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Anti-terrorist protection of public facilities and critical infrastructure against attacks with motor vehicles

Abstract

The use of vehicles as tools for terrorist attacks, which has been occurring over the past few years, has led to the increasing use of anti-terrorist blockades around critical infrastructure buildings and in public spaces. This process has progressed as awareness and knowledge of the existence of this type of threat has increased among decision-makers. The variety of devices used to protect against attacks and their selection is not obvious and easy to implement. In this article, the author attempts to describe the occurrence of risks to critical infrastructure facilities from road vehicles used as weapons to carry out attacks. He describes the possibilities of preventing this type of event and recommends solutions to help in the design and implementation of external building security systems. The guidelines contained in the article can be a source of knowledge for those responsible for the security of facilities, but in addition to the theoretical basis in the design of external security of facilities, it is necessary in each case to carry out a specialised risk assessment, carried out by a qualified consultant.

Keywords:

protection of public spaces and critical infrastructure, anti-terrorist barriers, VSB, reducing the risk of attack with hostile vehicles, HVM, vehicle used as a weapon, VAW, standards: PAS 68, IWA 14, ASTM F2656, DOS (SD STD-02.1)

This paper presents the basic issues concerning the topic of anti-terrorist roadblocks as part of hostile vehicle mitigation (HVM). The author has attempted to organise information on the specifics of barrier and vehicle behaviour during a crash, as there are several standards for conducting such tests, known as crash tests or colloquially as standards. Being aware of the differences between them is very important when it comes to choosing a product that is appropriate to the level of risk posed by using a vehicle as an attack tool. Decision-makers may choose products from different suppliers that have been tested to different types of standards, as the results of such tests are not mutually exclusive and may be comparable. However, standards may not be used interchangeably in all cases, so expert knowledge in this area is important. For example, it is inappropriate to directly compare an 'American' vehicle, with an engine compartment design in front of the cab, with a 'European' vehicle where the engine is located under the driver's cab. The American DOS assessment standard (SD STD-02.1) was one of the first standards for crash tests, in use since April 1985. It was the basis for other standards in use today, which vary according to country of origin and local requirements.

There are a number of factors involved in analysing the risk of a vehicle-based attack, the most important of which is determining the likelihood of such an event due to political, religious and racial considerations and selecting appropriate preventive measures. The remainder of this article presents, among other things, an analysis of the possibility of carrying out preventive action against a potential threat, regardless of the genesis of its origin.

The main role of vehicle security barriers (VSBs) is to create pedestrian-friendly zones in city centres, to control the flow of traffic, to manage road and street traffic, to manage vehicle access to protected areas and public buildings, including critical infrastructure, and to protect these places from vehicle attacks. To fulfil their purpose, the barriers are constructed in a specific way and to strict standards, which distinguishes them from other roadblock devices. In comparison, road barriers used on public roads between lanes or at the edges of bends have a protective function, i.e. they reduce the magnitude of unintentional road traffic collisions involving vehicles travelling on public roads. They are tested according to different parameters and standards than anti-terrorist barriers. Therefore, the results obtained after testing road barriers cannot be considered as a basis for using this type of device as a protection against a vehicle-based attack. Various solutions are used to create anti-terrorist protection against an attack, ranging from simple parking posts without a specific security level, considered as orderly protection, to certified road barrier systems with the highest level of protection (stopping vehicles weighing up to 30 t and with a speed of 80 kph).

Historical background to the development of HVM road safety features

Technological progress is inextricably linked to changes in the nature of human safety risks. As motorisation has developed, there has also been an increase in the number of different types of incidents occurring as a result of the intentional or unintentional actions of vehicle drivers. The twentieth century, which saw a marked increase in terrorist activities around the world, brought a new type of threat to people. These are attacks using Vehicle bomb, known in English as VBIEDs (vehicle-borne improvised explosive device). Another type of vehicle-borne attack is (vehicle as a weapon): running people over. This has emerged in the 2010s.

The European country that experienced the earliest trauma of counter-terrorism in the 20th century was the UK. The first widely known and widely reported incident was the bomb attack carried out by the Irish Republican Army (IRA) on 25 August 1939. The attack was carried out by planting a charge in a bicycle basket in the Broadgate area of Coventry (Image 1). The incident left five people dead, 10 seriously injured and 40 hospitalised.

Image 1. The area around Astley's shop in Coventry after the bomb explosion.
Source: https://www.historiccoventry.co.uk/articles/content.php?pg=not-forgotten [accessed: 24 IX 2022].

Over the years, adequate methods of preventing and mitigating such attacks have developed in response to various terrorist threats. As technology has advanced, devices have also been developed to prevent vehicle-based attacks. In various parts of the globe, security experts, engineers and manufacturers, drawing on their own experience and the results of analysis of potential threats, have developed a basis for classifying and selecting devices to prevent attacks. In the design of today's anti-terrorist barriers, consideration must be given to the threats posed not only by light passenger vehicles, but also by heavy goods vehicles. This, in turn, results in the continuous development of new technological solutions used to make security systems more resistant to vehicle attack[1].

Fundamentals of risk analysis in facilities

The analysis of threats in public facilities clearly indicates that the design of technical anti-terrorist security systems cannot only refer to the area inside the facilities and selected types of incidents, such as the planting of an explosive charge. Terrorist attacks carried out with motor vehicles and unintentional traffic accidents endanger both the occupants inside buildings and those in the immediate vicinity, including pedestrian and vehicular routes. The use of various types of anti-terrorist barriers aims to minimise the risk to human life and damage to facilities. Events where the use of VSBs could minimise the impact of an attack are listed below (the description also includes information on the vehicle used in the attack).

- Nice, July 2016 - 87 killed, 434 injured,
  vehicle: 20 t truck, speed approx. 80 kph, distance travelled approx. 1,800 m;
- Berlin, December 2016 - 12 killed, 56 injured,
  vehicle: truck 40 t, speed 80 kph, distance travelled - 80 m;
- Barcelona, March 2017 - 13 killed, 130 injured,
  vehicle: delivery van 3.5 t, speed 60 kph, distance travelled - 500 m;

[1] See: J. Jaźwiński, *Blokady drogowe i zapory antyterrorystyczne jako elementy zapewniania bezpieczeństwa w obiektach użyteczności publicznej* (Eng. Roadblocks and anti-terrorist barriers as elements of providing security in public facilities), in: *Zabezpieczenia Techniczne w Bezpieczeństwie Antyterrorystycznym Budynków Użyteczności Publicznej* (Eng. Technical Security in the Anti-Terrorism Security of Public Buildings), J. Stelmach, P. Szczuka, M. Kożuszek (eds.), Wrocław 2021, p. 206.

- Westminster, March 2017 - 5 killed, 50 injured,
  vehicle: passenger vehicle 1.5 t, speed approx. 110 kph, distance travelled - 300 m;
- Stockholm, April 2017 - 5 killed, 15 injured,
  vehicle: truck 12.5 t, speed 60 kph, distance travelled - 500 m;
- London Bridge, June 2017 - 5 killed, 15 injured,
  vehicle: van 2 t, speed approx. 80 kph, distance travelled - 300 m;
- New York, October 2017 - 8 killed, 15 injured,
  vehicle: delivery van 3 t, speed approx. 100 kph, distance travelled - 1500 m;
- Toronto, April 2018 - 10 killed, 16 injured,
  vehicle: van 2.5 t, speed approx. 70 kph, distance travelled - 2,300 m[2].

Of the above-mentioned incidents, due to their magnitude and consequences, the most notorious is the one that occurred in Nice. During France's national Bastille Day celebrations, after a fireworks display, at around 10.40 pm, a truck driven by an assassin rammed barriers and drove onto the promenade. The car was driven by Mohamed Lahouaiej Bouhlel, a 31-year-old Tunisian national who was legally in France and held a permanent residence card. He deliberately drove into people on the promenade. Unstopped, he covered a distance of approximately 1,800 metres. It was only in the vicinity of the Palais de la Méditerranée hotel that the vehicle was fired upon by police, resulting in the perpetrator's death (image 2).

Image 2. Perpetrator's car after immobilisation.

Source: https://www.nbcnews.com/news/us-news/tsa-report-warns-against-truck-ramming-attacks-terrorists-n754576 [accessed: 24 IX 2022].

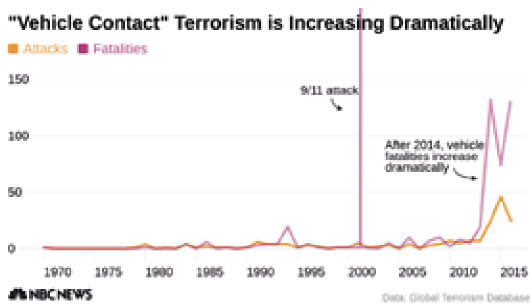
2 https://hvmhub.com/ [accessed: 24 IX 2022].

The course of the attack in Nice and the route taken by the vehicle driven by the bomber are shown in Figure 1[3].

Figure 1. The course of the incident in Nice (first point marked on the map - lorry drives onto the pavement - first victims; second point marked on the map - lorry continues to deliberately drive through the crowd; third point marked on the map - lorry stops, police fire ensues; perpetrator is killed).

Source: https://www.politico.eu/article/nice-bastille-day-attack-live-blog/ [accessed: 24 IX 2022].

After 2014, there was a significant increase in the number of attacks carried out using vehicles and a significant increase in the number of fatalities from these attacks, as illustrated in the graph. The events cited have had a huge impact on the increase in the number of anti-terrorist barriers being installed as an effective means of reducing the impact of a VAW attack.



Graph. Attacks carried out between 1970 and 2015 using vehicles, including fatalities caused by these attacks (the number of victims of the 11 September 2000 attacks is marked for comparison).

