and with adequate rooting are often offered as VSBs, but research has indicated that they are not always as effective in determined vehicle impact as might be presumed. If used, care must be taken to monitor the ongoing health and structural integrity of the trees. Trees will also need to be maintained such that their limbs do not provide an easy climbing aid close to a perimeter fence, and that evergreen or seasonal foliage does not obscure sight lines for guard force or CCTV surveillance. It is rare to be able to rely solely on trees as a vehicle security barrier due to the inability to grow suitable trees of sufficient size at a spacing that will deny vehicle access between them.

When installing discrete VSBs, they should be located with a setback of at least 450 mm from a kerb line when live traffic is present (sometimes negotiable with the highway authority to 300 mm at certain locations). The VSBs should be spaced such that the maximum clear distance between permanent measures is no greater than 1200 mm. Where the VSB tapers in elevation, the 1200 mm clear dimension is to be measured at a height of 600 mm above the finished ground level. The 1200 mm dimension has been optimised to limit the opportunity for a hostile vehicle to encroach through the barrier line, while providing sufficient access for pushchairs and wheelchairs.

Active vehicle security barriers

The term ‘active’ VSB (also sometimes referred to as ‘operable’, ‘motive’ or ‘automatic’), relates to powered and manual vehicle security barrier systems such as rising arm barriers, retractable road blockers and bollards, and sliding and hinged gates. Active VSBs are typically installed at vehicle access control points (VACPs), emergency access points or vehicle entrances to buildings. Effectively there are two forms of active VSB: those that are manually operated by a person and those that include a drive mechanism. Thus:

- Manually operated barriers typically comprise a physical barrier, foundations and a human operator to physically open and close the barrier.
- Powered barrier systems normally comprise the following elements: physical barrier, foundations and infrastructure, power supplies, control system, drive mechanism and a user interface, which could be either a human operator or an automatic access control system (AACS).

Modern-day threats have seen the rapid development of vehicle barrier systems capable of resisting high-energy vehicle impacts and so barriers can be split further into the following categories:

- Access control vehicle barriers, which are used to control consensual vehicle access into sites or are simply revenue collection systems. Typically, these barriers do not have any inherent structural resilience capable of preventing unauthorised vehicle access or vandalism. They are often deployed in car parks and business entrances.
- Anti-ram vehicle barriers, which are often used on sites when there is a need to control consensual vehicles but also to deter and prevent unauthorised vehicle access. They tend to be physically robust in appearance and may or may not have been formally tested against vehicle impact. These barriers are typically installed in locations where illegal entry or exit is to be deterred and are designed to produce a delay at the boundary of the site (e.g. vehicle rental compounds, prestigious locations, shops with high-value assets). These products tend to be road blockers, bollards or heavy-duty gates.
- Counter-terrorist vehicle security barriers have been on the market for many years. However, in recent years the threat of SVBIED delivery has spawned a tremendous growth in barrier systems not only capable of countering the terrorist threat but also that of more aggressive criminal attacks. These barrier systems, by nature of the threat, are now regularly being deployed at military and government locations but also more frequently at secure conference

venues, cash handling centres, precious materials processing and production facilities, critical national infrastructure sites and sports stadia.

VACP barriers are typically installed in three basic configurations:

1. *Single line of barriers*. These comprise an access control method (e.g. card reader or guard force intervention) and a single barrier product in the lane, such as a set of bollards, a blocker, rising arm barrier or gate (Figure 11.4(a)).
2. *Inter-locked barriers*. This set-up creates a secure containment area with inner and outer active barriers into which vehicles must drive. At no point during the transit will both sets of active barriers be in the open position. Transit is first through successful verification of occupant and vehicle identity and then operation of either the inner or outer barriers. The second set of barriers will only open upon the others closing fully. This solution is significantly more secure than a single line of barriers but has cost implications and significantly reduced vehicle throughput (Figure 11.4(b)).
3. *Final denial barriers* (with or without an access control barrier) consist of two key areas: the pass check location and the final denial active VSB some distance away. The final denial active VSB would normally be in the open position so as not to fetter traffic flow. This approach is often adopted in locations where available room and enforceable stand-off are not an issue, but traffic throughput is. This solution in theory could be considered very secure on condition that there is a backup guard force overwatch facility and sufficient time for the guard force to recognise and correctly interpret a potential threat activity and then to react proportionately in a timely manner to close the final denial barrier. The design of the system is totally reliant on the guard force having sufficient time to activate the barrier before the threat vehicle reaches the final denial location (Figure 11.4(c)). The effectiveness of this system in countering a hostile attack is greatly reduced if designed or manned incorrectly and its deterrent value might be questioned because the VSB is normally in the open position.

