Anti-terrorism protection and protective design measures for hotels

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Abstract

In today's security climate, terrorists do not target key government installations or so-called "hard targets." Rather, terrorists have been targeting "soft targets" such as public areas with high human traffic volumes, and private establishments. There are numerous global examples to support this. What more can a hotel do to enhance security without compromising its basic function – to encourage the public to enter its premises? If it is a question of when, not if, hotels succumb to terrorist attacks, how prepared are they to mitigate the consequences of an attack? A paradigm shift in response strategy, moving beyond perimeter security to include hardening and protective measures is clearly required. This paper summarizes the methodology, threat scenarios, blast overpressure calculations, structural assessment and results for the hotels industry.
Keywords: anti-terrorism, hotel security, protective design, blast effects, bomb threat.

1 Introduction

Terrorism is real, evolving, and continues to increase in frequency and lethality throughout the world. The unyielding, tenacious, and patient nature of the terrorists forces us to closely examine existing practices for deterring, disrupting, and mitigating potential attacks specifically against hotels. Today, terrorist attacks can impact anyone, at any time, at any location. The attacks can take many forms. While terrorists have many tactics available to them, they frequently use explosive devices when they target hotels (see table 1). The four

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Table 1: Selected recent terrorist attacks on hotels.

Hotel	**Date**	**Where occurred**	**Deaths/ injured**	**Cause**
Baghdad Hotels, Iraq	01/2010	Ext.	37/104	Car bomb
Marriott and Ritz Carlton, Jakarta, Indonesia	07/17/09	Dining and meeting areas	9/50	Suicide bombings
Oberoi Trident and Taj Mahal Palace, Mumbai, India	11/2008	Across the city	173/308	Small arms
Marriott Hotel, Islamabad, Pakistan	09/2008	Ext.	54/266	Truck bomb
Amman Hotel	2005	Wedding hall	56	Suicide bombing
Sharm el-Sheikh, Egypt	2005	Ext.	89	Car bombing
Bali	2002	Ext.	202/240	Suicide/car bombing
Luxury hotel, Jerusalem	12/05/01	Ext.	01/06	Bomb outside entrance
International chain hotel in Uganda	04/1998	Ext.	05/0	Arson
Two 5-star hotels in Colombo, Sri Lanka	10/1997	Ext.	11/105	Truck bomb
Diplomat hotel, Bahrain	02/11/96	Lobby	0/4	Home-made bomb
Le Royal Meridian, Bahrain	01/17/96	Upper floor	0/0	Time-bomb
Glenavna hotel, Newtownabbey, north of Belfast	10/13/93	Ext.	0/0	Car bomb outside the hotel
Hotel Crillon, Lima	10/21/93	Ext.	2/30	Car bomb behind the hotel
Gosford House Hotel, Markethill, North Ireland	09/30/93	Ext.	0/0	Car bomb
Hotel Cabana, Spain	07/24/93	Ext.	0/0	Bomb in garden

basic physical protection strategies for hotels to resist explosive threats are: establishing a secure perimeter; mitigating debris hazards resulting from the damaged façade; preventing progressive collapse; and isolating internal threats from occupied spaces. Other considerations, such as the tethering of non-structural components and the protection of emergency services are also key design objectives that require special attention. The intent of these protective measures is to minimize the possibility of mass casualties in hotel buildings. These measures provide appropriate, implementable, and enforceable measures to establish a level of protection against terrorist attacks for hotel buildings where no known threat of terrorist activity currently exists. Most existing hotel buildings offer little protection from terrorist attacks. By applying the protective measures for hotel buildings described in this paper, they become less of an opportunity target for terrorists.

As currently built, hotel locations are inherently vulnerable to an explosive event that may be achieved through a wide array of possible improvised explosive device (IED) configurations and delivery methods for the following reasons:

- The opportunities to maximize standoff distance were not fully addressed during initial design phases;
- Significant constraints on space;
- All facilities contain large amount of surfaces covered with standard glass panes;
- Large portions of hotel buildings have exposed load bearing columns;
- Car parking in the basements of hotel buildings;
- Valet/taxi drop off/pickup zone location underneath the structures;
- Opportunities to host academic conferences, workshops, lectures, film series, performances, and other public programs;
- Buildings layout, shape and geometry; and
- The presence of westerners from all over the world.