Source: S. Petula, *Vehicles Are Becoming the Weapons of Choice for Terrorists*, https://www.nbcnews.com/news/world/vehicles-are-becoming-weapons-choice-terrorists-n768846 [accessed: 24 IX 2022].

[3] https://www.reuters.com/article/us-europe-attacks-nice-killings-idUSKCN0ZV1VG [accessed: 24 IX 2022].

The use of anti-terrorist security devices is of great preventive importance and deters possible perpetrators from carrying out attacks using vehicles in areas where such devices have been installed. Effective security can be said to be effective when it prevents penetration, i.e. the movement of a vehicle beyond a predetermined line of protection. Figure 2 illustrates the potential threat posed by inadequate security.

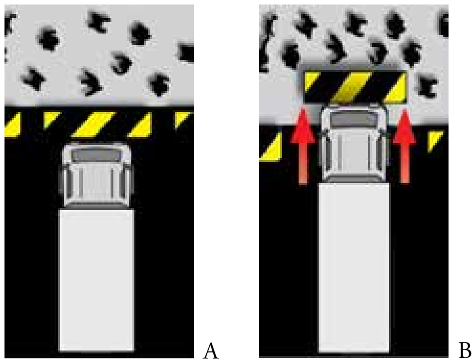


Figure 2. Risks resulting from improperly installed or ill-fitting safety devices: impact of a truck (A), displacement of a safety barrier (B).

Source: ATG Access materials.

The causes of the potential danger could be: concrete blocks that provide protection against attack not being bound to the ground, the use of uncertified barriers, the use of barriers inappropriately selected for the magnitude of the danger. In these situations, the barrier will not stop the vehicle and will allow it to continue moving, sliding along with it. This will result in a danger that is difficult to quantify, as it is not known how long the vehicle will continue to move and what distance it will cover before it stops. During crash tests, one of the parameters taken into account when checking the effectiveness of the protection is the so-called penetration distance. This determines how far beyond the barrier line a vehicle can travel. Knowing this parameter, it should be taken into account when designing the distance of the barrier from the protected objects or footpaths to stand-off distance.

During mass events, it is common practice to use concrete blocks as public space barriers. If they are not connected to ground, or each other, or are not heavy enough, these barriers are ineffective, ad hoc protection against a possibly planned VAW attack. An example of this is shown in Image 3 A - although the concrete blocks have their policing use here (preventing the entry of passenger vehicles), they do not provide protection against heavier vehicles.

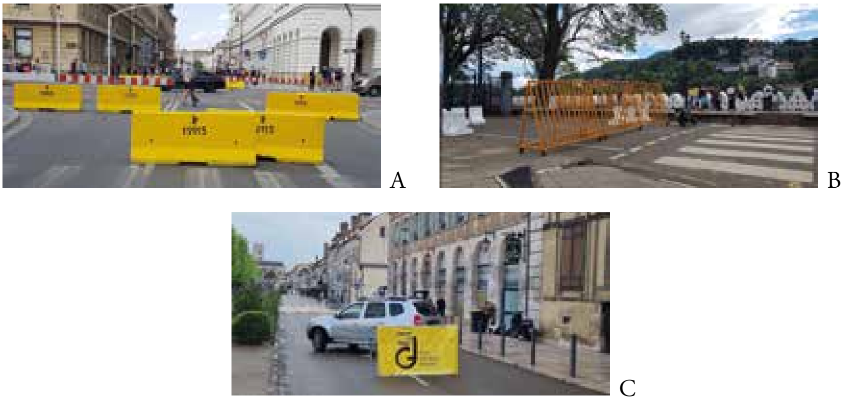


Image 3. Use of inadequate security features: uncertified temporary blockades (Poland, Warsaw, Nowy Świat Street - A, Sri Lanka, city of Kandy - B), use of vehicle as anti-terrorist blockade (France, Auxerre - C).

Source: own elaboration.

To understand how ineffective such protection is, it is useful to see a video of crash tests carried out by one of the DEKRA testing institutes (access to the video - Figure 3). After a collision with this type of barrier, the vehicle continues to move and can travel a considerable distance, even more than 100 m.

Figure 3. QR code with link to DEKRA tests.

Source: DEKRA materials, https://youtu.be/V33fbfmAgTo [accessed: 24 IX 2022].

Image 4 shows an example of the correct installation of barriers to protect against attacks made by vehicles.

Image 4. Example of the correct use of automatic and fixed post security (France, Paris, Rue des Petits Carreaux).

Source: own elaboration.

Steps in assessing the risks associated with using a vehicle as an attack tool

The risk assessment process can be divided into three steps that can help decision-makers (including national security institutions) to prioritise security using VSBs. This is done by defining and understanding the interrelated factors that influence the choice of devices used as preventive measures.

When determining the type of risk for a specific site, the three phases associated with it should be considered: threat, consequences and vulnerability. The additional identification of assumptions at each phase allows the selection of devices from a wide range of different certified products that can effectively prevent or reduce the effects of vehicle ramming attacks. It is also important to consider the cost of the solutions adopted, as by applying preventive measures appropriate to the likelihood of a particular type of risk occurring, the most appropriate and also least costly device can be selected.

It is not justifiable for an external security system to include oversized barriers protecting, for example, against attack by a vehicle weighing 7.5 tonnes [t] travelling at 80 kph, in an area where the analyses carried out indicate that only vehicles weighing up to 3.5 t and capable of speeds of up to 50 kph are likely to move. It is imperative that the choice of equipment corresponds to the real needs of the site to be protected.

Stage one: identification of potential terrorist threats relevant for the target under consideration

Estimates of the likelihood of an attack using a vehicle as a battering ram should be made on the basis of statistics on this type of attack, taking into account the preferred modus operandi of terrorists. Information can be obtained from sources such as the internet, bulletins and analyses from public institutions, reports from law enforcement and intelligence services or counter-terrorism units. However, the most valuable information is not publicly available. They can only be consulted by authorised persons, including security consultants. Data obtained independently by facility managers is insufficient to carry out the analysis properly. Preparing a correct assessment of the threat level is possible primarily by using the knowledge of security consultants and experts.

The modus operandi and attack locations chosen by terrorists are constantly changing. They are determined by many factors, including: their skills and knowledge, the availability of adequate financial and human resources, and the area of operation. It is therefore important to check whether similar incidents have occurred in the geographically closest areas. After analysing attacks carried out using vehicles over the last few years, it can be seen that attacks on civilians have been more frequent in public spaces, as they have a low level of security. It is easier to both carry out an attack in them and to obtain the attack tool, i.e. the vehicle[4].

Stage two: impact assessment

In recent years, the majority of attacks have been carried out against so-called soft targets, i.e. places characterised by high concentrations of people and a lack of security, unprotected or less protected. These are in contrast to so-called hard targets, which include high-security areas and facilities that are subject to monitoring. The attractiveness of a place to a perpetrator of a potential attack depends on many different factors, including the symbolic nature of the place. Symbolism may attract terrorist groups who, by attacking a widely recognised and popular site, attempt to attract media attention and intimidate the public. Such terrorist targets may include religious sites or cultural centres considered to promote Western lifestyles, capitalism and/or democracy. Popular tourist sites, outdoor

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[4] See: M. Larcher, V. Karlos, *Protection Of Public Spaces*, in: V. Karlos, M. Larcher, G. Solomos, *Review on Soft target/Public space protection guidance*, European Commission Joint Research Centre, https://www.researchgate.net/publication/330221013 [accessed: 12 VIII 2022].

festivals, sporting events, landmarks (habitual meeting places) and areas where many people are present are also attractive to bombers.

Terrorists with different motivations may also attack facilities that represent government jurisdictions, taxation, law enforcement, financial institutions, etc. The consequences of an attack are directly related to the type of target chosen by the aggressors and the population density of the area at the time of the attack.

In the case of a pedestrian area or a city square, the consequences of an attack will be very different if it is carried out during rush hour or during social events when the crowd is at its largest. When estimating the occurrence of a terrorist attack affecting people (deaths, injuries, reduced morale, etc.) and the economy (cost of repairs, disruption of services, etc.), the worst-case scenario should be used as a reference point, as terrorists most often strike during popular events or peak hours. The assessment of the consequences of an attack carried out may vary depending on the stakeholder carrying out the analysis, but the primary priority during the assessment process should be the protection of human life. This should be followed by attention to the damage to infrastructure, the economic impact, and the psychological impact on society[5].

Stage three: vulnerability assessment

Security vulnerabilities can be exploited by perpetrators when planning or executing an attack, so it is necessary to identify optimal strategies to minimise the vulnerability of a facility, increase its resilience and apply effective mitigation measures. Vulnerability assessment requires a detailed preparation of the scenario, revealing weaknesses and security flaws that would encourage aggressors to develop an attack plan. The fewer security measures in place, the more attractive - in the eyes of the perpetrators - a site or area is as a target, as the chances of success increase significantly.

An analysis of the site by experienced professionals allows weaknesses in the security system to be identified and appropriate measures to be taken to minimise these weaknesses and the resulting danger. A thorough visual inspection of the site layout and familiarisation with the characteristics of the security system during the operational phase can effectively reveal deficiencies in the security design, which should be addressed in an updated mitigation plan. Drawing up an objective assessment of the vulnerability

5 Ibid.

of a public space is a difficult task, as many different factors need to be taken into account, such as the accessibility of the target, its location, its importance, the shape of the public space - current security arrangements, etc. The following are examples of vulnerability categorisation for public spaces:

– **low vulnerability**: the public space under consideration is equipped with adequate countermeasures (to deter potential aggressors): controlled access, security personnel, perimeter protection. The space is unattractive as a potential target for attack;
– **moderate vulnerability**: the public space under study may be equipped with some security measures and is only locally known (no controlled access, limited number of security personnel, partial perimeter protection, etc.);
– **high vulnerability**: the surveyed public space is characterised by insufficient security measures and is nationally known and recognisable;
– **very high vulnerability**: the examined public space is characterised by insufficient countermeasures, is internationally known[6].

