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Abstract: Terrorist impacts have been increasing over time in many countries, being one of the most significant threats for the Built Environment (BE), intended as a network of open spaces (streets, squares) and facing buildings, and their users. Such risk is affected by a combination of strategic functions and crowd conditions. This work traces, for the first time, the state-of-the-art consolidated Risk Mitigation and Reduction Strategies (RMRSs). Solid RMRS regulatory frameworks from all over the world are collected. The results show how classification criteria distinguish them by attack targets and typologies, effectiveness over time/space, and physical implementation versus management-based deployment. Nevertheless, these criteria seem to be too fragmented, failing in pursuing RMRSs selection in a holistic outlook. Thus, a new classification adopting the BE composing elements (physical elements, layout, access/surveillance systems, safety/security management) as key-factors is provided. Features, dependencies and coordination among them are discussed in a sustainability-based perspective, by showing how the main challenges for RMRSs' design concern applicability, redundancy, and users' emergency support. Safety/security management strategies have the overall highest sustainability level and play a pivotal role with respect to the other BE composing elements, which should be planned in reference to them. In addition, a human-centred approach (individuals' interactions with BEs and RMRSs) will also be needed. These results will support efforts to include simulation-oriented approaches into RMRSs selection, effectiveness and feasibility analyses.

Keywords: terrorist attack; sustainability; risk reduction; classification; Built Environment; emergency management; human-centred factors; open spaces

1. Introduction

Terrorist impacts have been increasing over time in many countries, being one of the most significant threats for the Built Environment (BE) and its users [1,2]. Emergency conditions due to a terrorist act occur quickly and unexpectedly and are moved by the "will" of the attackers "to hurt innocent people, kill or injure them, or inflict significant damage on essential infrastructure at a single instant or over time, or plan to do so, to bring about political, religious or ideological aims" [3]. Thus, they can be categorized as man-made destructive actions [4,5]. Due to their unpredictable occurrences, they are assimilable to Sudden Onset Disasters (SUOD) [6,7].

The more frequent environments where terrorists perform attacks seem to be urban BEs, especially if highly populated [2,8–10]. According to consolidated approaches [11–13], targets are defined in terms of: (1) quantity, such as the number and typologies of BE users, tourist presence, the economic values of a BE and hosted activities; (2) quality, by preferring strategic buildings and symbolic targets, such as cultural, religious and institutional places and their occupants. Large cities seem to be more potentially affected by terrorist acts,

since here the effects can be maximized [8,10,14]. The BE for terrorist act targets should be considered as the system of indoor (the building) and outdoor areas (the open spaces in the BE) because of their complexity in case of an attack [8]. As for other SUODs, in fact, the outdoor area (the open spaces in the BE, e.g., streets, squares) and each facing building are characterized by layout, facilities, use, occupants' presence and management strategies that interact in case of an emergency and so also alter the risk levels for their users [15–17].

International classifications of terrorist targets, by including the ones of the European Commission definitions, recognize "hard" and "soft" targets in relation to the protection strategies and risk management that are applied to them [10,13,18,19]. Government buildings, military institutions and additional strategic buildings are "hard targets", characterized by codified and significant control levels (including restricted access to the public) and protection (including armed guards) measures [18,20]. On the contrary, urban BEs (including open spaces) are ideally "soft targets" for terrorist acts, being characterized by a "high concentration of people, low or no security against violent attacks and attraction for the attacker" due to the exposure contents [19]. They "may be selected by terrorists [. . .] thus inflicting fear to the population and attaining media coverage" [13]. Sights are an example of a significant BE at risk. In fact, such outdoor pedestrian areas (e.g., public spaces, squares, avenues) and the symbolic (historic or religious) buildings facing them could lead to a critical crowding level [13,14,19,21]. Moreover, such places can also temporarily host mass gathering events (e.g., concerts, festivals), becoming very attractive for attackers "for their insufficient or minimal security measures" [10]. In this sense, human-centred factors have a significant role in the overall risk and effects of a terrorist act, as well as of possible risk management strategies, as for other SUODs [22–26]. Finally, further specific buildings could catch the attention of terrorists. For example, public facilities devoted to educational and health purposes (e.g., schools, hospitals) usually host sensible and exposed people to risks [10,13]. Additionally, the same buildings can be drastically affected by potential crowding conditions.

To increase the safety of the BE, Risk Mitigation and Reduction Strategies (RMRSs) can operate in two different manners and times [8,9,13,27]. Before the event, they are aimed at deterring, detecting and delaying emergency conditions through preventive measures or management procedures implemented by stakeholders and Law Enforcement Agencies (LEAs). During the attack, they are applied to reduce the number of victims and manage the evacuation with the LEAs' support and the BE layout defensive organization, which can lead to people adopting safe behaviours during the emergency phases. In addition to this general classification, strategies applied at the single building scale are generally well codified, especially for "hard targets". Here, RMRSs follow codified standards for counterterrorism actions provided by governments and intelligence forces [8,9,20,28–31]. When considering the hosted users, they also relate to common evacuation safety regulations, which are applied to both hard and soft targets [22,27,32]. However, the coordination of RMRSs in BE application, the inclusion of human-centred issues in RMRSs definition, and the presence of holistic-based methodologies for BE stakeholders' decision support seem to be generally poor if compared to other kinds of SUODs, such as fires or earthquakes [33,34].