When considering the most effective barrier configuration for a site, the threats to be mitigated (parked, encroachment, penetrative, deception, duress, armed or physical attack or a layered attack) must first be clearly identified. Once identified, the potential vulnerabilities of each configuration against the defined threats may be assessed.

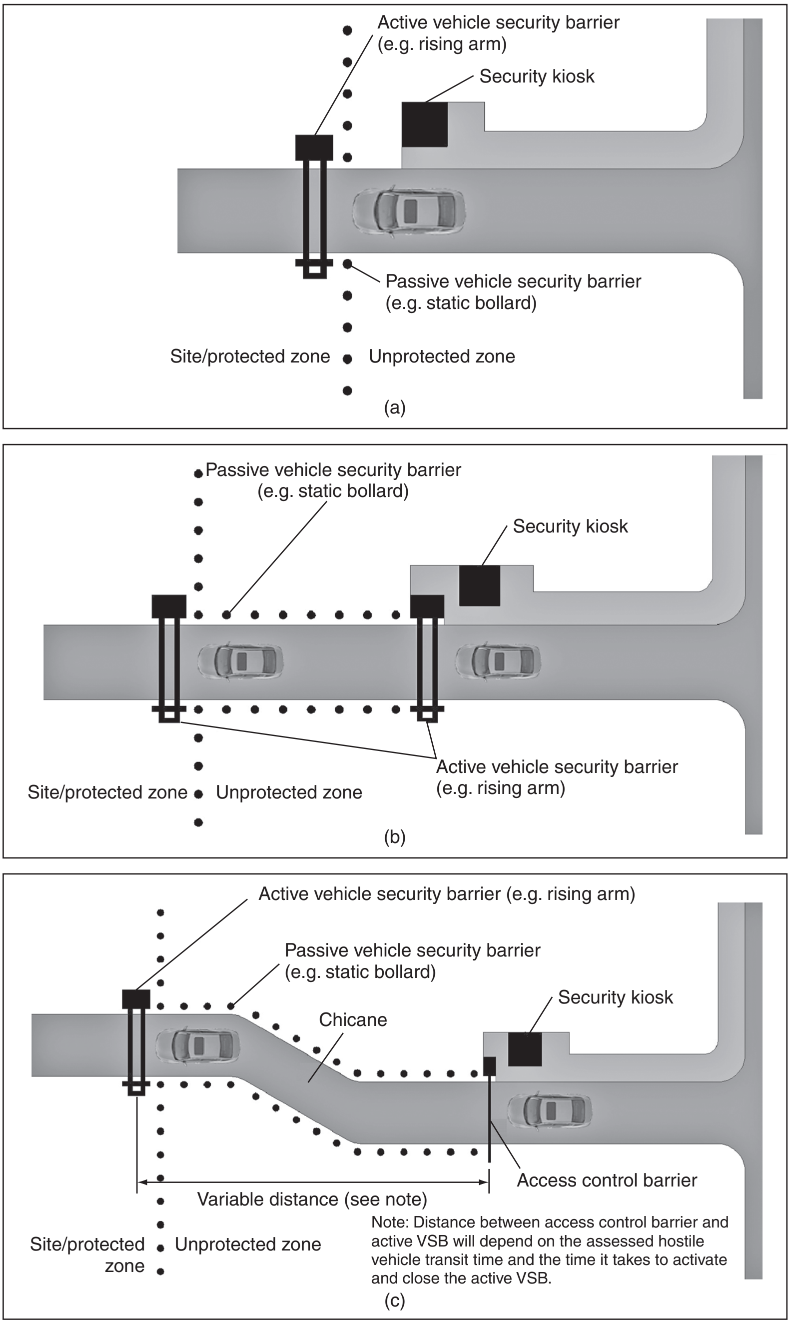

Figure 11.4. Example vehicle access control points. (a) Single line perimeter. (b) Interlock. (c) Final denial barrier

Active vehicle security barriers – method of operation

Barriers can be controlled in numerous ways, including:

- The use of free entry or free exit systems such as inductive road loops or photocells that detect the presence and passage of a vehicle.
- Guard force control using intervention through, for example, a push-button control console.
- Automatic access control system (AACS) providing automated access and egress rights through the use of systems such as card readers, keypads, VHF transmitters, vehicle tokens or automatic vehicle recognition systems.

Each of these methods has advantages and disadvantages in terms of security, safety, traffic management and short- and long-term costs. In the particular case of vulnerabilities it can be advantageous to undertake a security and safety risk assessment.

Powered barrier systems by nature of their design should be considered to be machinery and hence designed, maintained and operated accordingly. This becomes apparent when considering the commonality of design illustrated in Figure 11.5.