Partial conclusions: the role of prevention and deterrence

The most effective counter-terrorism measure is to prevent an attack from occurring in the first place. If the attack is prevented, there will be neither casualties nor damage to the environment. The presence of security barriers, even with less blocking capability, can potentially deter a perpetrator from carrying out an attack, as his or her chances of successful action appear limited. However, if such an incident does occur, the installed security barriers will minimise any kind of damage resulting from it.

Fundamentals of the use of roadblocks and anti-terrorist barriers

The selection of suitable anti-terrorist road barriers is not a simple and obvious task. During the arrangements for the preparation of such devices, their suppliers pose the following questions to the decision-makers responsible for the security of the facility:

- What mass of a vehicle can be a source of danger?
- At what maximum speed can the vehicle travel?

6 Ibid.

- What is the permissible penetration range, i.e. how far behind the interlock line can the vehicle move?
- Does the penetration have to be zero or is a greater range acceptable (e.g. 1 metre)?

If you don't know the answers to the above questions, then to be sure of the right choice of security solutions against a vehicle attack, you should order an engineering study by certified specialists with industry knowledge beyond that of those on the list of qualified technical security personnel[7].

The current situation in the anti-terrorist security market in Poland is quite complicated due to the shortage of qualified HVM experts. In the case of e.g. the UK, such services are quite commonly provided by design offices. Advice and designs are carried out by a combination of trained Police Counter Terrorism Security Advisors, the Register of Security Engineers and Specialists[8], Chartered Security Professionals[9], and vehicle security barrier manufacturers. The Government's Centre for the Protection of National Infrastructure and National Counter Terrorism Security Office[10] (NaCTSO) provide support to these groups.

The situation becomes easier for Polish decision-makers if the design office performing the design of the facility including technical and anti-terrorist security systems employs engineers with foreign qualifications. This is most often the case in design offices originating from Western European countries or the USA, where - as part of the commissioned service - it is the practice to prepare an engineering study as an integral part of the design. When designing and implementing technical security systems, it is very important to take into account that the designer is dealing with access to classified information, including but not limited to security procedures, e.g. procedures for emergency opening of crossings for the relevant services or the location and operation of controllers.

[7] J. Stelmach, M. Kożuszek, *Założenia i rekomendacje do wykonywania planów ochrony w obiektach podlegających obowiązkowej ochronie* (Eng. Assumptions and recommendations for the execution of security plans in facilities subject to mandatory protection), in: *Bezpieczeństwo antyterrorystyczne budynków użyteczności publicznej* (Eng. Anti-terrorism security of public buildings), vol. 4: *Założenia i rekomendacje do prowadzenia działań antyterrorystycznych w wybranych kategoriach obiektów* (Eng. Assumptions and recommendations for conducting anti-terrorist activities in selected categories of facilities), B. Wiśniewska-Paź, J. Stelmach (eds.), Toruń 2019.

[8] https://www.rses.org.uk.

[9] https://security-institute.org/csyp/.

[10] https://www.proteyp/.

As classified information should be protected, companies involved in the project should have an industrial security clearance and their employees should have security clearance of the appropriate level. The developer should determine already at the project initiation stage which levels of access to classified information are required and in which design and implementation areas they are necessary[11].

Current standards for testing barriers against vehicle attacks

Vehicle crash barrier test standards are applied to a number of factors that influence the classification of a device. In order to properly select and install a barrier, several parameters need to be taken into account, which are included in the results of the crash tests carried out. These are:

- **the test object** - the vehicle (V), i.e. the motor vehicle,
- **vehicle mass** (class) - expressed in kilograms [kg] or pounds [lbs] depending on the country of origin of the standard,
- **impact speed** - expressed in kilometres per hour [kph] or miles [mph], depending on the country of origin of the standard,
- **angle of impact** - expressed in degrees; for the standards listed below it is 90°, i.e. impact perpendicular to the barrier under test (reference line of the barrier under test),
- **penetration**- expressed in metres [m] or feet [ft] depending on the country of origin of the standard or local requirements. When measuring this parameter, the location of the reference line of measurement (datum line) is important, i.e. determining the difference between the distance of vehicle displacement and the barrier (how far the vehicle has travelled beyond the reference line).
- **dispersion** (according to PAS 68:2013) - expressed in metres [m] or feet [ft]. This measurement relates to the dispersion distance of detached components of the test vehicle or its ballast. The measurement is taken from the reference line to the furthest edge of the detached component. Only elements whose mass is ≥ 25 kg are considered[12].

An important measurement criterion is to determine the position of the measurement reference line, which may be at the initial or final

[11] See: J. Jaźwiński, *Blokady drogowe i zapory antyterrorystyczne…*

[12] Based on: *BSI PAS 68:2013 – Impact test specifications for* vehicle *security barrier systems.*

edge of the barrier. In the case of bollards (i.e. posts) this difference is insignificant, approx. 20-30 cm, but in the case of roadblocks the difference can be up to approx. 1 m. Figure 4 shows the reference line for PAS 68, IWA 14-1 and ASTM F2656.

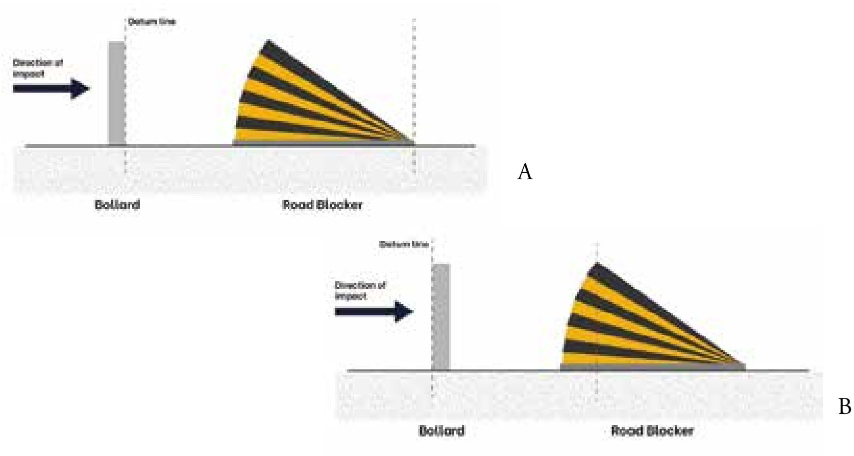


Figure 4. Reference lines (Datum lines): for PAS 68:2013 (A), for IWA 14-1:2013 and ASTM F2656-20 (B).

Source: own elaboration based on ATG Access materials, https://www.atgaccess.com/news/guides/what-is-iwa-14, https://atgaccess.com/what-is-pas-68/[accessed: 24 IX 2022].

Another important criterion is to identify the measuring points located on the vehicles and measure the distance between this point and the reference line. For passenger cars, the measuring point is located at the bottom of the front pillar of the vehicle body. For trucks and vans, the measuring point is located behind the rear bulkhead of the driver's cab (Figure 5).

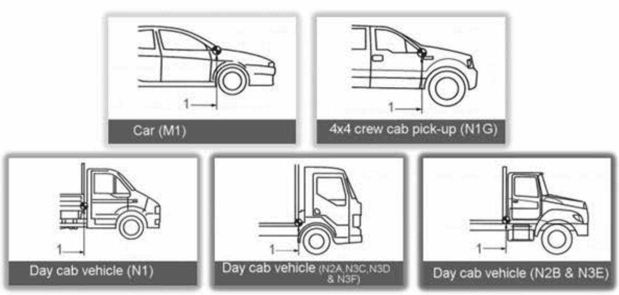


Figure 5. Location of the measuring point for cars and trucks.

Source: own elaboration based on https://www.cpni.gov.uk/resources/impact-testing-vehicle-security--barriers [accessed: 24 IX 2022].

Comparison of existing global standards for VSB

The leading standards relating to the parameters of anti-terrorist barriers are PAS 68 and PAS 69, developed in the UK, and the American ASTM F2656-20 standard, as well as the global standards IWA14-1 and IWA14-2, which have been developed through a commonality of provisions found in these standards. In the European market, parameters relating to these standards are sometimes quoted interchangeably, so it is important to know their characteristics. In the following section, the main assumptions and criteria from the area of VSB standardisation are presented.

UK - Standards: PAS 68 and PAS 69

PAS 68 provides the results and specifications of crash tests for VSB equipment, while PAS 69 sets out guidelines for the selection, installation and use of VSB systems. Barrier tests were performed using the following criteria:

- six vehicle categories,
- range of impact speeds tested: 16-112 kph,
- penetration measured from the end of the interlock (in the ASTM standard, measurement is from the beginning of the interlock).

An example of product classification according to PAS 68:2013: test result V/7500(N2)/80/90:0.0/3.6 indicates an N2 vehicle (7500 kg) travelling at 80 kph, impact angle 90°, penetration 0.0 m, dispersion 3.6 m[13]. The following criteria are taken into account in the results: test object (vehicle type), vehicle mass [kg], impact speed [kph], impact angle, penetration behind the barrier reference line [m] and debris dispersion [m].

Vehicle classes for PAS 68 (class):

- 1500 kg - passenger car (M1),
- 2500 kg - 4×4 pick-up (N1G),
- 3500 kg - van (N1),
- 7500 kg - 2 axle truck (N2),
- 18 000 kg - truck with 2 axles (N3),
- 30 000 kg - truck with 4 axles (N3).

[13] See: *Impact Testing of Vehicle Security Barriers*, August 2020, https://www.cpni.gov.uk/hostile-vehicle-mitigation [accessed: 24 IX 2022].

North and South America - Standard ASTM F2656-20.

