BUILDING VULNERABILITY ASSESSMENT FOR EXPLOSIVE AND CBR TERRORIST ATTACKS

MARCO CARBONELLI[1], RICCARDO QUARANTA[1], ANDREA MALIZIA[2],
PASQUALE GAUDIO[1], DANIELE DI GIOVANNI[1,3] & GRACE P. XERRI[1]
[1]Industrial Engineering Department, University of Rome Tor Vergata, Italy
[2]Department of Biomedicine and Prevention, University of Rome Tor Vergata, Italy
[3]Unicamillus-Saint Camillus International University of Health Sciences, Italy

ABSTRACT

Assessing the vulnerabilities of a building/site for a specific threat is one of the key issues in the risk assessment process. A vulnerability is defined as any weakness that can be exploited by an aggressor to make an asset susceptible to damage. The purpose of the vulnerability assessment process discussed in this paper is to identify the main vulnerabilities which influence a building's risk level when a specific explosive or chemical, biological, radiological (CBR) threat arises. Vulnerability assessments are designed to provide an in-depth analysis of the characteristics of a facility and its associated elements to identify building weaknesses and lack of redundancy, as well as to determine protective or corrective actions that can be designed or implemented to reduce building vulnerabilities. This work proposes an innovative building vulnerability assessment method (BVAM), comprised of three steps. The first step, building criticality analysis (BCA), seeks to verify the criticality of several building aspects elaborated from best practices on the analysis of building structure and function. The result of this BCA determines if critical building components or systems, designed for the deterrence, detection, and limitation of damages, can continue to function properly during a crisis, and to ensure the correct operation of the emergency systems. The second step aims at characterising the application of a given number of specific threats to the building. The third step focuses on a final assessment of the level of vulnerability associated with the various applied threats, for the specific building and the specific assets to be protected. This result is achieved by employing a proposed seven-level vulnerability scale. The result of the evaluation of the level of vulnerability can be used for the final risk assessment phase.

Keywords: risk assessment, vulnerability assessment, buildings, terrorism, explosive, unconventional attacks, CBR.

1 INTRODUCTION

Many definitions of risk are available in the technical literature [1]–[6]. In any of these works, the concept of risk is always associated with uncertainties related to future events.

In practice, risk is a hazard or an exposure to a possibility of loss or damage, or ability to suffer a possible loss [4]. The estimation of risk [2] is usually found by the probability of the event occurring multiplied by the consequence of the event, given that it has occurred. In other words, risk is considered as a combination of the consequences of an event and the associated likelihood/probability of its occurrence [1], [7], [8]. Hereafter, three approaches to the risk assessment are briefly described.

According to the USA DHS [9], risk "R" is mathematically expressed as a function of the threat probability "T" to a target/area, the vulnerability "V" of the target/area, and the consequence "C" of an attack on that target/area, as described in eqn (1):

$$\mathrm{R} = f(\mathrm{T}, \mathrm{V}, \mathrm{C}). \tag{1}$$

In the approach proposed by the UN [10], risk "R" is expressed as a function of hazard probability "H", vulnerability "V" and exposure "E", as described in eqn (2):

$$\mathrm{R} = f(\mathrm{H}, \mathrm{V}, \mathrm{E}). \tag{2}$$

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Finally, in the European approach [9], risk "R" is a function of the probability of occurrence of a hazard "P", the exposure "E" (total value of all elements at risk), and the vulnerability "V", as described in eqn (3):

$$R = f(P, V, E). \quad (3)$$

The EU technicians highlight that the impacts of a hazard are also a function of the preventive and preparatory measures that are employed to reduce the risk. In other words, effective prevention and preparedness measures can decrease the vulnerability and therefore the risk.

As a general statement, vulnerabilities are the characteristics of an asset, system, location, process, or operation that render it susceptible to destruction, incapacitation, or exploitation by mechanical failures, natural hazards, terrorist attacks, or other malicious acts. A vulnerability can therefore be defined as any weakness that can be exploited by an aggressor to make an asset susceptible to damage.