1.1. Work Aims

In view of the above, sustainable and effective solutions for risk mitigation in the BE should take advantage of the elements composing the BE itself to increase the safety levels for BE users before and during a terrorist act, by deterring it and managing its possible emergency consequences, respectively [35]. In a sustainability-based and holistic perspective, redundancy, adaptability, coordination and costs are used to compare RMRSs and to evaluate how RMRSs combined applications can be implemented [8,21]. A human-centred perspective is assumed to additionally evaluate how the RMRSs can effectively support the BE occupants before and during an emergency due to a terrorist act, also in view of the liveability of the BE in ordinary conditions. According to previous research [22,36–40], this work considers the following leading factors for human-centred issues: (1) interactions

between RMRSs and emergency behaviours; (2) individuals' perception issues, including liveability of the BE; (3) applicability of the strategies in different users' presence contexts, by mainly focusing on mass gatherings as critical conditions for BE use; (4) and capabilities given by behavioural simulation models in the RMRSs definition and validation process.

In agreement with these objectives, this work is structured in the following sections. Section 2 collects solid regulatory frameworks and guidelines from high-risk affected countries all over the world, and then resumes the existing classification criteria of RMRSs provided by them and in view of previous literature works, according to a classical review approach. Section 3 organizes data from the regulatory frameworks into the different elements composing the BE and its management, while Section 4 discusses them according to the sustainability-based, holistic and human-centred perspectives.

The described goals and instruments are functional and are part of the National Relevant Interest Research Project BE S^{2}ECURe (funded by the Italian Ministry of Education, University, and Research), in which the terrorist risk assessment in crowded BEs is combined with other threats (earthquakes, heat waves and pollution) in order to determine a performance-based approach useful in measuring the multi-risk resilience of BEs [41]. In this holistic approach, the project and this work include human-centred factors as a key metric element, thus overcoming the limitation of current approaches, which seem to generally underestimate the influence of users' behaviour in disasters and their relation with elements composing the BE and its management.

2. Overview of Considerable Regulations and Classifications in Risk Management and Reduction Strategies for Terrorist Acts

2.1. Selection Methodology, Selected Materials and Review Organization Methods

The main regulations and guidelines of specific countries from all over the world concerning general RMRSs for terrorist act-prone BEs are analysed. The documents have been selected by starting from existing international reports [13] and by essentially considering: (1) the impact of terrorist acts and the high exposure to these type of attacks of selected countries, especially in the last few years, according to global terrorism databases and reports such as [1,2]; (2) in view of the previous point 1, the presence of solid regulatory frameworks and guidelines which are freely available online in a complete version; (3) direct reference to the built environment as the common goal of the regulatory frameworks, including both its layout and its emergency management system, rather than the inclusion of general counter-terrorism measures such as intelligence-oriented ones, based on actions by Law Enforcement Agencies.

Appendix A—Table A1 summarizes the list of documents selected by the current work. The main European countries and the United States of America are selected because they seem to represent the most significant scenarios according to the aforementioned criteria. Some additional countries, i.e., Australia and India, are included in view of their exposure levels as well as of the availability of documents concerning organized regulatory frameworks. Considering the 2019 reports on terrorism risk all over the world, "in North America, Western Europe, and Oceania, far-right attacks increased by 320% over the past five years" (that is the period 2013–2018) [1]. Meanwhile, the number of incidents in the countries placed in these geographical areas increased by about +114% in comparison to the years 2009–2013 [2]. For India, an increase of 40% in incidents was noticed in comparison to the years 2009–2013 [2].

2.2. Classifications of Terrorist Act Risk Management and Reduction Strategies

According to the literature overview discussed in Section 1.1, RMRSs can be classified according to the main criteria summarized in Table 1. Target-oriented classifications are based on the specific features of the BE prone to the terrorist act, mainly in terms of hosted activities (Section 2.2.1). The attack-oriented classification highlights that RMRSs should face specific threat conditions (Section 2.2.2). Time-dependent and space-dependent strategies underline how RMRSs have different goals depending on their relationship with

the terrorist attack timing (Section 2.2.3). Space-dependent oriented classifications are based on the localization of the strategies into the BE itself (Section 2.2.4), thus sharing implementation criteria with architectural and management issues in RMRSs' application in the BE (Section 2.2.5).

Table 1. Summary of classification of Risk Mitigation and Reduction Strategies (RMRSs) in terrorism-prone Built Environments (BEs), by outlining main classification options, differences to classify the RMRSs depending on their purpose or implementation-related features, the main references and the interactions among the classification criteria.