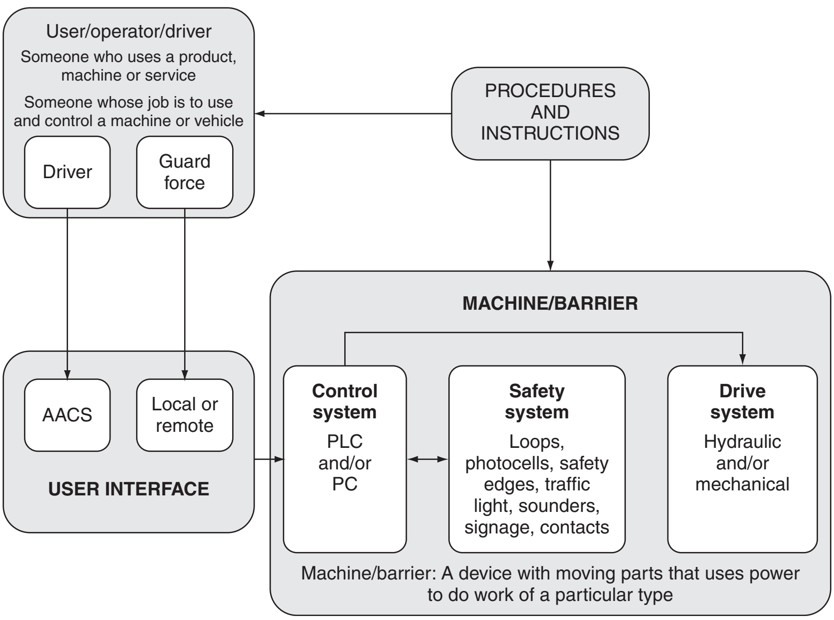

Figure 11.5. Commonality of machinery and motive vehicle barrier systems

Integrated security systems

Traffic calming and VSBs should not be installed in isolation of other security systems. The need to think about holistic and integrated security is of great importance when designing HVM measures. Physical, electronic and procedural security measures are reliant on one another and to implement them in isolation often results in expensive mistakes and significantly compromised levels of security. Equally, without thinking about the long-term training, maintenance and service requirements and associated costs, the barriers may simply become ineffective through breakdowns, misuse, a lack of funding or issues about ownership.

Operational requirements

In view of the above considerations, it is necessary to develop a robust Operational Requirement [1] together with a URD that can be given to potential suppliers together with tender documents, or can be used as the basis of the tender documents. In designing the configuration of a VACP due consideration should be given to its location relative to assets or business-critical infrastructure, the requirements for blast stand-off, security, safety, traffic management, appearance and environmental impact and integration with other security systems or infrastructure.