Based on this consideration and the approaches abovementioned, assessing the vulnerabilities of a building for a specific threat is one of the key issues in the risk assessment process.

Vulnerability assessments (VAs) for buildings [11] are designed to provide an in-depth analysis of the characteristics of the facility or its associated elements to identify weaknesses and lack of redundancy, as well as to determine protective or corrective actions that can be designed or implemented to reduce the vulnerabilities.

2 OBJECTIVES

In this work, an original building vulnerability assessment method (BVAM) is proposed. The purpose of this VA process is to identify the vulnerabilities that mainly influence the level of risk of a building when a specific explosive or CBR threat arises. The method proposed is based on an analytical procedure structured around 76 different items organised into nine topics, which include physical and organisational aspects and social, economic, structural and institutional factors, with the aim of identifying the building criticalities. The result of the BVAM is based on a seven-level vulnerability scale and will provide numerical values that represent, for the scenario analysed, different levels of vulnerability. The numerical value of the vulnerability level thus assessed can be used, in combination with the values of threat level and exposure level, in the calculation of the level of risk associated with a building.

3 BUILDING VULNERABILITY ASSESSMENT METHOD

The BVAM proposed in this paper, has been developed and adapted from the USA Department of Veterans Affairs checklist [11] and from the risk analysis model presented in Carbonelli [1].

The method is structured in three different steps, as represented in Fig. 1.

- Step 1: Proposes to verify, through the building criticality analysis (BCA), the criticality of 76 items, grouped into nine topics, elaborated from the best practices on the analysis of building structure and functions.
- Step 2: Aims at characterising a given number of specific threats to be applied to the building.
- Step 3: Focuses on the final assessment of vulnerability associated with the specific considered threats, for the specific building, and for the specific assets to be protected, using a proposed Vulnerability Scale comprised of 7 levels.

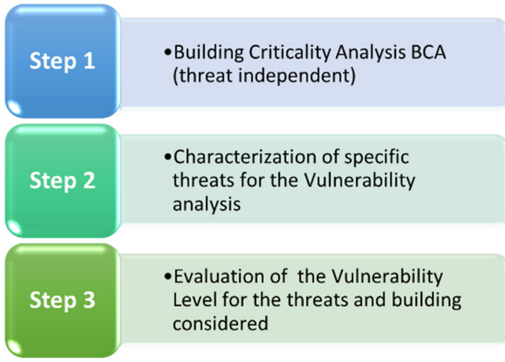

Figure 1: Building vulnerability assessment method in three steps.

The result of the VA provides a numerical value which can be used in the final risk assessment.

3.1 Step 1: Building criticality analysis (BCA)

The BCA proposed in Step 1 can be considered as a preliminary assessment of the weaknesses of different aspects of the building site, structure, and functions. In addition, this analysis allows for the evaluation of design issues that could potentially reveal exploitable vulnerabilities.

The result of the analysis determines if, during a crisis, critical components/systems will continue to work properly in order to enhance deterrence, detection, and limitation of damages, and to ensure the correct operation of the emergency systems. The BCA is categorised in nine sections, indicated as "topics", listed in Table 1.

Table 1: Criticality topics and number of items per topic (Step 1).

Topic	Criticality topics	No. of items
1	Site characteristics	12
2	Architecture	10
3	Structural systems	7
4	Building envelope	5
5	Utility systems	8
6	Mechanical systems and HVAC	10
7	Infrastructure and systems of internal essential services (plumbing, gas systems, electrical power, fire alarms, telephone and ICT services)	11
8	Security systems	8
9	Emergency, security and operation continuity plans	5
Total	Nine topics	76 items

To conduct a complete building VA, each topic should be assigned to the identified assessment team (AT). Such a team should be composed by engineers, architects, or subject matter experts who are knowledgeable and qualified to perform an accurate analysis. The AT should carefully analyse the topics in Table 1 (from the site characterisation to the emergency, security and operation continuity plans) in order to highlight possible criticalities and potential related vulnerabilities.