General Classification Criteria (Section Number)	Main Classification Options	Differences in RMRSs	Main References
Target-oriented (Section 2.2.1)	Hard/soft target	Based or not based on restricted access control, invasive surveillance and strongly protected BE border limits	[10,11,18]
	Level of (in)visibility	Perception by the BE users due to the level of implementation in the BE	[8]
	BE main intended use	Differences of operational procedures in BE use and BE configuration due to the normal use by occupants and stakeholders	[13,42,43]
	Safety/security	Limiting failures and protecting the public versus limiting intentional damages and protecting the public order	[7,44]
Attack-oriented (Section 2.2.2)	Threat type	Where/from where the attack is performed by the terrorists	[43]
	Typology of attack	Facing the effects of weapons used by the assaulters	[10,19,35,42]
Time-dependent (Section 2.2.3)	Before/during	Effectiveness before the attack (e.g., to deter it) or during it (e.g., to manage the consequences)	[35]
Space-dependent (Section 2.2.4)	Different zones (layer of defence) of the BE	Area/line of application of the strategy in the BE layout in respect to the surrounding and internal elements	[44–46]
Physical versus Management (Section 2.2.5)	physical/management	Implemented into physical elements of the BE or by using operational procedures (based on staff actions)	[13,32,42]

2.2.1. Target-Oriented Classifications

A basic classification of RMRSs can be related to the *target definition* on which they are applied [10,11,18]. The classification of general RMRSs for "hard targets" mainly involves the restriction of area access to the public and the existence of invasive surveillance solutions by Security Forces. On the contrary, RMRSs for "soft targets" do not involve such severe measures. Moreover, RMRSs can generally be divided into *active and passive control*. According to consolidated literature definitions [8], *active control* includes "electronic surveillance, private security guards, and the laws and rules of conduct that can restrict actions, influence behaviours or impede interaction", while *passive control* measures are "rather more subtle and include aesthetic and 'streetscape' features".

Additional target-oriented classification can focus on the whole actions identified according to the users' participation [42,47–50], by outlining:

- *Active actions*, where a bi-univocal relation between overarching governances and urban users is activated by including prevention (i.e., active military intelligence), mitigation (i.e., active education of BE users) and security/safety (active surveillance solutions);

- *Passive actions*, in which any feedback is established by users and overarching rules/ guidelines/indications are simply applied, by including prevention (i.e., passive normative regulations), mitigation (i.e., passive information of the BE users) and security/safety (i.e., *passive control* for urban space design and security).

In this sense, such strategies can have a relation of impact concerning: (1) the implementation through the aforementioned strategies for "hard" and "soft" targets; (2) the interactions with the users.

Active and passive RMRSs could be classified according to their *level of (in)visibility in the BE*, thus influencing the different perception levels of the hosted users as well as the terrorists [8]. In particular, *invasive RMRSs* are generally characterized by a high impact on the BE in terms of application. In fact, they include a widespread implementation of measures (active strategies such as video surveillance systems or Security Forces control) and a significant aesthetic impact (passive strategies such as heavy barriers), thus being more oriented towards the context of hard targets. They generally have a low level of sustainability (i.e., scarce adaptability, invasive for citizens) for the BE, especially in relation to normal use conditions, being oriented to overt security purposes. On the contrary, *visible RMRSs* are integrated into the BE by maintaining a reduced aesthetic impact since they can also be used for normal use conditions according to a "camouflaged" approach (passive strategies such as urban furniture that can be used as barriers in case of a terrorist attack). Finally, according to consolidated definitions [8], *invisible RMRSs* are not perceived by the public since they are "covertly embedded within the urban landscape" or they are applied to specific elements in the BE that are not generally acknowledged as security-oriented by the public (e.g., façades). In this sense, *visible* and *invisible RMRSs* are more oriented towards soft target application, leading to a "security by design" approach for a sustainable BE [13]. Table 2 summarizes the countermeasures according to the concept of "visibility" and "activeness" of the involved elements.

Table 2. Main terrorism countermeasures according to [30,48–51] relating the "visibility" of measures and "activeness" of urban users. "N.A." means not assessed since no measure can be evidenced in existing research.

	High Visibility	Integrated	Invisible
ACTIVE MEASURES	- Video surveillance; - Closed-circuit television (CCTV); - Surveillance; - Vigilance and control of accesses; - Mobile Barrier; - Rising Wedge Barriers; - Drop Arm Crash Beams; - Crash Gates; - Surface-Mounted Rotating Plates	- Mobile barriers (implemented in an integrated manner in the BE); - Mobile vehicle bollards (retractable, turntable)	N.A.
PASSIVE MEASURES	- Traditional Passive barriers; - Fixed vehicle bollard; - Walls, berms; - Jersey barriers in fixed and anchored installations; - Fences (Chain-link, Monumental and metal fences, Anti-climb fence, Wire)	- Fixed urban furniture; - Flowerpots; - heavy objects (e.g., monuments); - Engineered planters; - Reinforced street furniture, fixtures and trees; - Integrated Fixed barrier; - NOGO barrier; - TigerTrap	- Urban Mobility Planning; - Controlled Traffic Zone - Pedestrian zone - Parking Design, etc.; - Designing external features of buildings; - The positioning of glazed surfaces, also using laminated glass