Each of the above elements can have an adverse effect on the others and so, at the very earliest stages of the project, thought must be given to what acceptable compromises can be made, particularly with regard to the security and safety elements of the barrier systems. Additionally it must be ensured that the installation of a barrier does not compromise the effectiveness of other security systems through obstruction (cover from view), vibration or creating pedestrian intruder scaling aids.

At a basic level, there is likely to be a need to prevent unauthorised vehicle movement, to allow the safe and secure transit of legitimate vehicles and not to adversely affect vehicle transit times and throughput. Additionally, long-term security issues relating to system reliability and a change in threat level can also compromise the initial Operational Requirements. An unreliable VSB is often left as an open barrier and a change in threat can result in heightened security response levels and barrier systems that cannot operate either safely or securely in that new environment.

In deploying VSBs, particularly active systems, it is recommended that particular attention should be paid to the following:

- traffic management
- threats to be mitigated
- security vulnerabilities
- barrier safety systems
- user and operator training
- manuals and user guides
- control systems and logic
- user lines of sight
- system visibility and appearance
- guard force protection against inclement weather
- signage and instructions
- segregation of pedestrians and vehicles
- integration with other physical security systems such as:
  - closed-circuit television (CCTV) systems and recording systems
  - building intruder detection systems (BIDS)
  - perimeter intruder detection systems (PIDS)
  - security lighting
  - adjacent security fences
- street and safety lighting
- audit capabilities
- emergency response
- developing a strategy for dealing with accident or breakdowns
- maintenance regimes and service contracts.

Principles of design of vehicle security barriers for high-energy impact

The following information will have been established from the site assessment to enable the most appropriate form of VSBs to be specified and designed:

- Definition of threat vehicles and attack MO likely to be used.
- The conclusion of the vehicle dynamics assessment (VDA) to establish vehicle mass and impact speed at all perceived vulnerable site locations.
- Identification of the enforceable perimeter to determine the most appropriate or practical position for the VSB to be installed.
- Site constraints, particularly at the VACP (i.e. road finishes, levels, camber gradients and drainage) and the proximity of adjacent structures.
- Subsurface services: search enquires should be made to the local utility suppliers for location of their below-ground services.

- Trial holes and geotechnical investigation to provide confirmation of the ground conditions into which the measures are to be installed. Information includes water table level, settlement characteristics and proximity to vulnerable/sensitive services.
- Knowledge of impact-tested VSBs and the advantages and disadvantages of different types would allow the design of a site-specific, fully integrated solution combining different barrier types.

Impact energy

Subject to the threat vehicle range and impact speeds being derived from the VDA, the energy transferred on impact can be established as the kinetic energy of the threat vehicle $KE = \frac{1}{2}mv^2$, where m is vehicle mass and v is vehicle velocity.

Table 11.1 gives typical values for a range of vehicles and impact speeds.

There is considerable variation in the response of a barrier and vehicle to an impact, mainly due to dimensional and stiffness differences in vehicle structures. Thus it should not be assumed that the performance of a system when impacted by a 7500 kg vehicle at 64 kph will be the same as if the same barrier were impacted by a 2500 kg vehicle at 112 kph (Table 11.1) despite there being very similar kinetic energy levels.

Table 11.1. Kinetic energy for various vehicle types and impact speeds

Nominal speed		Kinetic energy: kJ				
		Car	4 × 4	Goods vehicle		
mph	kph	1500 kg	2500 kg	3500 kg	7500 kg	30 000 kg
(10)	**16**	15	25	35	74	296
(20)	**32**	59	99	138	296	**1185**
(30)	**48**	133	222	311	667	2667
(40)	**64**	237	395	553	**1185**	4741
(50)	**80**	370	617	864	1852	7407
(60)	**96**	533	889	**1244**	2667	10 667
(70)	**112**	726	**1210**	1694	3630	
(80)	**128**	948	1580	2212		
(90)	**144**	**1200**	2000			

Note: all values are approximate.