A criticality is intended as a general weakness that could be potentially exploited for an attack. In this approach, a criticality becomes a vulnerability when a detailed and specific threat is considered and applied to a specific building and asset. It is important to observe that not all the criticalities generate a correspondent vulnerability; this correlation depends on the specific threat, asset and building considered, as discussed below.

The nine topics suggested reflect different aspects and functions typical of a building; the objective of the BCA is to illustrate all the essential building characteristics to determine an accurate result. For each topic, a list of items – associated with one or more questions – is included. These 76 items are independent of a specific threat and must be considered and evaluated by the AT through a criticality scale (Table 2) to determine their criticality. The criticality evaluation of a single item is carried out by adopting a four-level scale based on a quantitative weight score (WS). For this scale, the tripling criteria is applied. The rationales for adopting a quantitative scale based on the tripling criteria is widely discussed in Carbonelli [1].

Table 2: Criticality scale for item analysis on four levels.

Criticality scale (for items)	**Criticality WS**
Extreme	27
Elevated	9
Marginal	3
Negligible	1
Not applicable	–

As an example, one of the 76 different criticality scales used in this method is reported in Table 3, that responds to the question: *Are there any major/critical infrastructures surrounding the building*?

Table 3: Criticality scale relative to item 1.1 (Surrounding structures/facilities).

1.1: Criticality scale (Surrounding structures/facilities)		**WS**
Extreme	Many significant critical infrastructures are adjacent to the main building considered	27
Elevated	Some significant critical infrastructures are adjacent to the main building considered	9
Marginal	No major critical infrastructure and only infrastructures of secondary importance are adjacent to the main building considered	3
Negligible	No significant infrastructure is adjacent to the main building considered	1
N/A	Not applicable: it is not possible to give a relevant answer to this question	–

Using these scales, the AT can provide for each item a relevant WS to highlight the criticality conditions for the final VA.

For each topic, a cumulative criticality evaluation is then obtained by calculating for all the WSs, the average “m”, the standard deviation “s” [12], and the modified average “m_{mod}”, as defined in eqn (4):

$$m_{mod} = m + s. \quad (4)$$

Below, one of the nine topic tables used in the BCA is presented as an example (Table 4). Each line of every table represents a specific item and the questions that the AT must answer to evaluate the criticality, taking into account the relative criticality scale. Each of the nine tables enables the evaluation of the relative items expressed by a criticality WS assigned by the AT, and the average and standard deviation of the WSs. These values provide a rapid indication of the general criticality of the topic.

Table 4: Topic 1 – Site characteristics, table of items.

Topic 2: Architecture			
Item no.	**Item**	**Question**	**WS**
1.1	Surrounding structures/facilities	Are there major/critical infrastructures surrounding the building?	
1.2	Terrain characteristics	Does the terrain place the building in a depression or low area?	
1.3	Curb lane parking characteristics	Is curb lane parking for unmonitored parked vehicles unacceptably close to the building?	
1.4	Perimeter barriers for pedestrian access	Is a perimeter fence, or other types of barrier controls, in place for the pedestrian access?	
1.5	Vehicle access points	Are the vehicle access points well designed?	
1.6	Pedestrian access control	Is pedestrian access controlled at the perimeter of the building?	
1.7	Private vehicle access control	Is private vehicle access controlled at the perimeter of the building?	
1.8	Shipping/delivery vehicle access control	Are shipping and delivery vehicles controlled at the building entrance?	
1.9	Alternative potential access	Are there any exploitable potential access points to the building through utility paths or water runoff?	
1.10	Anti-ram devices	What are the types of vehicle anti-ram devices at the building?	
1.11	Site lighting in the external area	Is the site lighting adequate from a security perspective in roadway access and parking areas?	
1.12	External connection to the building	Are any of the nearby in-ground and out-ground infrastructures directly connected to the building?	
Topic 1			
Average of criticality WSs			
Standard deviation of criticality WSs			

3.2 Step 2: Characterisation of specific threats for the VA

Once the general criticalities of the building have been examined, it is necessary to introduce and describe the specific threats deemed to be more likely applied to the building under assessment. In Step 2 of this BVAM method, a specific VA is carried out by the AT that performs the following activities, considering the selected threats:

- for each selected threat, the agent/explosive and vector types, the possible maximum size/quantity of the agent/material used in the attack, and the possible specific locations in the building are analysed in detail.
- the BCA results obtained in Step 1 provide immediate indications of the weaknesses that can be exploited, becoming effective vulnerabilities. These indications provide crucial elements to mitigate the vulnerability, by reducing the associated criticality, and assessing the specific vulnerability of the building (Step 3) related to the considered threats.