Physical hardening of hotels against explosive, active shooter, sniper and ballistic attacks forms an essential part of all new, high-threat, and iconic developments. The method of construction, and materials used (including doors and windows) contribute to the overall level of protection offered against these types of attacks.

2 Risk analysis

The risk analysis is carried out after the threat and vulnerability assessments are complete. Once the relevant information is collected and possible risks identified, it must be collated and presented in a form that is easily understood. It is important that the process be replicable so that later repetition is possible. Next, the information collected on threats, vulnerabilities and potential impacts is translated into a statement of likelihood and consequence. There are potentially three ways of achieving this, which can be illustrated by using the "bow tie" model to represent a risk (Figure 1).

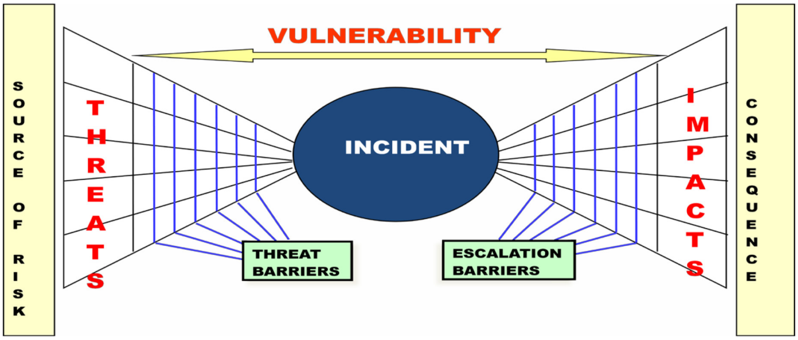

Figure 1: Representation of risk.

The first way of deriving likelihood and consequence ratings may be presented as follows:

- Likelihood consists of threats and vulnerabilities (preventative and responsive)
- Consequence refers to the severity of the impact of the threat on the organization.

Applying consequence ratings involves measuring the likely outcomes from the incident against the organization's risk appetite. Conversely, the likelihood rating incorporates a very broad range of information about the risk context (threat) as well as the specific attributes and operations of the organization (vulnerabilities).

The second way that risk could be expressed is to distinguish between preventative and responsive vulnerabilities. In this case likelihood is assessed based on the threat and the vulnerabilities that may be exploited to cause an incident. The consequences are assessed based on the capacity of the organization to manage the incident and the severity of the potential consequences. In this case, likelihood refers to the probability that the incident will occur, and consequences to the effects of incident on the organization.

The primary advantage of this approach is that it separates the different vulnerabilities. This makes them easier to track in the risk treatment process and facilitates more effective linkage between the assessment and treatment stages of the risk management process.

The third way in which risks may be expressed is to associate likelihood with the threat such that it refers to the probability of the threat targeting or affecting the organization. Consequences are assessed with reference to all the vulnerabilities that may be exploited by the threats as well as the severity of the outcomes.

A significant advantage of this approach is that it reflects the different processes involved in the threat assessment compared to those in the vulnerability analysis and consequence analysis. Generally, threat assessment is mostly focused on factors outside of the organization and in the context in which the organization operates. Vulnerability and consequence analyses are focused on the specific attributes and operations of the organization itself. This approach

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facilitates a more streamlined approach to information gathering and processing during the assessment process.

The overall risk rating will not be changed for any of these approaches, as it is accepted that risk is a function of threat, vulnerability and consequences. However, it is important to determine which model will be used at the beginning of the process and to properly define each of the elements. This will avoid confusion during the assessment process, which can lead to some factors being over-stated or repeated [1].