According to the aforementioned target-oriented classification and focusing on "soft target" related issues, other approaches can distinguish RMRSs depending on the *BE main intended use* (both indoors and outdoors), based on the national regulations concerning them [13,42,43]. In particular, RMRSs can be divided according to the classification in Table 3, which is based on the combination between the intended use of a BE and crowd conditions such as occupants' loads and typology of hosted individuals in terms of famil-

iarity with the BE (for BEs as working places, please also compare strategies related to the safety and health of workers from a national point of view).

Table 3. The main classification of the intended use of BE and crowd conditions in reference to the RMRSs proposal.

BE Classification	Examples of Intended Uses	Related Main RMRSs
Public spaces	commercial (mainly, great shopping centres), sporting (stadia, arenas and playgrounds in general, both indoor and outdoor);	Closely combined with those related to additional safety fields, i.e., fire safety and workers' safety and health, especially for those hosted by buildings in the BE
	entertainment (e.g., theatres, cinemas);	
	accommodation facilities (e.g., hotels)	
	restaurants and bars/pubs	
	BEs hosting mass gathering events or possible crowd conditions (both indoor and outdoor, e.g., pedestrian areas)	
BEs for the community, having also a symbolic feature as a terrorist target	BEs for education (mainly, schools)	Grouped in with similar crowd conditions and partially controlled access systems (e.g., depending on the different areas of the BE, such as for schools or hospitals), and also correlated to RMRSs for public spaces
	BEs for religion (e.g., churches, temples)	
	healthcare centres (e.g., hospitals)	
BEs for transportation	public spaces for transportation (e.g., airports, train stations, harbours)	Possibility of areas with restricted access and also need to coordinate the RMRSs by contemporarily involving the BE occupants' and passengers' (onboard the means of transport) safety, the modelling of specific damage and injuries due to the transportation hub typology, and the business continuity elements
	the means of transport themselves	
Other BEs (almost private ones)	BEs as working places	Low complexity strategies thanking the possibility of access control in the areas, thus intervening in specific elements of the BE or in management issues (also compare with Section 2.2.4 classification)
	residential buildings	

In such a context, RMRSs connected to significant crowd levels in these BEs assume a transversal role due to the risk-increasing factors induced in the management of terrorist acts [42,52]. Nevertheless, regulations and guidelines evidence the dependency between such scenarios and specific RMRSs in outdoor areas [32,53] with respect to: (1) the hosted event (in terms of crowd typology and quantity); (2) the event layout; (3) the definition of different zones open to the public; (4) the access system; (5) the emergency management system and facilities.

Finally, differences between *safety* and *security* goals can distinguish RMRSs in the BE [7,32,42,44]. Although additional differences and similarities between the two goals exist, current frameworks [7,44] evidence how:

- *Safety* strategies are essentially oriented towards the protection of the hosted users from all the failures that can appear in the BE. They limit the fatalities due to their use in some risk-increasing conditions, such as those of mass gathering events, as well as due to the consequences of the terrorist acts, such as injuries and deaths due to the attack-related emergency;
- *Security* strategies are essentially oriented towards the contrast of intentional actions due to the terrorist act and thus preserve the public order. They mainly include all the measures performed by the Security Forces before and during the attack.

Such differences have also been clearly codified in some national regulations (i.e., in Italy, compare to: circolare 7/6/17 Min. Interni n. 555/OP/0001991/2017/1; direttiva del Capo Dipartimento VVF, Soccorso Pubblico e Difesa Civile, prot. 11464 del 19/6/17; circolare 28/7/17 N. 11001/110(10) Min. Interni) to provide specific support to designers while deploying strategies in a certain context, i.e., those connected to mass gathering events, which can be used as RMRSs (e.g., also compare the concept of safety personnel and security personnel [32]).

2.2.2. Attack-Oriented Classification

RMRSs are differently organized to respond to the specific features of the terrorist acts. Main classifications can refer to the following issues.

Firstly, RMRSs can be organized according to the types of threat to be faced [43]. Internal threats essentially involve intrusion into the building by a person or persons with the intent of executing an attack. They could be mainly faced by access control strategies (compare to hard/soft target classifications) inside the BE, contrary to external threats, which imply an attack from the outside of the BE.

Secondly, some RMRSs can be effective in a limited number of *typologies of attack* [10,19,35,42]. Although the "*modus operandi*" of the terrorists can vary over time and space, main recurring typologies can be classified, as remarked by by Table 4. In particular, Table 4 organizes the *typologies of attack* according to the analogous attack types definedby Global Terrorism Database (GTD) classification, and traces if short-term or long-term (up to disruption) effects on the BE and its users can be provoked by the attack typology.