America had a DOS standard (SD STD-02.1) for many years, which was withdrawn in April 1985[14]. In 2007, it was replaced by ASTM F2656, which provided more test details. The following criteria are used for standardisation:

- six vehicle categories,
- range of impact speeds tested: 48-100 kph,
- penetration measured from the end of the interlock, penetration rating ‘P’ 1, 2, 3 and 4.

Example of product classification according to ASTM F2656: test result C7:50-P3 means C7 vehicle (7200 kg) travelling at 50 mph, penetration P3 between 23 ft and 98 ft. The following criteria are considered in the test results: vehicle category, impact speed [mph], penetration range scale from P1 to P4 [ft].

Vehicle classes for ASTM F2656 (class):

- 1100 kg - car (S.C),
- 2100 kg - car (FS),
- 2300 kg - pickup truck (PU),
- 6800 kg - truck with 2 axles (US type M),
- 7200 kg - truck with 2 axles (EU type C7),
- 29 500 kg - truck with 4 axles (H).

Penetration size:

- P1 - less than 3 ft,
- P2 - between 3.3 ft and 23 ft,
- P3 - between 23 ft and 98 ft,
- P4 - above 98 ft.

North and South America - DOS standard withdrawn (SD STD-02.1)

As many anti-terrorist devices have been tested to the DOS standard (SD STD-02.1), it is still possible to find products that have such approvals. Of course, such tested barriers may be appropriate on a par with other barriers that have been classified according to the other standards already mentioned.

The classification of products according to this standard implies only three categories and therefore only one of them is given when describing the products:

1) K12 = M50 - medium truck, 15 000 lbs (6.8 t), tests at 50 mph (≈80 kph),

[14] https://hvmhub.com/ [accessed: 24 IX 2022].

2) K8 = M40 - medium truck, 15,000 lbs (6.8 t), testing at 40 mph (≈64 kph),
3) K4 = M30 - medium truck, 15,000 lbs (6.8 t), test at 30 mph (≈50 kph).

World Standards: IWA 14-1 and IWA 14-2

The IWA 14-1 standard does not negate previous testing of products meeting ASTM, DOS or PAS 68 and 69 standards; it aims to internationalise and combine previous risk assessment standards common to all continents. The IWA 14-2 standard provides guidance on the selection, installation and use of vehicle safety barriers and describes the requirements to be taken into account for testing, which are:

- nine vehicle categories - this is primarily due to the specific design of US and European vehicles,
- the range of impact speeds tested: 16-112 kph,
- penetration measured from the beginning of the blockade,
- debris dispersion measurements; these are omitted from the classification of results (table), but are recorded in the full test report.

Example of product classification according to IWA 14-1: test result V/7200(N2A)/80/90:0.0 indicates an N2A vehicle (7200 kg) travelling at 80 kph, impact angle 90°, penetration 0.0 m.

Vehicle classes for IWA 14-1 (class):

- 1500 kg - passenger car (M1),
- 2500 kg - 4×4 pick-up (N1G),
- 3500 kg - van (N1),
- 7200 kg - truck with 2 axles (N2A),
- 7200 kg - truck with 2 axles (N2B),
- 7200 kg - truck with 2 axles (N3C),
- 12 000 kg - truck with 2 axles (N2D),
- 24 000 kg - truck with 3 axles (N3E),
- 30 000 kg - truck with 4 axles (N3F).

Comparison of vehicle categories by weight for all cited standards

The summary shown in Figures 6 and 7 allows the results of crash tests carried out to different standards to be compared. This makes it possible to determine whether the devices proposed by different manufacturers meet the requirements outlined in the building security concept. This gives decision-makers a much greater opportunity to select equipment from manufacturers who have tested and certified their products to different standards, depending on the country of origin.

Figure 6. Comparison of standards for: cars and vans.

Source: https://hvmhub.com/wp-content/uploads/2018/09/HVMhub-Crash-Testing-Standards-Explained-v1.2.pdf [accessed: 24 IX 2022].

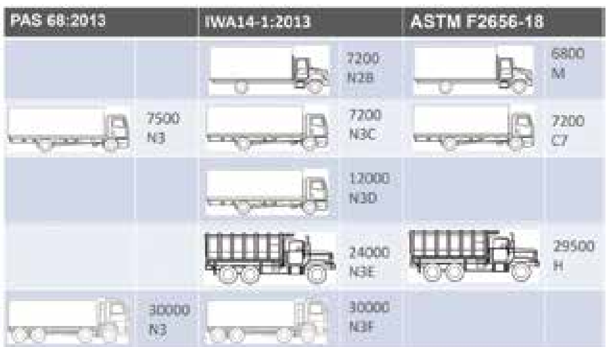


Figure 7. Comparison of standards for: for trucks (B).

Source: https://hvmhub.com/wp-content/uploads/2018/09/HVMhub-Crash-Testing-Standards-Explained-v1.2.pdf [accessed: 24 IX 2022].

Tables and descriptions can sometimes be inadequate and may raise doubts about the equivalence of the devices classified in them. To check whether a device will do the job, a mathematical formula can be used for calculations, comparing the kinetic energy magnitudes arising from the movement of the vehicles included in the tests.

$$\text{Kinetic energy} = \frac{\text{mass} \times \text{velocity}^2}{2}$$

where: kinetic energy is expressed in kJ, mass in t, velocity in m/s.

The following are examples of calculations of kinetic energy values for cars of different masses.

A 7.5 t vehicle (e.g. N2 according to PAS 68) travelling at 40 mph (≈64 kph) achieves a kinetic energy value of 1185 kJ on impact with the barrier:

$$\frac{7{,}5 \times (64 \times 1000 \div 3600)^2}{2} = \mathbf{1185\ kJ}$$

A 12 t vehicle (e.g. N3D according to IWA 14-1) travelling at 32 mph (≈50 kph) achieves a kinetic energy value of 1157 kJ on impact with the barrier:

$$\frac{12 \times (50 \times 1000 \div 3600)^2}{2} = \mathbf{1157\ kJ}$$

As can be seen from the kinetic energy calculation examples for the two vehicles having different masses and travelling at different speeds, it is similar, so a barrier that has been tested successfully for a kinetic energy of 1185 kJ can probably effectively stop both vehicles with the parameters indicated. However, the kinetic energy calculation is not a substitute for the crash test that should be carried out for these vehicles. Vehicles have different structures and heights, so will test barriers in different ways. It should not be assumed that similar kinetic energy means a similar vehicle impact test result.

Most frequently compared vehicles classified according to different standards

Table compares the kinetic energy values calculated according to the formula presented earlier for different categories of cars with different weights, allowing a quick comparison between vehicles classified according to different standards.

Table. Comparison of kinetic energy for vehicles of different weights and travelling at different speeds, calculated according to each standard.

Standard	PAS 68	IWA 14-1	ASTM F2656	ASTM F 2566	DOS SC /STD2.01
Vehicle category	N2	N2A	Truck (M)	Truck (C7)	N2A
Vehicle weight [kg]	7500	7200	6800	7200	6800
Velocity [km/h]	48	48	50 (30 mph/h)	50 (30 mph/h)	50 (30 mph/h)
Kinetic energy [kJ]	667	640	656	694	656
Velocity [km/h]	64	64	65 (40 mph/h)	65 (40 mph/h)	65 (40 mph/h)
Kinetic energy [kJ]	1185	1138	1108	1174	1108
Velocity [km/h]	Unclassified	80	80 (50 mph/h)	80 (50 mph/h)	80 (50 mph/h)
Kinetic energy [kJ]		1778	1679	1778	1679

Source: own elaboration based on: https://hvmhub.com [accessed: 24 IX 2022].

Research results and product testing. Conclusions

A very important element in the equipment selection process is to obtain test results from a potential supplier from an accredited testing body. Many companies report that they have so-called engineered solutions products, which means that they have been designed according to good engineering practice, but have not been tested. In order to be tested, destructive tests have to be carried out for different categories of vehicles, which is costly, but provides a guarantee that the device on offer will protect the object in the desired way. The tests are carried out under specific conditions and the installation of the barriers should replicate the actual conditions. All these guidelines, e.g. what time must elapse between the pouring of the concrete with reinforcement and the installation of the barrier and the crash test, are described in the individual standards, Crash tests are very costly not only in terms of the cost for the testing laboratory to perform the test, but also in terms of the cost of the tested barriers themselves, which will be destroyed, and the vehicle, which must meet the standards of an approved vehicle. This means that the vehicle must have a functioning suspension, brakes, naturally acceptable tyres and many other features that are similarly described in the standards of each standard. The maximum age of the vehicle that can be tested is also specified. All of this combined means that installed barriers and constructed foundations will be damaged or compromised during the test trials and will be impossible to reuse for subsequent tests. Therefore, usually only a small number of possible attack scenarios are assessed, i.e. one barrier length or a minimum number of bollards is chosen.

In recent years, numerical computational methods have been successfully used to assess and verify what happens to structural and non-structural elements during various dynamic events, such as vehicle or aircraft collisions (crash simulations). The use of numerical models can occur in the case of vehicle-barrier impact interactions. Achieving a high level of confidence in numerical solutions requires the use of reliable and efficient computational element algorithms, which are being considered by researchers as an alternative to physical experiments. Computer models should be used as part of barrier design development, and not as the only method to prove if the barrier will stop a vehicle. Figure 8 shows a QR code under which a video of a test using a 7.2 t vehicle travelling at 48 kph is available[15].

Figure 8. QR code with link leading to Horiba-Mira test.

Source: Horiba-Mira laboratory materials, https://www.youtube.com/watch?v=Rq4IPZu7nv8 [accessed: 24 IX 2022].

Standards for intrusion resistance

In addition to the threat posed by the use of a vehicle, there are other risks arising from, for example, an attempt to forcefully penetrate the perimeter of the protected area. Such risks and the ability of technical security devices to prevent them are classified according to standards testing resistance to

[15] The test was performed by the Horiba Mira research laboratory, https://www.horiba-mira.com/ [accessed: 24 IX 2022].

break-ins. Intrusion tests are carried out to determine the resistance time of the security device when an intruder attempts to force it through. If VSBs, such as sliding or swinging gates, are required, additional parameters for burglary resistance can also be determined. This is particularly the case where intrusion resistance is a parameter that occurs as a requirement for a fixed fence that is a perimeter security line.