3.3 Step 3: Evaluation of the vulnerability level (VL) for the building

At the end of Step 2, the AT has a clear picture of the exploitable criticalities of the building with respect to the threats and the assets considered. The overall VL is assessed in this Step 3. For each threat considered, the AT evaluates a specific building VL, using a seven-level vulnerability scale which provides qualitative and quantitative definitions for each level. The vulnerability scale is described in Table 5. The seven levels proposed in the table represent seven contiguous ranges of vulnerability in the interval from 0 to 1, where 0 represents the minimum vulnerability value (i.e., totally invulnerable) and 1 represents the maximum vulnerability value (i.e., totally vulnerable).

Following the method proposed, the AT has, at this point, a clear picture of the building criticalities and the threats to be applied. Only under this condition is it possible to provide a reliable evaluation of the specific VL. This proposed vulnerability scale provides not only qualitative descriptions of the VL but also measurable quantitative values and adopts a logarithmic approach for the definition of the range of each level. This type of approach, as discussed in Carbonelli [1], has many advantages over a linear approach. The quantitative value can be used in the calculation of the overall risk associated with the building.

4 BVAM APPLICATION TO A CASE STUDY

In order to render the BVAM more tangible, a practical application of the proposed method has been carried out by analysing a real shopping centre to establish a relevant case study. The shopping centre, whose exact information is not disclosed for security purposes, is located in the outskirts of an important Italian town. The following three scenarios have been considered:

- the explosion of a suicide belt bomb.
- the explosion of a van bomb.
- the explosion of a Caesium-137 dirty bomb.

4.1 Building criticality analysis (BVAM Step 1)

The data of this study has been collected through an inspection of the shopping centre, with permission from the property. The results were processed using a prototype BCA software tool developed on a spreadsheet application specifically for this work. The results obtained for this case study are reported in ten tables, of which one is presented as an example (Table 6). The criticality WS values were entered by the AT. The quantitative WS values correspond, instead, to the automatic data processing of the software tool.

Table 5: Seven level vulnerability scale.

Vulnerability rating	Qualitative	Quantitative (no. of successes/no. of attempts)	Level description
7	Very high	From 3^{-1} to 3^{0} (1/3–1)	One or more major vulnerabilities that make the asset extremely susceptible to an aggressor, for the specific threat considered. The building lacks redundancies/physical protection/ resilience. The entire building would only be functional again a very long period of time after an event.
6	High	from 3^{-2} to 3^{-1} (1/9–1/3)	One or more major vulnerabilities that make the asset highly susceptible to an aggressor, for the specific threat considered. The building has poor redundancies/physical protection/ resilience, and most parts of the building would only be functional again a long period of time after an event.
5	Medium high	from 3^{-3} to 3^{-2} (1/27–1/9)	An important vulnerability that makes the asset very susceptible to an aggressor, for the specific threat considered. The building has inadequate redundancies/physical protection/resilience, and most critical functions would only be operational again a long period of time after an event.
4	Medium	from 3^{-4} to 3^{-3} (1/81–1/27)	A vulnerability that makes the asset fairly susceptible to an aggressor, for the specific threat considered. The building has insufficient redundancies/physical protection/ resilience, and most parts of the building would only be functional again a considerable period of time after an event.
3	Medium low	from 3^{-5} to 3^{-4} (1/243–1/81)	A vulnerability that makes the asset somewhat susceptible to an aggressor, for the specific threat considered. The building has a fair level of redundancies/physical protection/ resilience, and most critical functions would only be operational again a considerable period of time after an event.
2	Low	from 3^{-6} to 3^{-5} (1/729–1/243)	A minor vulnerability that slightly increases the susceptibility of the asset to an aggressor, for the specific threat considered. The building has a good level of redundancies/physical protection/resilience, and the building would be operational within a short period of time after an event.
1	Very low	$< 3^{-6}$ (< 1/729)	No relevant vulnerability appears after the analysis. The building has excellent redundancies/physical protection/resilience, and the building would be operational immediately after an event.