Finally, terrorist attacks are evolving dynamically, "shifting from symbolic, highly planned attacks to attacks that could occur anywhere, at any time, with the potential for mass casualties and infrastructure damage" [54]. RMRSs could be required to face localized attacks as well as Complex Coordinated Terrorist Attacks (CCTAs), such as multiple attackers' teams, attack locations, and attack types. RMRSs against CCTAs require a more complex cooperation system between the solutions implemented within the BE, the First Responders, the Security Forces, and the community [54,55].

2.2.3. Time-Dependent Classifications

RMRSs could also be distinguished *depending on time*, thus being correlated to the kind of threat and attack, as discussed in Section 2.2.2. Preventive (effective *before*, i.e., to deter, detect and delay) and emergency management (effective *during*) strategies can be mainly identified since they respond to different counter-terrorism goals [3,27,35,40,43,44]. Furthermore, emergency management strategies to be applied during and after the incident have different priorities depending on the operational timeline, thus limiting the effectiveness of some of them to specific time spans [35]. This kind of classification can also be related to the timing of behavioural issues in case of a terrorist act, thus linking the RMRSs to the contrast of risky behaviours or the promotion of correct responses by the users of the elements composing the BE [3,22,34,40,44]. In this view, RMRSs could be related to the different phases characterizing a terrorist act, which show different behaviours depending on the man–man, man–BE and man–threat sources interactions [22,44].

2.2.4. Space-Dependent Classifications

Regardless of the BE target-related features and main intended use and of the BE specific layout (e.g., building-related configuration of outdoor areas), RMRSs could be distinguished *depending on space*, thus being correlated to the kind of threat and attack as for time-dependent classification.

Table 4. Global Terrorism Database (GTD) classification of the "modus operandi" of the terrorists and correlation with attack typologies, their specifications and main terms of their effects.

GTD Classification (Modus Operandi)	Attack Typologies	Specifications	Terms of the Effects	
			Short	Long
Bombing/Explosion	Bombing attack	Explosive devices (including Improvised Explosive Devices—IDEs), directly placed in the BE; car bomb (parked); suicide bombing attack and car bomb driven by a suicide attacker running into the target, based on the terrorist's actions in the BE; bomb delivered by mail	x	x
Armed Assault	Armed assault (pistol, machine gun and so on)	It implies one or more active shooters (including sniper's assault), and which lead to an assassination	x	
	Attack with a cold weapon (e.g., knife)	By one or more active terrorists	x	
	Vehicle running into the target	It could be performed in open spaces in the BE or towards the BE elements perimeter	x	
	Arson	It can be essentially fought by combining RMRSs with fire safety strategies	x	x
	Unmanned aircraft systems	It can be used to perform direct attacks as well as to support the use of other weapons or to collect information before an attack	x	
	Chemical, Biological and Radiological (CBR) attacks	It can be performed in different ways, as for bombing attack-related ones		x
Barricade Incident; Kidnapping; Hijacking	Hostage-taking and barricade situations	In transportation BEs, also hijacking	x	
Unarmed Assault	Crowd attack to a soft target	Such as in case of insurrections	x	
Facility/Infrastructure Attack	Facility attacks	It can compromise the functionality of a BE by limiting/affecting the state of their infrastructural elements (e.g., water or electrical supply, cyberterrorism towards the BE facilities), thus provoking not only physical damages but also economic and social ones		x (disruption)

From a general point of view, since terrorist acts are generally focused on specific elements composing the BE, RMRSs should be differently organized according to the considered distance from the target by creating different zones [46,52,56,57]. This concept is mainly associated with bombing or armed assaults, such as in the definition of stand-off distances and zones, but it could be extended to other kinds of attack, e.g., vehicle attacks (i.e., the relation between areas that can be accessible or not by vehicles). As a consequence, such a classification evidences how the strategies should be deployed by considering the effective BE features for RMRSs deployment and the relationship between each part of it and the surrounding BEs [45,46,56].