Testing and classification of vehicle security barriers

There are various international testing standards for VSBs. Those most widely referred to are the UK's British Standards Institution (BSI) Publicly Available Specification (PAS) 68 [2] and the US standard ASTM F 2656 [3]. Separate advice on site assessment and installation considerations are contained in the UK's BSI PAS 69 [4]. At time of writing, a European CEN Workshop Agreement (CWA) is being drafted [5] using the UK's BSI PAS 68 and 69 documents as source texts.

The PAS 68 standard defines the vehicle type, test mass and impact speed together with the required measurements, vehicle and test item details that should be recorded and reported. Post impact, if the test item is not breached or deformed beyond defined limits, then typically the penetration of the front of the vehicle cargo load bed past the position of the original back face of the VSB is measured and classified. The dispersion distance of major debris is also measured as this may be a consideration at certain sites. The resulting classifications can be used by site operators to decide if such penetration after impact of a potentially hostile vehicle, or the dispersion of major debris, is acceptable or whether an alternative VSB would be more appropriate.

Independent destructive testing may have been carried out to characterise the effect of various cutting tools or explosive charges on the VSB to identify whether it can be breached by means other than vehicle impact. TNT-equivalent IED charge sizes that represent the likely threat are used and one measure of performance is whether the VSB itself would disintegrate and project lethal secondary fragments beyond the lethal range for lung damage from blast pressures, which would potentially increase the existing hazard and thus add to the number of casualties.

It must be remembered that testing uses repeatable test criteria and may not replicate the precise dynamics of real-life attacks or vehicle configurations. However, it provides a common baseline against which to classify performance of alternative systems. Products that have been tested to the relevant standard need an appropriate installation which is tailored to the local ground and environmental conditions of the site to ensure adequate performance if ever challenged in a hostile vehicle attack.

Foundation requirements for vehicle security barriers

VSB foundations need to be sized accordingly to the impact energy. Each manufacturer who offers a crash-tested VSB must also be able to offer a tested and approved foundation solution. However, this foundation is only proven to be effective in the ground conditions of the test site. In the majority of circumstances, the actual site constraints and ground conditions will not facilitate the installation of the as-tested foundation and modification of the design will be required. Modification will necessitate the specialist advice of the VSB manufacturer to demonstrate that the foundation system will still perform appropriately when impacted by the threat vehicle.

Due to the presence of a number of services in the highway, the installation of VSBs usually means that some service diversions are required. As a precaution, those services that are left in close proximity to the VSB will benefit from the assurance offered by the addition of appropriate protection. However, some of the available VSBs (including active VSBs) employ very shallow foundations or are surface mounted. This can significantly reduce the difficulties and costs associated with service diversions for deep foundations.

An example of the importance of foundation design for high-energy impacts is illustrated by the most common VSB, namely static bollards. When impacted, a well-designed torsionally reinforced continuous concrete beam foundation has demonstrated that actual rotation and displacement of the foundation is minimal (Figure 11.6).

Figure 11.6. Torsionally reinforced continuous concrete beam foundation (showing reinforcing cage prior to placing of concrete)

The actual energy transferred into the foundation as a result of the dynamic impact is significantly reduced due to a number of factors. The vehicle deceleration and the resulting load transferred to the bollard at foundation are transient and, hence, only last a few milliseconds. The deformation of the vehicle accounts for the majority of energy absorption. Potential deflection of the bollard further absorbs the output energy. Finally, the residual energy is transferred by the bollard into the foundation. The foundation, due to torsional reinforcement, engages a long length of structure, attempting to mobilise it. As this takes longer than the duration of the impact energy, minimal rotation and displacement occurs. This theory has been substantiated through numerous tests.

Typically the ground conditions for installing crash-tested products should provide a stable excavation and a minimum allowable ground-bearing pressure of 75 kN/m^2.

References

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