Table 6: Case study results of the BCA for Topic 3 – Structural systems.

Topic 3: Structural systems				
Item no.	**Item**	**Questions**	**Criticality WS**	**Quantitative WS**
3.1	Construction characteristics	What type of construction? What type of concrete and reinforcing steel? What type of steel? What type of foundation?	Marginal	3
3.2	Structural and non-structural components	Are any of the structural/non-structural components vulnerable either directly or indirectly to explosive blast?	Elevated	9
3.3	Progressive collapse	Is the building capable of sustaining the removal of a column for one floor above grade at the building perimeter without progressive collapse?	Marginal	3
3.4	Floor of loading dock	Will the loading dock design limit damage to adjacent areas and vent explosive force to the exterior of the building?	Extreme	27
3.5	Mailroom explosion mitigation	Are mailrooms, where packages are received and opened for inspection, and unscreened retail spaces designed to mitigate the effects of a blast on primary vertical or lateral bracing members?	Elevated	9
3.6	In-ground structural systems	Would failure of part of the in-ground infrastructure affect the structural system of the building?	Elevated	9
3.7	Underground water presence	Does the presence of underground water under the building generate instability and unacceptable flooding?	Elevated	9
Topic 3				
Average of criticality WSs			9.86	
Standard deviation of criticality WSs			7.47	

The total results of the BCA of the shopping centre, for all the nine topics, are summarised in Table 7.

Table 7: Summary of the results obtained for the shopping centre case study.

Topic criticality analysis				
Topic no.	**Topic name**	**m**	**s**	**m_{mod}**
1	Site characteristics	7.00	6.93	13.93
2	Architecture	13.67	9.71	23.37
3	Structural systems	9.86	7.47	17.33
4	Building envelope	11.40	8.14	19.54
5	Utility systems and internal distribution infrastructures	6.75	7.9	14.65
6	Mechanical systems – HVAC	15.00	10.04	25.04
7	Infrastructures and systems of internal essential services	4.09	2.31	6.41
8	Security systems	10.33	6.18	16.52
9	Emergency, security and operation continuity plans	7.80	2.40	10.20

The m_{mod} index can be interpreted using a final criticality scale (Table 8).

Table 8: Criticality Scale based on m_{mod}.

Criticality m_{mod} Scale	**Range**
Extreme	>15
Elevated	7–15
Marginal	3–6.99
Negligible	1–2.99
NA	–

Based on Table 8, the analysis of the results from Table 7 highlights that:

- Topics #2, 3, 4, 6, 8 show an extreme criticality.
- Topics #1, 5, 7, 9 show an elevated criticality.
- Topic #7 shows a marginal criticality.

These results indicate a high level of criticality of the building due to the weaknesses identified through the 76 items analysed.

4.2 Characterisation of specific threats (BVAM Step 2)

As abovementioned, three threats were considered in this phase. For each threat, the AT must specify in detail the following:

- the type of agent/explosive.
- the type of vector for the agent/explosive.
- the possible maximum size/quantity of the agent/material.
- the possible specific location, with respect to the building, where the threat might be applied.

Specific and detailed information on different types of explosion and blast characteristics [13] can be found also in a recent European Commission JRC technical report [14] and in the USA FEMA "Reference manual to mitigate attacks against buildings" [11].

Tables 9–11 summarise the assumptions made by the AT in this phase.

Table 9: Characterisation of the threats for the “suicide belt bomb” case.

Case: Suicide belt-bomb	**Specific data**
Type of agent/explosive	TNT
Type of vector	Belt-bomb
Maximum size/quantity of the agent/material	5 kg
Specific location, with respect to the building, where the threat might be applied	Immediately inside the building from shopping centre entrance

Table 10: Characterisation of the threats for the “van bomb” case.