3 Tactics

Comprehensive threat and vulnerability assessments and risk analysis can help the design team understand the potential threats, vulnerabilities, and risks associated with a building, as well as determine the design threat for which a building should be designed to resist. Usually, the definition of the design threat is based on history and expectation. However, it is limited by the size of the means of delivery. For example, a hand-carried device, if efficiently packaged, could occupy as little as half a cubic foot of space and could be easily concealed in a large brief case, or small piece of luggage, and be introduced deep into the structure where it could do considerable damage. As a result, screening stations at entrances, mailrooms, and loading docks provide the best means of preventing hand-carried satchel threats from entering the occupied spaces.

On the other hand, a vehicle threat, which can carry significantly larger explosive charge weights, requires secured perimeters and comprehensive screening procedures for underground parking structures or loading docks. Screening procedures, however, have limitations and the potential for threats to bypass their scrutiny must be recognized in the physical protection scheme. Therefore, the selection of the design level explosive threat depends on the features of the building, the site conditions, and the level of risk the client is prepared to accept.

Aggressors have historically used a wide range of offensive strategies that reflect their capabilities and objectives. These offensive strategies are categorized into Design Basis Threats (DBTs) that are specific methods of achieving aggressor goals. Separating these tactics into categories allows facility planners and physical-security personnel to define threats in standardized terms, and be usable as a basis for facility and security-system design. Common aggressor tactics include:

4 The explosion

An explosion is the rapid release of stored energy. This energy is released in part as thermal radiation; the rest manifesting as shock waves that are combinations of air blast and ground shock. The air blast is the main damage mechanism. Air blast has a primary effect, which is the ambient overpressure or incident pressure, and a secondary effect, which is the dynamic pressure or drag load. The first effect is caused by the air blast (due to shock waves) that propagates at supersonic velocity, and compresses air molecules in its path. As the shock wave encounters a wall, it is reflected, thus amplifying the overpressure, often by some significant factor greater than two. The air blast enters the building through wall openings and failed windows, affecting floor slabs, partitions, and contents within the building. The shock waves undergo diffraction as they interact with various surfaces, thus increasing or decreasing in pressure. Eventually, the air blast subjects the entire building to overpressure. The pressure decays exponentially in time, with radial distance from the epicenter, and eventually becomes negative (negative loading phase), creating suction forces.

Dynamic pressure or drag loading manifests itself as a high velocity wind that propels debris generated by the blast. Another secondary effect is the ground shock that produces motions similar to high-intensity, short duration earthquakes [2].

5 Vehicle bombs

Vehicle-bomb tactics include both moving and stationary vehicle bombs. In the case of a moving vehicle bomb, the aggressor drives the vehicle into the target. This is commonly known as a suicide attack. In a stationary vehicle bomb, the aggressor parks the vehicle and detonates the bomb remotely or on a timed delay.

While it may be possible to predict effects of a certain charge weight at a specified standoff distance, the actual charge weight of the explosive used by a terrorist, the efficiency of the chemical reaction and the source location cannot be reliably predicted. Given the uncertainties, the most effective means of protecting a structure is to keep the explosive as far away as possible by maximizing the keep-out or standoff distance. However, this approach is only necessary if an analysis identifies the building to be at risk of attack as opposed to suffering collateral damage due to an attack on a nearby target.

6 Damage assessment

Damage due to the air-blast shock wave may be divided into direct air-blast effects and progressive collapse. Direct air-blast effects are damage caused by the high-intensity pressures of the air blast close to the explosion. These may induce localized failure of exterior walls, windows, roof systems, floor systems, and columns.

Progressive collapse refers to the spread of an initial local failure from element to element, eventually resulting in a disproportionate extent of collapse relative to the zone of initial damage. Localized damage due to direct air-blast effects may or may not progress, depending on the design and construction of the building. To produce a progressive collapse, the weapon must be in close proximity to a critical load-bearing element. Progressive collapse can propagate vertically upward or downward from the source of the explosion, and it can propagate laterally from bay to bay as well. A bay is the span between two supporting structural members.