EN 1627 defines intrusion resistance as a property of the following products: doors, windows, curtain walls, grilles and blinds. The tests examine the time (in minutes [min]) taken to resist attempts to forcibly enter the protected room or area through the use of physical force and specific tools. The degree of resistance of the security device determines its assignment to the appropriate intrusion resistance class. In EN 1627, **6 classes of intrusion resistance** (denoted by the RC symbol) are taken into account for building products, including windows and doors, depending on the level of resistance to attempted break-ins, and the expected methods and attempts to gain access, i.e. the time it takes to force an obstruction, are also specified for them:

- RC1 - RC3: for the assumption of the “casual burglar” - the variable is the tools used; the test result determines the intrusion resistance time (respectively: RC1 - 0 min, RC2 - 3 min, RC3 - 5 min),
- RC4: for the “skilled burglar” assumption - the variable is the tools used; the test result determines the intrusion resistance time (RC4 - 10 min),
- RC5 - RC6: for the assumption of an “experienced burglar”, the variable is the tools used; the test result determines the intrusion resistance time, respectively RC5 - 15 min, RC6 - 20 min.

The test result is the assignment of resistance classes from RC1 to RC6 to the products, which corresponds to the time of penetration of the partition from 0 to 20 min[16].

Another standard describing categories of resistance to forced entry, practically unknown in Poland, is the British LPS standard[17] 1175, version 8, created and implemented by BRE Global. Part of this organisation is the LPCB research office[18]. The result of testing and certification according to this standard is the assignment of resistance to products in **48 classes**,

[16] See: https://badaniaokien.pl/ [accessed: 24 IX 2022].

[17] Loss Prevention Standards, LPS.

[18] Loss Prevention Certification Board.

which corresponds to an intrusion time of 0 to 20 min, depending on the type of tools used and the experience and qualifications of the intruder.

The LPS 1175 standard covers a wide range of assessments of physical security products. It deals with scenarios of possible threats caused by the entry of intruders who do not pay attention to the noise that accompanies an attempt to gain access to assets, property and people. The development of the standard is the result of many years of partnership working with government, insurers and police and other services. LPS standards are now widely recognised and used in the fire and security sectors around the world. The LPCB offers certification as an independent certification body.

The latest version of LPS 1175 (8) defines intruder resistance indicators consisting of two elements:

1) threat level - denoted by the letters A to H corresponding to the toolkit - used to assess the product's resistance to intruders and the number of people involved,
2) delay - denoted by letters: 1, 3, 5, 10, 15 or 20 corresponding to the minimum delay (in min) guaranteed by the product - tested after lockout.

Products certified according to LPS 1175 take into account in the test:

- amateur attacks with hand-held, small and easily concealed tools, with an attempted forced entry of approximately 1 min (Class A1),
- professional attacks with a wide range of mechanical, electrical and thermal tools, with an intrusion attempt lasting approximately 20 minutes (security class H20).

The test results obtained enable products to be assigned a corresponding resistance class, which corresponds to the time taken to force a partition from 0 to 20 min[19].

Partial conclusions on intrusion resistance standards

Products tested to the above-mentioned standards are not fully resistant to burglary and the active actions of perpetrators. Their function is to resist an intruder forcing a given security measure for a certain period of time. EN 1627 deals with the testing and certification of doors, windows, partition walls, grilles and shutters. LPS 1175 (8) focuses on the testing and certification of a much broader range of products that are not covered by

[19] www.bregroup.co.uk [accessed: 24 IX 2022].

EN 1627. **Therefore, the use of LPS 1175 (8) classified products together with VSB classified products is an excellent complement used in the design of comprehensive perimeter security.**

Classification of anti-terrorist barriers - breakdown by type of control and type of mounting

The basic characteristics of the various types of external technical security equipment are presented below.

Fixed bollards

Fixed bollards are the units with the simplest design and the most commonly used. A steel tube is installed in a reinforced concrete foundation (image 5). The depth of the foundation does not usually exceed 1 400 mm and the height above ground level does not exceed 1 200 mm. The foundationis designed with engineering care and then subjected to crash tests to determine the actual resistance according to previously described standards.

Image 5. Fixed bollards installed at a London underground station.
Source: ATG Access marketing materials.

Removable bollards

The design of removable bollards is the same as fixed bollards in terms of foundation size, pipe diameter and materials used. The main difference is that they can be temporarily dismantled. In practice, this means that the upper part of the pipe is attached to the lower part of the pipe and to the foundation using bolts or specialised 'snaps' (Figure 9). This type of bollard is installed, for example, in areas where mass events are periodically held, which requires part of the area to be temporarily cordoned off. In addition to the economic advantage of this solution, which is cheaper than automatic bollards, the undoubted benefit is that once the barriers are removed, the place where they are installed is not a traffic obstacle for vehicular or pedestrian traffic. On the other hand, the disadvantage is the need to transport the dismantled posts, their storage and the cost of employing an installation team.

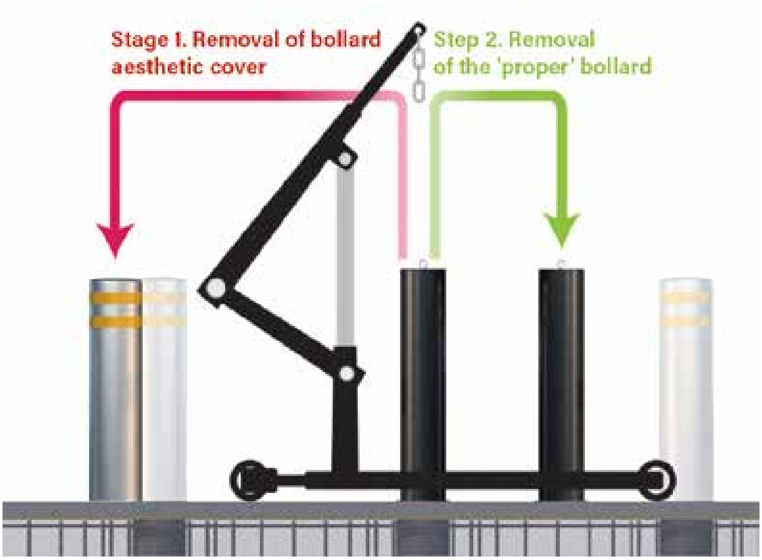


Figure 9. Diagram of bollard removal.

Source: https://www.frontierpitts.com/products/bollards/hvm-static-bollards/pas68-removable-jupiter-7550/[accessed: 24 IX 2022].

Fixed bollards - shallow installation

In city centres, where the probability of vehicle collisions with urban installations is very high, shallow bollard structures are used. This type of static bollard solution is characterised by the absence of a traditional foundation with reinforcement (Figures 10 and 11).

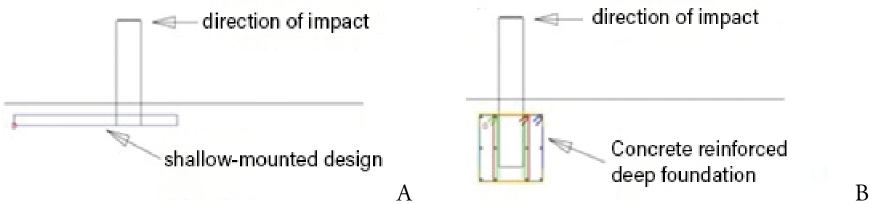


Figure 10. Comparison of bollard foundations: shallow installation (A), standard deep installation (B).

Source: ATG Access marketing material.

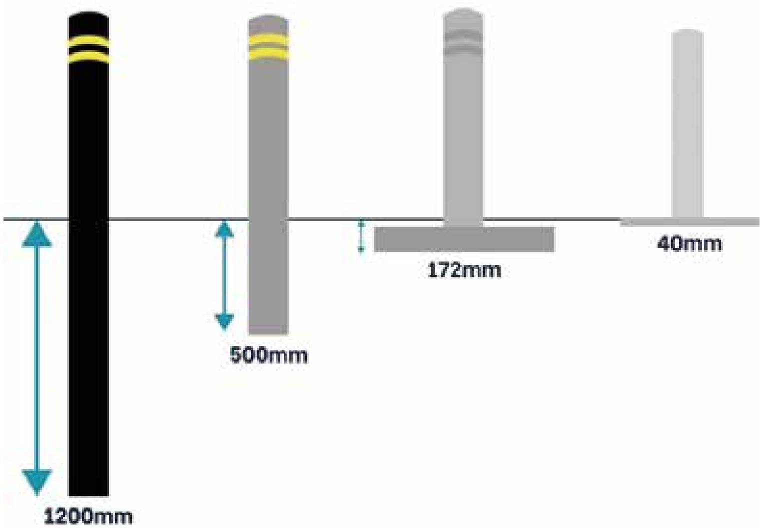


Figure 11. Comparison of different bollard installation depths.

Source: ATG Access marketing material.

The installation of the equipment is carried out directly on the prepared substrate by joining the prefabricated elements in a line, which does not have to be straight (Figure 12). During design, the bollard installation line is established according to risk assessment parameters, e.g. the distance from the object due to penetration and the dispersion of waste.

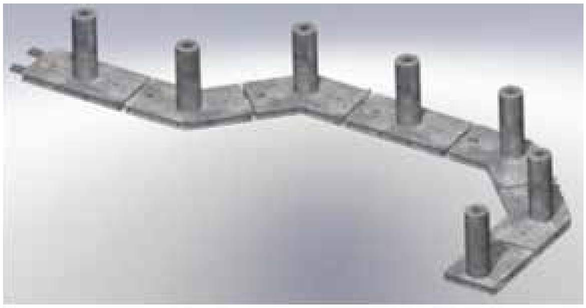


Figure 12. Shallow mount bollards fitted in accordance with risk assessment parameters.