On this basis, "zone" or "layer of defence" design approaches have been organized by previous guidelines, thus focusing on the BE site definition [45,46]. Figure 1 schematizes the main elements of the "zone" and the "layer of defence" design approaches for general (e.g., the simplest configuration of an isolated building site—see Figure 1A), linear (see Figure 1B) and areal (see Figure 1C) situations.
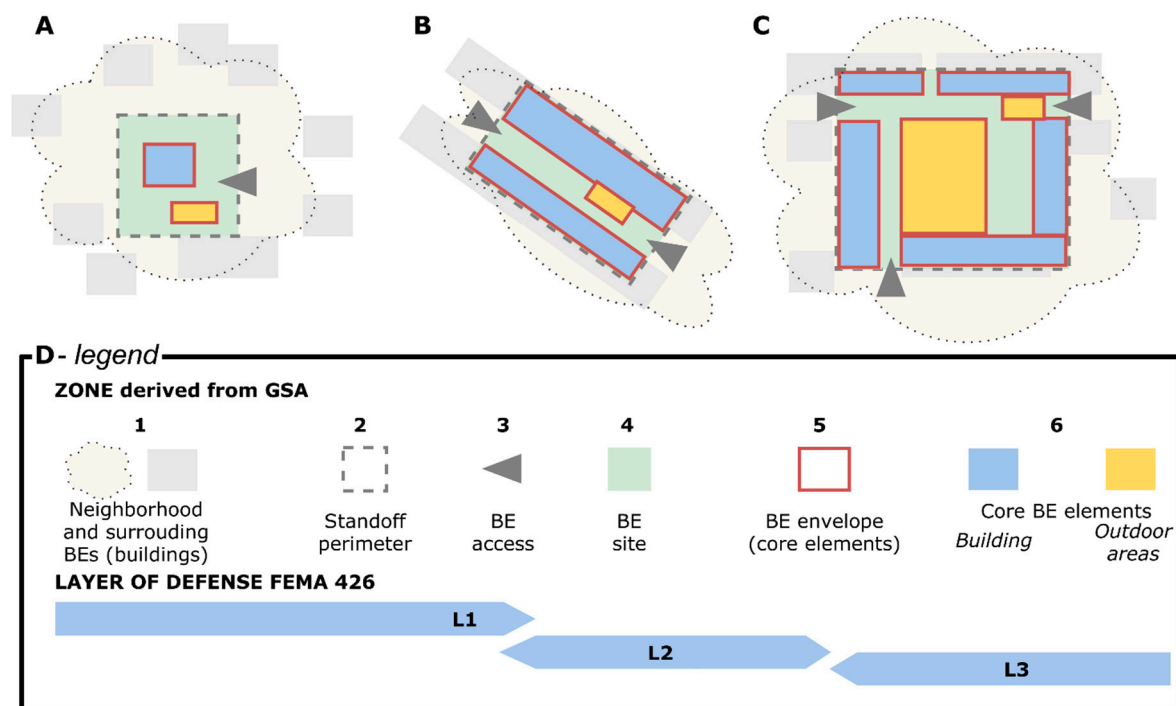
Figure 1. Scheme of the "zones" and "layer of defence" approaches to RMRSs in a BE for: (**A**) general BE (e.g., isolated or single buildings); (**B**) linear BE; (**C**) areal BE. On the bottom (**D**), the zoning scheme derived from GSA (U.S. General Services Administration) [45] is compared to the layer of defence given by FEMA 426 [46], by evidencing the legend for the upper part of the figure.

In particular, the main and essential RMRSs-related scheme can be based on existing regulations based on the following three "layers of defence" [46]:

- The *First* (or *Outer*) *Layer* (in the following, *L1*) is composed of all the barriers placed at the borders of the considered open space (e.g., for isolated buildings, the property line; for complex linear or areal BEs in urban scenarios, the limit of the area considered to be protected by RMRSs). The urban areas and the BEs placed beyond *L1* are not controlled by the BE stakeholders and users. *L1*-related RMRSs are essentially based on the possibility to create a limit for the BE-related RMRSs and to relate all the RMRSs involved in increasing urban resilience (e.g., involvement of the population, security and safety strategies for urban areas, security forces operation and counterterrorism actions) [3,13,29];
- The *Second* (or *Middle*) *Layer* (in the following, *L2*) is associated with the areas and objects deployed from the BE internal border to the exterior limit of the core elements. It refers to the physical envelope of subparts of the BE also outdoors, such as specific barriers enclosing areas in the BE, that are courtyards, gardens, restricted access areas in public open spaces (including those related to temporary BE use conditions, such as for mass gathering events). *L2*-related RMRSs provide a standoff into the open spaces in the BE, being under the direct control of their stakeholders. The site includes all the related areas, by referring to both those which can host the core elements (compare to the following Third Layer) and to the (outdoor) distribution spaces (e.g., access roads, evacuation paths, ancillary spaces);
- The *Third* (or *Inner*) *Layer* (in the following, *L3*) usually refers to the envelope and/or to the inside of the core elements, which can be majorly identified as attack goals. It can mainly involve specific buildings [46], but also outdoor areas, such as band stages, art stands, and observation areas open to the audience [44,54]. This layer separates "unsecured from secured areas". As a consequence, *L3*-related RMRSs are effective to limit the possibility that a terrorist act could happen or affect the core of the BE.

2.2.5. Physical Versus Management-Oriented Classifications

Previous works categorize RMRSs depending on *physical and management-related elements* composing the BE on which designers should act to reduce or to respond to the terrorist risk [13,32,42,43,46].

According to Section 1, the main *physical* elements are essentially the buildings and the open spaces in the BE (by including urban furniture). In this sense, they follow the general "layer of defence" organization [46]. In particular, if considering the furniture, a permanent or a temporary application of the RMRSs-related elements can be distinguished, thus dealing with livability and (in)visibility concepts [8,32,58].