The pressures that an explosion exerts on building surfaces may be several orders of magnitude greater than the loads for which the building is designed. The shock wave also acts in directions that the building may not have been designed for, such as upward pressure on the floor system. In terms of sequence of response, the air blast first impinges the exterior envelope of the building. The pressure wave pushes on the exterior walls and may cause wall failure and window breakage. As the shock wave continues to expand, it enters the structure, pushing both upward on the ceilings and downward on the floors.

Floor failure is common in large-scale vehicle-delivered explosive attacks, because floor slabs typically have a large surface area for the pressure to act on and a comparably small thickness. Floor failure is particularly common for close-in and internal explosions. The loss of a floor system increases the non-braced height of the supporting columns, which may lead to structural instability [3].

For hand-carried weapons that are brought into the building and placed on the floor away from a primary vertical load-bearing element, the response will be more localized with damage and injuries extending a bay or two in each direction. Although the weapon is smaller, the air-blast effects are amplified due to multiple reflections from interior surfaces. Typical damage types that may be expected include:

- localized failure of the floor system immediately below the weapon;
- damage and possible localized failure of the floor system above the weapon;
- damage and possible localized failure of nearby concrete and masonry walls;
- failure of nonstructural elements such as partition walls, false ceilings, ductwork, window treatments; and
- flying debris generated by furniture, computer equipment, and other contents.

7 Physical protection measures

For each terrorist tactic addressed earlier in this paper, protective measures will be presented. Keep in mind, though, the methods presented under various tactics are not limited to those tactics – many are suitable for several threat situations. There are, however, some minimum measures, most of which are relatively inexpensive, that should be considered for overall protection of virtually all assets.

To guarantee the maximum standoff distance between unscreened vehicles and the structure, anti-ram bollards or large planters must be placed at the curb around the perimeter of the building. The site conditions will determine the maximum speeds attainable, and thus the kinetic energy that must be resisted. Both the bollard and its foundation must be designed to resist the maximum load. Conversely, if design restrictions limit the capacity of the bollard or its foundation, then site restrictions will be required to limit the maximum speed

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attainable. Furthermore, public parking abutting the building must be secured or eliminated, and street parking should not be permitted adjacent to the building. Removing one lane of traffic and turning it into an extended sidewalk or plaza can gain additional standoff distance. However, the practical benefit of increasing the standoff depends on the charge weight. If the charge weight is small, this measure will significantly reduce the forces to a more manageable level. If the threat is a large charge weight, the blast forces may overwhelm the structure despite the addition of nine or ten feet to the standoff distance and the measure may not significantly improve survivability of the occupants or the structure [4].

7.1 General design strategy

Blast pressures near an exploding vehicle bomb are very high, but they decrease rapidly with distance from the explosion. The design strategy for these tactics is to maintain as much standoff distance as possible between the vehicle bomb and the facility and then, if necessary, to harden the facility for the resulting blast pressures. Barriers on the perimeter of the resulting standoff zone maintain the required standoff distance. The difference between moving and stationary vehicle-bomb tactics is that the aggressor using the moving vehicle bomb will attempt to crash through the vehicle barriers; the aggressor using the stationary vehicle bomb will not try. Therefore, vehicle barriers for the moving vehicle bomb must be capable of stopping a moving vehicle at the perimeter of the standoff zone. For a stationary vehicle bomb, vehicle barriers must mark the perimeter of the standoff zone, but they are not required to stop the moving vehicle. They only need to make it obvious if an aggressor attempts to breach the perimeter.

7.2 Stationary vehicle bomb

To defeat the stationary vehicle bomb tactic, one must keep the vehicle as far as possible from the target selected. Standoff zones discussed earlier provide the basic “line of defense” against this tactic. In this case, however, any passive barriers used are meant to mark the boundaries of the standoff zone rather than attempt to stop a vehicle from entering. As the goal of the stationary bomb tactic is to remain undetected, barriers need only make it difficult to cross the boundary without being noticed. In addition to most of the passive barriers, some lower cost, simple alternatives exist. High curbs, low berms, shallow ditches, trees or shrubs, and fences would be generally effective for barriers. A vehicle passing through any of these barriers would attract attention. While not particularly common, another effective barrier would be any body of water with sufficient depth to submerge exhaust pipes of vehicles.