Case: Van bomb	**Specific data**
Type of agent/explosive	TNT
Type of vector	Van
Maximum size/quantity of the agent/material	800 kg
Specific location, with respect to the building, where the threat might be applied	Area of access for shipping/delivery vehicles

Table 11: Characterisation of the threats for the “Caesium-137 dirty bomb” case.

Case: Caesium-137 dirty bomb	**Specific data**
Type of agent/explosive	TNT and Caesium-137
Type of vector	Pick-up truck
Maximum size/quantity of the agent/material	400 kg TNT and 90 g Caesium-137
Specific location, with respect to the building, where the threat might be applied	In the external parking area

Finally, a further evaluation of the criticality items of Step 1 was carried out with the aim of highlighting both the primary weaknesses that can be directly exploited as actual vulnerabilities for threat under analysis, and the secondary weaknesses that, in an indirect manner, contribute to making the consequences of the attack more severe. These were noted with a criticality level as “elevated” or “extreme” in Step 1.

If mitigation actions against the vulnerabilities are to be taken by the AT, the primary vulnerabilities should be reduced first and, only if adequate resources are available, the secondary vulnerabilities should be addressed.

4.3 Evaluation of vulnerability level (BVAM Step 3)

Considering the results obtained in the two previous steps, it was possible for the AT to evaluate the specific vulnerability of the building.

The three threats considered present elevated or extreme VL. In the “suicide belt bomb” case, the area of concern relating to impacts on human health involved the building’s internal area. For the other two scenarios, the greatest impacts were found in the external areas of the shopping centre, with maximum consequences in terms of area impacted in the “dirty bomb” explosion case.

Using Table 5, the AT was able to determine the vulnerability rating for the three threats, for example, by assigning a VL of 7 (very high) to the three considered cases.

Table 12: Main exploitable vulnerabilities in case of a “suicide belt bomb” explosion.

Criticality item – Exploitable vulnerability (suicide belt-bomb)	**Level of criticality**	**Vulnerability type**
1.6: No pedestrian access control at the perimeter of the building	Elevated	Primary
2.4: Public and employee entrances do not include equipment for access control-screening	Extreme	Primary
2.7: Critical assets (people, activities, building systems and components) are not well separated from main entrance, vehicle circulation, parking	Elevated	Secondary
2.10: Ceiling, internal walls, overhead utilities and lighting systems are not designed to remain in place without generating debris in hazardous events	Extreme	Secondary
4.3: Glazing of the building are not secure in case of blast	Elevated	Secondary
5.6: No redundant and reliable electrical service source	Extreme	Secondary
7.11: No mass notification system that reaches all building occupants	Elevated	Secondary
8.1: CCTV cameras used, 24 hours/7 days a week recorded and monitored at the perimeter and in the critical areas of the building are insufficient	Elevated	Secondary
8.2: Video quality not adequate both in daylight and darkness	Elevated	Secondary
8.6: Security scanners (x-ray, magnetometer, magnetic imaging, etc.) are not used for security purposes in some areas of the building	Extreme	Primary
9.4: Emergency plan not up-to-date and not well designed	Elevated	Secondary
9.5: Operational continuity plan to apply no up-to-date and well-designed	Elevated	Secondary

Table 13: Main exploitable vulnerabilities in case of a "van bomb" explosion.