Source: ATG Access marketing material.

Automatic bollards

The structure of automatic bollards is, in simple terms, a movable steel tube with a drive installed in a concrete and reinforced foundation (image 6). The depth of the foundation usually does not exceed 2 300 mm, the height above ground level does not exceed 1 200 mm. A smaller-diameter pipe is placed in the larger-diameter pipe, which moves inside using the telescopic principle. It is retracted or extended above ground level as required. In these units, a hydraulic drive with control electronics is most desirable. The hydraulic drive allows the barriers to open or close very smoothly and quickly.

Image 6. Automatic bollards.

Source: ATG Access marketing material.

The automatic version of the bollard offers great opportunities to protect selected zones, allowing unrestricted pedestrian traffic with limited vehicle admittance. The lock allows a large number of bollard movement operations, so it is ideal for high-traffic areas. It can be a component of a larger access control system, an entire remote security management system or operate as a stand-alone system. For specific requirements, a fast opening or emergency closing function is also possible. In addition to the above-mentioned advantages, it should be noted that the price of automatic units relative to fixed bollards is higher.

A very important option is the Emergency Fast Operation (EFO). Such a system allows the automatic barrier to be extended almost immediately, even in less than 2 s. This is an additional function that must be foreseen before production starts, i.e. at the order placement stage. When assessing the risk of overcoming an obstacle, the consultant can recommend the use of EFO as an element of safety enhancement.

Automatic bollards for shallow installation

An example of an unusual solution is the automatic shallow-mount bollard, which has an original double retractable design based on the telescope principle (image 7). The bollard is constructed with a casing tube and two moving tubes moving inside. The whole is installed in a concrete reinforced foundation.

Image 7. Shallow-mounted automatic bollards.
Source: ATG Access marketing material.

Most certified automatic posts have a foundation approximately 1 500 mm deep. This innovative product has a foundation of just 900 mm, or less than 1 m. This solution allows installation in areas where deep excavation is not possible or there is a risk of damage to underground utilities.

Bollards without an automatic drive - manually operated

The design of these bollards is similar to that of automatic bollards, except that the role of the automatic electric-hydraulic drives is taken over by a human operator. Using muscle power or screwdrivers with patented adapters, the extension of the bollard tube can be adjusted. The steel pipe is installed in a reinforced concrete foundation. The depth of the foundation usually does not exceed 1 400 mm, the height above ground level does not exceed 1 200 mm. A smaller-diameter pipe is placed in the larger-diameter pipe, which moves inside using the telescopic principle and is either hidden or extended above ground level as required (image 8).

Image 8. Manually controlled bollard.
Source: ATG Access marketing material.

These types of barriers are installed at access points to permanently protected areas where there is an occasional need for vehicles to enter, such as exhibition centres or galleries requiring periodic change of exhibitions. The advantage over automatic devices is the lower price, the inconvenience is the need for staff to be present on site. An additional advantage over demountable bollards is that there is no need to transport the units or hire installation crews.

Automatic and manual roadblocks

Roadblocks are typically used to secure sites with wide entrances, where functionality and level of security are the most important criteria rather than aesthetics. They will be most effective when used as the ultimate control point (image 9). Roadblocks can be classified as follows:

- automatic blockades with hydraulic drive,
- manual blockades to be used for occasional opening of the passageway,
- shallow or surface mounted blockades,
- deep mount blockades.

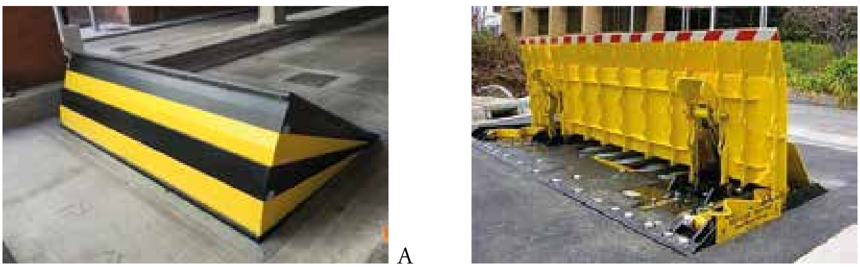

A B

Image 9. Automatic road bollards: shallow mounting (A), surface mounting (B).
Source: ATG Access marketing material.

Barriers

Barriers are used where it is impractical and unnecessary to place foundations on the road surface. Image 10 shows a barrier with foundations on both sides of the road. The depth of the foundations ranges from 500 mm to 1 500 mm.

Image 10. Barrier as VSB security.

Source: https://www.jacksons-security.co.uk/crash-rated-products/crash-rated-manual-arm-barrier [accessed: 24 IX 2022].

This is an aesthetically pleasing alternative to entrance gates, as it provides a faster opening of the entrance than most gates available on the market. The barriers can also be equipped with additional infills mounted below the moving arm to prevent pedestrians, cyclists or motorcyclists from bypassing the barrier.

Different types of products are available on the market - with manual or automatic drive, depending on the number of daily cycles of the crossing opening. They are tested even for vehicles weighing 7.5 t travelling at 80 kph.

Gates

The anti-terrorist gates tested are used as the ultimate physical access control for both vehicles and pedestrians. They can provide effective protection against VAW attacks and attempted intrusions by individuals. Gates also complement the perimeter protection of the site as a whole and are integrated into the permanent fence. A very common argument for the use of gates is that they are trouble-free, easy to maintain and operate, and reputable manufacturers guarantee trouble-free operation for a long time.

When testing the products, the same principles apply as for bollards, and for these devices too, results of high resistance to attack are obtained even for vehicles weighing 7.5 t travelling at 80 kph.

The name 'gate' refers to a whole diverse range of solutions, including: sliding gates, folding double-sided gates, double-leaf swing gates and gates for temporary installation. The choice of gate type depends on the opening possibilities, e.g. whether there is enough space to move the gate, the so-called return track for the sliding leaf, and in the case of folding gates, whether there is enough space to open them (Figure 13).

Figure 13. Shallow-mounted gate as VSB.
Source: Bakers Fencing, https://barkersfencing.com/product/vulcan-rcs/ [accessed: 24 IX 2022].

Gates are often chosen as a very effective solution due to their low penetration, as low as 0.0 m for some designs. An effective safeguard - in line with safety procedures - is the use of a gate in combination with other types of interlocking. The most common solution is to create a lock for vehicle control. The airlock can consist of automatic bollards mounted in front of the perimeter zone, which is the gate including the fence. This solution allows a two-stage verification level: in front of the lock and inside the lock area. A vehicle stopped at the lock can be subjected to a detailed inspection, including scanning the underside for explosives.

Fixed wire fences

Protecting only the access roads without supplementing it with an effective perimeter fence is often insufficient. The construction of a permanent barrier is often not possible due to considerable costs and installation difficulties, e.g. installation time, size of excavations, foundation work and collisions. For this reason, complementary systems are available on the product market, which are rope fences.

Rope fences are a system of tensioned steel ropes fed through intermediate posts that can be mounted at a distance of more than 1 200 mm from each other and a height of approximately 1 200 mm (image 11). The ropes pass through the intermediate posts and the posts proper anchored in a deep foundation, which are an important element in the strength of the overall rope fence. The depth of the foundations depends on the type of posts - intermediate and proper - with a much greater depth for the proper posts. Crash tests have shown the resistance of this type of fencing to attack by vehicles weighing 7.5 t travelling at 80 kph.

Image 11. Bristorm wire fencing.

Source: https://hill-smith.co.uk/what-we-do/bristorm-hostile-vehicle-mitigation/ [accessed: 24 IX 2022].

Art & design blockades - street furniture

These types of solutions are installed in city centres and have been created to ensure architectural coherence. These types of blockades introduce a certain visual lightness, coupled at the same time with a high degree of protection in the event of a vehicle attack. They take a variety of forms, such as benches, flowerbeds, flower pots, handrails or bollards with special art & design external covers placed over them. Another solution used by space architects is the design of complete landscaping devices, which are tested according to previously described standards. Their installation uses an integrated structural element such as a foundation sunk below ground level. Images 12 and 13 show examples of solutions that, in addition to their utilitarian functions, are an effective anti-terrorist protection.

Image 12. Examples of blockades in the form of street furniture.
Source: ATG Access marketing material.

Image 13. Use of a blockade consisting of flowerbeds and permanent bollards.
Source: ATG Access marketing material.

Another interesting example of the practical application of the art & design concept is the 'City of London' fixed bollard, styled on historic city posts. This type of security can be found throughout London. It is a unique solution combining traditional design with the highest safety requirements and is crash certified.

Image 14. 'City of London' type bollards.
Source: ATG Access marketing material.

Temporary blockades

Surface-mounted barrier systems, i.e. barriers not permanently tied to the ground, are designed to temporarily protect selected areas, especially during mass events and various types of gatherings. They are installed for a limited period of time and their design allows both installation in a very short time and easy transport by light vehicles. The barriers are supplied in separate modules that are stacked several at a time, allowing transport on a pallet and facilitating storage, loading and unloading.

Installation of the barrier on a road of standard width can be done in just a few minutes with a small installation team, without the use of a forklift. The advantage of the system is the use of fewer vehicles required to deliver all the elements of the blockade compared to the transport of traditional barriers (such as concrete or steel blocks) and the complete abandonment of the use of a forklift truck. The blockade is supplied with a wide variety of prefabricated components and adaptors to allow installation at different surface levels and in areas restricted by kerbs or existing landscaping. The barrier is designed to be aesthetically pleasing for users of urban public spaces. The barrier surfaces can be used as advertising media, which bring additional marketing or financial benefits to the event organiser if a sponsor is attracted.