The physical measures adopted in three layers should be additionally supported by *management* strategies, essentially based on the operational aspects [13,21,42,46], and mainly on:

- Security and safety planning strategies to be applied before and after the attack, based on risk assessment methodologies which can better identify the BE vulnerabilities;
- People's involvement, improving risk awareness, preparedness and response of the users;
- Policies, regulation and finance (including insurance-oriented) supporting the hosted activities (mainly economic ones and those with social impact).

Finally, some RMRSs can involve different physical and management issues, regardless of the elements to protect. The main examples are represented by drone-based and video surveillance-based RMRSs, which should adopt specific management actions combined with physical measures in the BE [13,29].

3. Classifying Existing Paradigms by Considering the BE Elements

Existing RMRSs classifications in Section 2 suggest that RMRSs can be assigned to different elements composing the BE and its management [46]. This approach is consistent with the Section 2.2.5 outline and focuses on the effective elements to be planned by safety designers [13,32,42,43,46]. Based on the general definition for physical versus management-oriented classifications in Section 2.2.5, RMRSs can be classified considering the key factors organized by Figure 2. In particular, they encompass:

- The design of the physical elements composing the open space in the BE, by focusing on those used as perimeters (e.g., building façades, barriers in outdoor areas) and those placed inside it (e.g., outdoor areas and buildings having a specific function and/or feature) (Section 3.1);
- BE layout, by involving RMRSs dealing with the organization of indoor and outdoor spaces, distance-related issues (i.e., standoff), and emergency facilities (Section 3.2);
- Access control and surveillance, dealing with the strategies to be implemented towards such goals on the border of/inside the BE (Section 3.3);
- Safety and security management, evidencing how safety and security staff actions could reduce the risk before/during the threat (Section 3.4).

This classification ensures the creation of a unique analysis layer on which specific actions are assigned to compose physical and management-related aspects. It succeeds in having a possible multi-purpose standpoint with respect to the target, the attack, and the time and space dependency. Nevertheless, some approaches are related to specific attack types as a direct consequence of their design principles and goals. The following classification discussion tries to evidence such issues. Dependencies between the RMRSs are discussed to evidence how they could be jointly implemented to improve the sustainability of safety and security in terrorism-prone scenarios.
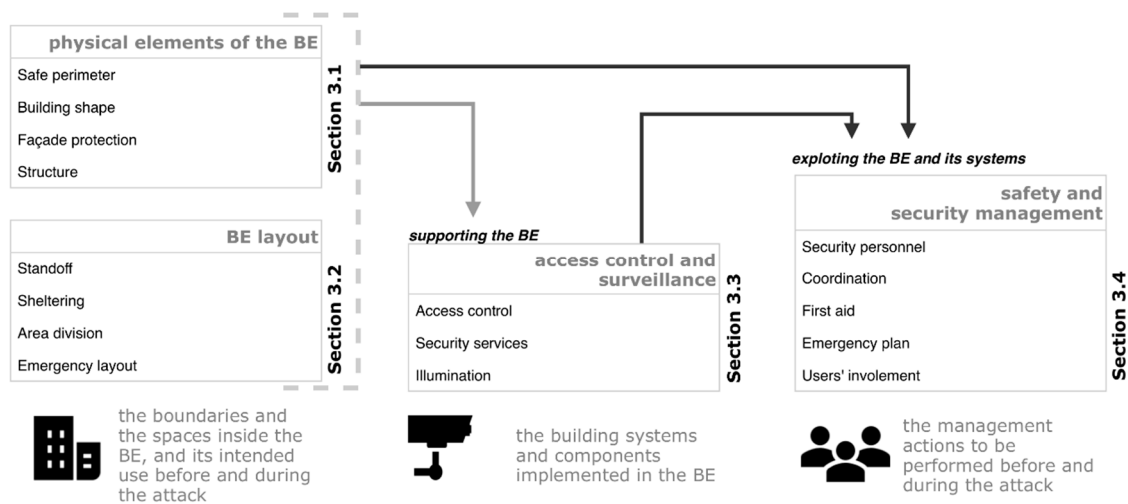
Figure 2. Scheme of the RMRSs classification based on the elements composing the BE and its management (vertical overview). For each key factor class, related RMRSs are listed and the reference sections in the work are outlined, while the relationships between the key factors are shown by the arrows.

3.1. RMRSs by the Design of the Physical Elements

The "*safe perimeter*" strategy can be performed by implementing specific obstacles along the frontier of the BE with the paramount aim of avoiding the access of vehicles to the target. According to their psychological effects in terms of users' insecurity [8,51], the physical elements evolved towards the concept of visible/invisible solutions, adding invisible or well-integrated products or solutions to traditional heavy barriers (e.g., concrete ones) [8,46]. All these solutions require discussion in terms of mitigation efficacy [32,44,46], aiming at their qualifications in terms of:

- Resistance to impacts that usually depend on vehicle typology and speed;
- Geometric efficacy when solutions are a system of independent elements;
- Emergency compatibility to guarantee the possibility of moving out of the BE site (e.g., correct dimensioning of passages, barriers that can be knocked out by evacuees).