Criticality item – Exploitable vulnerability (van-bomb)	**Level of criticality**	**Vulnerability type**
1.8: No vehicle access control at the shipping/delivery entry	Elevated	Primary
2.5: Doors and walls along the security screening not adequately reinforced	Elevated	Secondary
2.7: Critical assets (people, activities, building systems and components) are not well separated from main entrance, vehicle circulation, parking	Elevated	Secondary
2.10: Ceiling, internal walls, overhead utilities and lighting systems are not designed to remain in place without generating debris in hazardous events	Extreme	Secondary
4.1: Low designed or estimated protection level of the building envelope against a possible high magnitude explosive threat	Extreme	Secondary
4.3: Glazing of the building are not secure in case of blast	Elevated	Secondary
4.4: Building is not designed to resist to high external pressure (ex. blast)	Elevated	Secondary
5.6: No redundant and reliable electrical service source	Extreme	Secondary
7.11: No mass notification system that reaches all building occupants	Elevated	Secondary
8.1: CCTV cameras used, 24 hours/7 days a week recorded and monitored at the perimeter and in the critical areas of the building are insufficient	Elevated	Secondary
8.2: Video quality not adequate both in daylight and darkness	Elevated	Secondary
9.4: Emergency plan not up-to-date and not well designed	Elevated	Secondary
9.5: Operational continuity plan to apply no up-to-date and well-designed	Elevated	Secondary

Table 14: Main exploitable vulnerabilities in case of a "Caesium-137 dirty bomb" explosion.

Criticality item – Exploitable vulnerability (Caesium-137 dirty bomb)	**Level of criticality**	**Vulnerability type**
1.3: Curb lane parking for uncontrolled parked vehicles is placed unacceptably close to the building	Elevated	Primary
1.7: No private vehicle access control at the perimeter of the building	Elevated	Primary
2.5: Doors and walls along the security screening not adequately reinforced	Elevated	Secondary
2.7: Critical assets (people, activities, building systems and components) are not well separated from main entrance, vehicle circulation, parking	Elevated	Secondary
2.10: Ceiling, internal walls, overhead utilities and lighting systems are not designed to remain in place without generating debris in hazardous events	Extreme	Secondary
4.1: Low designed or estimated protection level of the building envelope against a possible high magnitude explosive threat	Extreme	Secondary
4.3: Glazing of the building are not secure in case of blast	Elevated	Secondary
4.4: Building is not designed to resist to high external pressure (ex. blast)	Elevated	Secondary
5.6: No redundant and reliable electrical service source	Extreme	Secondary
6.4: No provisions for air monitors or sensors for CBR agents	Extreme	Secondary
6.5: No method for fast air intakes and exhausts closure when necessary	Elevated	Secondary
7.11: No mass notification system that reaches all building occupants	Elevated	Secondary
8.1: CCTV cameras used, 24 hours/7 days a week recorded and monitored at the perimeter and in the critical areas of the building are insufficient	Elevated	Secondary
8.2: Video quality not adequate both in daylight and darkness	Elevated	Secondary
9.4: Emergency plan not up-to-date and not well designed	Elevated	Secondary
9.5: Operational continuity plan to apply no up-to-date and well-designed	Elevated	Secondary

5 DISCUSSION OF THE RESULTS

The case study analysed shows some interesting properties of the proposed BVAM method. It can be observed that:

- the adoption of the prototype BCA software tool developed for the analysis of the criticalities of the building greatly simplifies the activity of the AT. Furthermore, Table 7 provides, in a single screen, an effective description of the general criticalities of the building. It also provides a direct indication of the most significant areas where possible countermeasures for the mitigation of the vulnerabilities should be applied.
- the detailed description of the threats carried out in Step 2 highlights which criticalities are realistically exploitable, providing precise indications for the design of countermeasures.
- Step 3 allows for the selection of an appropriate VL by portraying a clear picture of what specific criticalities have emerged as a result of Step 2.

6 CONCLUSION

The proposed BVAM provides the assessment team with a qualitative and quantitative value assigned to the vulnerability of the building analysed, based on a vulnerability scale of seven levels. This value not only takes into account the physical and organisational aspects of the building, but also some of the social, economic, structural and institutional factors for different types of threats. The method described allows for the analysis of different kinds of vulnerabilities and the results obtained are useful for assessing the overall risk of different buildings for different threats. This enables for the prioritisation of actions and investments aimed at reducing vulnerabilities and thus reducing risk by enhancing the preparedness, protection and resilience of the buildings.

As a final consideration, it can be highlighted that the case study analysed shows consistent and easily interpretable results and objective assessments. This enables for the conduction of a coherent analysis and for the attainment of reliable results in an extremely complex context such as that related to risk assessment for terrorist attacks on a building.

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