A temporary barrier allows free access for pedestrians and cyclists only. In order to allow emergency services to pass through, a so-called vehicle access point can additionally be installed, which will be integrated into the standard barrier layout. Barriers of this type are crash tested with, for example, 7.5 t vehicles and are guaranteed to withstand impacts of up to 50 kph. As this system lacks a permanent connection to the ground, in the event of an impact the protected area can be penetrated by up to several metres. It is therefore necessary to plan the installation of the barriers so that they are positioned at a greater distance from the protected area than the penetration obtained in the tests (image 15).

Image 15. An example of a temporary barrier.
Source: https://www.pitagone.com/en/home/gallery [accessed: 24 IX 2022].

Earth blocks - embankments and ditches

Protected facilities can be secured by naturally formed barriers or by slight modification of existing landscaping, which can be part of effective perimeter protection against HVM. Natural barriers include rivers, ponds, lakes, densely wooded areas, steep slopes or unlevelled land surfaces. These types of barriers allow preventive measures to be carried out that result in the abandonment of an attack due to the lack of vehicular access. If such natural barriers do not exist in the perimeter protection area, it is possible to design them. The recommended solution is the construction of a ditch, embankment or a combination of these elements. Indications for the use of natural barriers may include:

- financial considerations - simple earthwork designs reduce the cost of installing expensive steel-built perimeter solutions,
- local availability of earthwork materials,
- ground considerations - potential for clashes with underground utilities that prevent the deep excavations needed for VSB installation;
- architectural correctness - the need to integrate the designed barriers into the existing landscape.

The design of natural barriers is not arbitrary and must be created based on guidelines, which are an important part of the HVM protection design. This type of protection should also be designed by an authorised, qualified designer. The ability of earth structures or landscape features to stop an attack will depend on their structure and dimensions. The main parameters to be analysed when creating this type of protection are:

- the strength of the material used, e.g. reinforcing embankments with additional stone filling,
- height, width, length, angle of slope of the edge - steepness in the case of a dike, depth in the case of a ditch.

Figures 14 and 15 illustrate which parameters need to be taken into account in order to use the terrain as protection against attack.

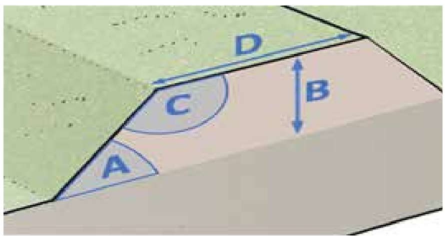


Figure 14. Parameters required for bund design: angles of inclination, length and height.

Source: *Guidance Note – HVM Earthworks and Landscaping Guidance Note*, https://www.cpni.gov.uk/resources/hvm-earthworks-and-landscaping, p. 11 [accessed: 24 IX 2022].

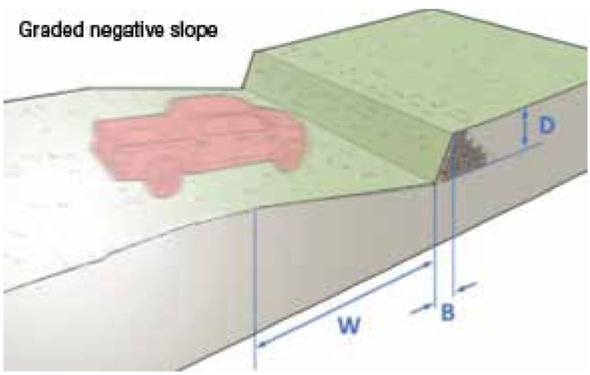


Figure 15. Parameters required for ditch design: slope angles, length, height, road over-run lengths.

Source: *Guidance Note – HVM Earthworks and Landscaping Guidance Note*, https://www.cpni.gov.uk/resources/hvm-earthworks-and-landscaping, p. 8 [accessed: 24 IX 2022].

Author's experience in security design

The author of this article has extensive knowledge of security design using VSBs. He points out that at the stage of developing the assumptions for VSBs, there are two conditions arising from the terrain that affect the implementation of the design.

The first case occurs when there are limited or no opportunities to influence the design of access roads. In this situation, there are likely to be many versions of possible security scenarios, and preparing a design suitable for the site requires the preparer to have the expertise to analyse many aspects resulting from the risk assessment of the attack. Therefore, only a qualified consultant is able to propose an optimal solution, which takes into account both the security features appropriate to the threat and optimises the costs of implementation. The following are examples of typical safeguards that can be applied to an access road. Figure 16 A shows an unprotected access road to a facility that is being protected, and the following figures show possible security measures under the same conditions.

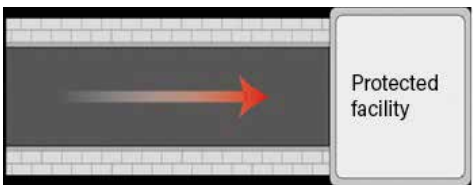


Figure 16. A protected building with no barriers.
Source: own elaboration based on ATG Access marketing material.

Figures 17-22 show the use of barriers matched to the estimated vehicle mass and speed obtained from the vehicle dynamic assessment (VDA) as protection for buildings. Based on the parameters described in the certificate for the selected bollards, they were installed at an appropriate distance from the building, taking into account the penetration and displacement of crash debris. The bollards were only installed in the carriageway area of the access road (Figure 17).

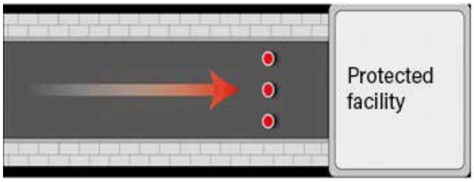


Figure 17. Automatic bollards only in the carriageway zone.
Source: own elaboration based on ATG Access marketing material.

Figure 18 illustrates the placement of additional bollards in the pedestrian walkway area. This is a complete and correct design example, as this is the only way to secure the entire façade of a protected building. The perpetrator will most likely not only move along the carriageway, but may also try to bypass the installed protection. After an analysis in a real-life situation, it may be necessary to use yet other, additional interlocks.

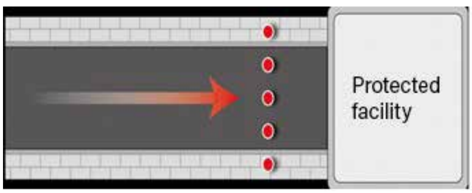


Figure 18. Fixed bollards in the carriageway zone and the pedestrian route zone.
Source: own elaboration based on ATG Access marketing material.

By placing chicanes in front of the anti-terrorist barrier, the cost of installing the products can be optimised. By limiting the speed of the vehicle used for the attack, barriers that are resistant to an attack by a vehicle travelling at 80 kph can be used instead of barriers that are resistant to an attack by a vehicle travelling at 50 kph or less (Figure 19).

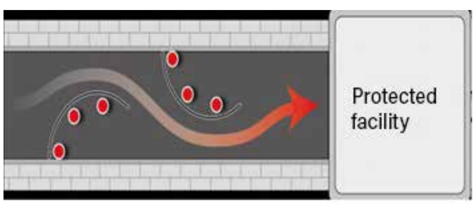


Figure 19. Chicanes to reduce vehicle speed in the carriageway zone only.
Source: own elaboration based on ATG Access marketing material.

The placement of additional chicanes in the pedestrian thoroughfare area creates a complete and correct example of HVM protection design (Figures 20 and 21).

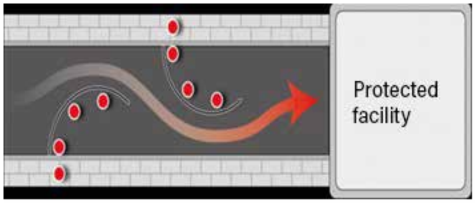


Figure 20. Chicanes reducing vehicle speed in the carriageway zone and the pedestrian route zone.
Source: own elaboration based on ATG Access marketing material.

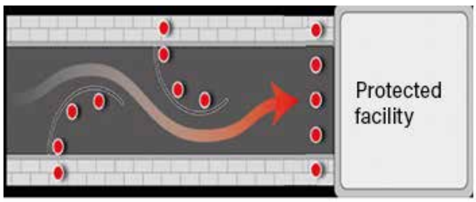


Figure 21. Correctly and cost-optimally designed installation of chicanes and bollards.
Source: own elaboration based on ATG Access marketing material.

The figures presented show examples of solutions used as preventive measures following a risk analysis. A qualified designer will not only correctly determine the required security levels for the various perimeter zones of a building, but will also be able to optimise the costs associated with the choice of specific products. Preparing the designs will allow a blockade system to be planned around the building with a consistent appearance, but with different attack resistance parameters and therefore different installation costs. The basis for doing this properly is to carry out a VDA to define which vehicles (weight and type) and at what maximum speed can be used during an attack.

The second case of conditions influencing project implementation is where designers have influence over the design of access roads at the design stage, so that they can limit the speed and size of moving vehicles. Figure 22 shows the solutions used in the design of access roads.

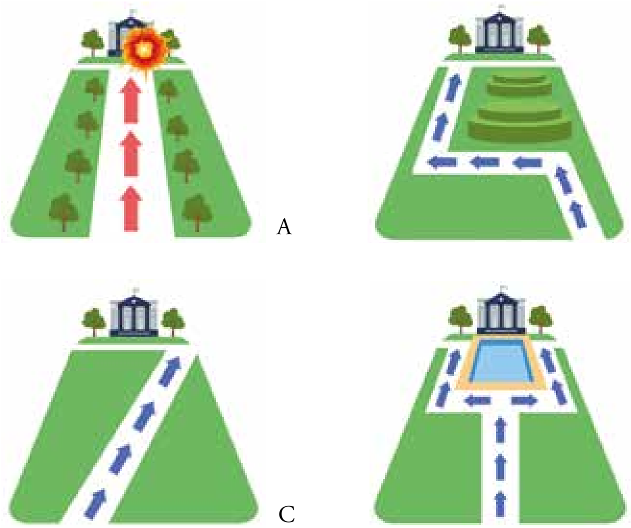


Figure 22. Preventing VAW attacks through access road design. Access road runs straight ahead (A), twisting access road and natural obstacles placed on the axis of the road (B), offsetting the access road in a 'diagonal' position (C), placing an obstacle, such as a body of water, on the axis of the access road (D).