7.3 Façade protection

The building's exterior is its first real defense against the effects of a bomb. How the façade responds to this loading will significantly affect the behavior of the structure. Hardening of the façade is typically the single most costly and controversial component of blast protection, and may produce a dramatic change to the exterior appearance of the structure such as smaller window sizes and more rugged attachments. Moreover, given the large surface areas of most buildings, modest levels of protection may not be cost-effective. Therefore, it may be best to concentrate on improving the post-damaged behavior of the façade.

Except for very thick lights, most glazing materials and components designed to respond to the blast loads will most likely be damaged by the blast overpressures. To improve the post-damage behavior of the glazing system, one could specify laminated glass for new construction or apply anti-shatter film to existing glazing. While these features do little to improve the strength of the glass, they attempt to hold the shards of glass together and better protect the occupants from hazardous debris. Laminated glass possesses the best post-damage behavior, may be used with a wide variety of glazing materials and thickness, and provides the highest degree of safety to occupants.

Equally important to the design of the glass is the design of the window frames. For the window to properly fail, the glass must be held in place long enough to fail. Short of that, the glazing will dislodge from the housing intact and cause serious damage or injury. The capacity of the frame system to resist blast loading should therefore exceed the corresponding capacity of the glazing, often referred to as the "glass fail first criteria." Factors of two to three, over the nominal capacity of the glass to resist breakage, may be required to design the frames. The bite, including the possible use of structural silicone sealant, must be adequate to assure the failed glass is retained within the frame. Depending on the façade, the mullions may be designed to span from floor to floor or tie into wall panels and must be capable of withstanding the reactions of a window loaded to failure. Finally, the walls to which the windows are attached must be designed to accept the reaction forces as well.

7.4 Curtain wall protection

Sample blast curtain wall engineered to take advantage of a flexible system. Some protective features may include: insulated glazing unit with laminated inner light; glazing adhered to mullion with structural silicone sealant; and curtain-wall frame with steel backup encased in aluminum.

A curtain wall is a nonbearing exterior enclosure that is supported by a building's structural steel or concrete frame and holds either glass, metal, stone, or precast concrete panels. Lightweight and composed of relatively slender extruded aluminum members, curtain-wall façades are considerably more flexible than conventional, hardened punched window systems. In a blast environment, the mullion support would absorb a portion of the blast energy and improve the performance of the glazing, allowing the glazing to sustain greater blast environments (although the mullions themselves should be designed to resist the forces collected by the glass).

It is important to take into account the inherent flexibility of curtain-wall systems when sizing members for blast loads and evaluating the glazing for hazard. This enables the engineer to both ascertain the true blast worthiness of the curtain wall as well as to properly calculate the reduced load transfer into supporting structural elements.

8 Conclusion

Under the current threat assumptions, one must recognize that most mitigation countermeasures fall between two extremes. The first extreme is the prevention of all damage at enormous cost, and the other extreme is to spend nothing and risk enormous damage. Hotel operators should take a risk-based approach on decisions related to the selection of blast countermeasures for its facilities, in order to achieve an acceptable level of damage at a reasonable cost. It is a mistake to discount the possibility that terrorists have observed operations and may attempt to coax first responders to an incident only to entrap them with secondary and possibly tertiary explosive devices. It is anticipated that without adequate attention to blast engineering analysis that more hotels could be completely destroyed or sustain heavy damage with a large number of deaths. The precise magnitude of such damage and loss can be estimated based on more elaborate analyses, which would be required during investigation of remedial measures. Such modifications could be possible, but are expected to require considerable reconstruction and hardening of the facilities.

To protect a hotel against acts of terrorism, it is recommended that hotel operators shall consider implementing Structural Hardening Management Systems (SHMS) such as façade system, anti-progressive collapse system, and most crucially adopting protective glazing system. With all these measures implemented, terrorists will find hotels to be difficult targets and no longer as vulnerable as they once were to these attacks.

References

[1] ISO 31000, *Risk management-Principles and guidelines*
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