Source: own elaboration based on: https://www.cpni.gov.uk/resources/integrated-security [accessed: 24 IX 2022].

The examples shown in the figure are for the following situations:
A – the access road to the protected site runs straight ahead, giving the VAW vehicle the opportunity to accelerate,
B – an access chicane in the form of a twisting access road and natural obstacles reduce the speed at which the vehicle can travel,
C – moving the access road 'diagonally' allows the direct access to the site to be offset organically,
D – pointing the access road in a different direction and placing an obstacle, such as a body of water, in front of the building on the road allows access to be obstructed, effectively reducing the possibility of an attack.

The examples cited above illustrate the variety of cases depending on the situation at the project site. Regardless of the landscaping possibilities around the protected area, there are solutions to secure any type of site.

Design guidelines and good practices

One very important parameter that must always be taken into account when designing safety features is the distance between barriers - this must not be greater than 1200 mm. This applies to all types of posts mounted in parallel next to each other and to road blocker barriers. This recommendation follows directly from the provisions of the standards for test conditions, which include also foundation testing as part of the certification process. Indirectly, it is due to the fact that there are passenger cars on the automotive market with a short wheelbase (e.g. the Fiat 500 has a wheelbase of 1414 mm). Figure 23 shows the distance that must be maintained between: cylindrical posts, street furniture in the form of concrete blocks, street furniture with irregular shapes and cone-shaped posts.

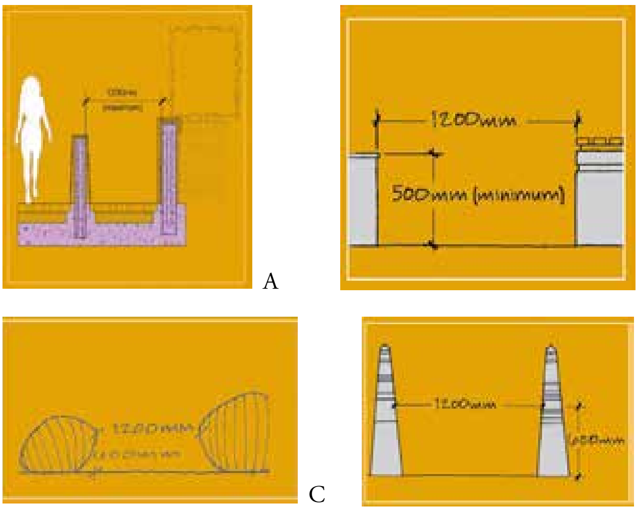


Figure 23. Maximum recommended distances between barriers: cylindrical posts (A), concrete block street furniture (B); irregularly shaped street furniture (C), 600-1200 mm spaced obstacles, cone-shaped posts (D).

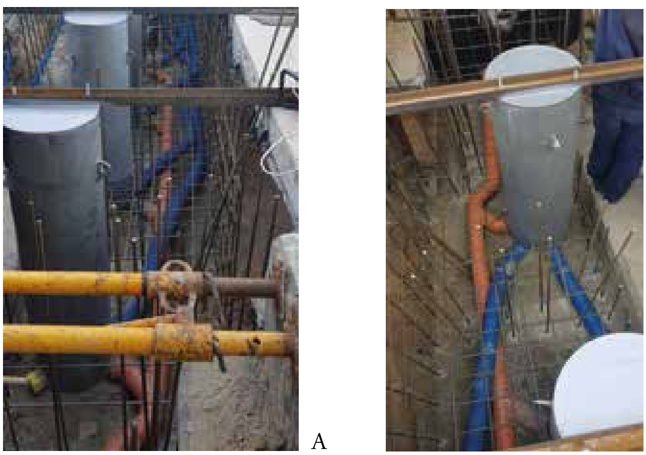
Source: own elaboration based on: https://www.cpni.gov.uk/hostile-vehicle-mitigation [accessed: 24 IX 2022].

Further recommendations that affect the proper installation of safety barriers, trouble-free operation and effective protection in the event of an attack are:

- making the correct size and depth of foundation with reinforcement and taking into account the concrete class, amount and density of reinforcement, according to the manufacturer's recommendations and the results of crash tests,

- construction of the drainage with the proper slope for automatic and manually controlled systems,
- levelling equipment, installing feeders in conduit covers to ensure their exchangeability in case of failure,
- establishment and implementation of a security procedure for emergency opening of the equipment in case of the need to enter the secured area by services such as ambulance, fire brigade and police or other authorised persons,
- agreeing service procedures, response times and maintaining continuity of VSB equipment.

An important role in the correct implementation of the project is played by supervision and knowledge of the technological details that determine the effectiveness of the safeguards installed (image 16). If the developer is unable to secure the cooperation of a qualified specialist, the use of independent experts in the area of anti-terrorist security is recommended.



A B

Image 16. Examples of correct installation of automatic bollards (A and B).

Source: own elaboration.

Implementation of projects

Nowadays, increasing importance is being placed around the world on the installation of proper technical security measures in places particularly vulnerable to attacks. One example of this is France and the anti-terrorist barriers near public places. One such site is the Gare de Lyon station, which is one of the six main stations in Paris, serving around 110 million passengers per year[20]. The possibility of a terrorist attack on the station building is very high, which is why, in addition to many security measures, VSBs have found their application there. In order to impede access to the site of a potential attack, automatic and fixed barriers were installed in front of the building, with resistance adapted to the anticipated threat. The designer used a cost-effective solution in this case, choosing devices that were appropriate to the size and speed of the vehicle that could be used as an attack tool in this particular case (image 17).

Image 17. Security at Gare de Lyon station in Paris.
Source: own elaboration.

Another example of the proper implementation of a 'hostile vehicle attack' project is securing the entrance to the security zone around the Élysée Palace, which is the official residence of the French President and the venue for government meetings. The vulnerability to terrorist attack for this facility is very high due to the constant presence of VIPs, important for the proper functioning of the state, and the organisation of mass events related to French national holidays. The solutions seen in image 18 were chosen and implemented in accordance with good engineering practice based on extensive knowledge of the protection of this type of facility.

[20] See: https://en.parisinfo.com/transport/73400/Gare-de-Lyon [accessed: 24 IX 2022].

The standard security measures against vehicle attack in this case are shallow-mounted automatic barriers and fixed locks, with very high resistance to attack. Complementing the installed blockades are temporary barriers used during mass events. The installation of the additional temporary barriers seen in the photo is linked to Bastille Day, a national holiday celebrated in France on 14 July (the day the photograph was taken). An additional security measure is a chain barrier that prevents single-track vehicles from entering the protected area.

Image 18. Access street to the Élysée Palace.
Source: own elaboration.

Summary

The description of the different types of anti-terrorist barriers and the principles of installation and good design practices presented in this article can serve as an introduction to the vast subject of securing facilities or grounds against vehicle attack. Terrorist attacks that have occurred in European Union countries have raised awareness among the public and made it possible to apply preventive measures, which is why services have started installing VSBs in many countries. The discussed solutions introduced in Paris are very good examples.

When considering the issues concerning VSBs, it should be remembered that knowledge about them is a new topic in Poland due to the initial stage of development and popularisation of installing this type of devices. This situation is directly related to the level and type of defined threats in our country, which determine such and not other dynamics of the emergence of anti-terrorist protections. When it is necessary to supply and install barriers, care and attention should always be paid to the professional execution of the project. It is recommended to take measures such as:

- carrying out a vehicle dynamics assessment, i.e. assessing which vehicle and its speed is the maximum risk for specific locations within the protected site,
- consulting a certified expert for studies and projects,
- establishing - in cooperation with the consultant and the services: ambulance, fire brigade and police - the emergency opening procedure for the blockades in the event of various threats,
- selecting suppliers of products and installations which are licensed by the Ministry of the Interior and Administration and have a facility security clearance issued by the Internal Security Agency;
- introduction of control of access to information for contractor's employees only to authorised persons and, in the case of classified documentation, admitting only employees with security clearance adequate to the level of classification,
- establishing maintenance procedures for periodic inspections and failures: response time, time for removal of failures and maintenance scopes in accordance with the original manufacturer's instructions.

It is very important during meetings related to this type of investment to share the knowledge of the investor and the equipment supplier. The following is a suggestion of questions to ask when discussing the preparation of a vehicle attack protection project. The answers will help create a vision of the needs, requirements and an assessment of the feasibility. Example questions:

- Has a VDA vehicle dynamics assessment been carried out?
- What is the required level of protection according to standards: PAS 68, IWA 14-1, ASTM F2656?
- What is the planned access control procedure for authorised vehicles, e.g. ambulance, fire brigade, police?
- What is the infrastructure of the site: power supply, internet network, access to water?
- What are the hours during which disruptive and non-disruptive installation work can be carried out?
- Are there any limits on the depth of foundation of the equipment (collisions)?

- What is the assumed number of opening/closing operations per day and night (frequency of operation of the device)?
- What is the average number of opening/closing operations during peak hours? When are the peak hours?
- How are the units supposed to operate in the event of power loss? Are they to remain in the open or closed position?
- Are there requirements for the appearance of the security (design aesthetics, art & design)?
- Will vehicles move in one direction or in both directions?
- Are static devices planned, in addition to the automatic devices to be installed?
- Has a Real System Cost analysis been carried out - advice to the customer on service and maintenance of the equipment?
- Is only the delivery of the equipment required or full construction work including electrical installations?

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