The "*Building shape*" is mainly applied to buildings with the main purposes of:

- Facing blast load effects. In this sense, these strategies firstly consider building geometry, size (e.g., horizontal development is preferred to a vertical one) and façade continuum (re-entrant corners, circular and concave forms). Furthermore, the immediate building surroundings could additionally ensure a positive effect, by using safe perimeter-based solutions (e.g., barriers against bombings, outdoor spaces plano-altimetric configuration, and so on);
- Preventing possible assaults of terrorists inside the buildings (e.g., intrusion and armed assaults or following bombing as internal threats) or in the immediate surroundings. In this sense, these strategies try to ensure the possibility of blocking views of the inside assets to perpetrators or improve the building control (see Section 3.3). As well for this attack type, the buffer zones could support such strategies while being combined with building orientation, vegetation use, building components and external area planning elements (e.g., obstruction screens and man-made hillsides).

According to existing frameworks [46], these measures should be combined with: (1) *safe perimeter* and *standoff* measures to reduce the risk of building occupants, by means of unoccupied or low occupancy areas in the proximity of the entrances and of the perimeter (e.g., buildings envelope); (2) management strategies, by identifying secured and unsecured areas within a building and separating them with buffer zones. Such characteristics evidence how they can be difficultly compatible in the case of application to existing BEs, unless the interventions are applied to the elements in the open spaces. Finally, the

coordination between *building shape* and *emergency layout*-oriented strategies could increase the evacuation motion towards the shelters or the building exits, as for general fire safety solutions.

The "*Façade protection*" can guarantee the limitations of threat and damages propagation from the outside into the buildings. Structural properties, in reacting to bombing attacks, assume a paramount role indeed [42,43,46]. However, it is referred to the most vulnerable element in facades (e.g., windows, doors or structural glass) as additional protection near to the discussed "*building shape*" as well as the BE layout-related RMRSs [46]. According to existing frameworks [35], technical details concern these ideas:

- Laminated glass with an inner layer of polyvinyl butyral well secured into the frames is preferred. Concerning their position, windows are placed low down, reducing the distance of flying glass into the room.
- Security doors provide enhanced protection against forced entry and overall resilience of the outer shield of the building; moreover, doors should be bomb resistant, bullet resistant and extreme-intrusion-attempts resistant.

Such characteristics evidence how they can be limitedly sustainable in case of application to existing BEs, unless the interventions are applied to the simple retrofit of the existing building components.

3.2. RMRSs by BE Layout

The "*standoff*" oriented RMRSs can be implemented in relation to the *safe perimeter* and related BE site layout, combining minimum distances with physical elements or specific area to keep vehicles away from the entrance of buildings or their more vulnerable parts [46]. *Standoff* oriented RMRSs are specifically adaptable to increase the distance between bombing sources and specific targets.

"*Sheltering*" RMRSs are a human-centred solution aimed at protecting the BE occupants in safe areas placed as close as possible to their position before the attack. Their efficiency depends on the implementation of proper "*emergency layout*" and "*emergency plan*" measures as well as on "*structure*" oriented measures to contrast the attack-related damages [57]. Such strategies are borrowed from emergency plans concerning fires or climate-related events (e.g., storms, hurricanes) and they are usually identified as safety areas located inside the buildings [34]. In fact, "sheltering" inside buildings (as an "invacuation" or "inward evacuation" procedure) can be a valid approach for outdoor areas in the BE in the case of attacks due to external threats in respect to the buildings themselves, such as vehicle attacks, armed assault or even low-level risk of chemical, biological and radiological (CBR) attacks [42,52,57]. The effectiveness of such RMRSs can be guaranteed when combined with:

- The design of physical elements in the BE, adopting "*Façade protection*" measures to contrast the attack itself;
- The aforementioned "*emergency layout*" strategies by integrating them with the support of management solutions. In this sense, additional RMRSs can mainly concern: (1) correctly signalling the sheltering areas by means of signs or by using "emergency plan" related actions by safety and security staff members; (2) also promoting "users' involvement" before the event;
- Additional "*access control and surveillance*" solutions to impede the attackers who could arrive at the shelters.

"*Area division*" and "*emergency layout*" related measures can be guaranteed by correctly applying the RMRSs relative to "*safe perimeter*". Through their implementation, the open spaces in the BE should be divided into sectors able to host a definite number of occupants, and they are fully designed in mass gathering events. Furthermore, the contribution of each outdoor and indoor element towards this analysis should be considered. Specific areas should be circumscribed when locating emergency facilities, and access and exit points should be identified with well-delineated borders by controlling

the crowd flows [32,44]. "*Emergency layout*" strategies can also limit critical phenomena in crowd motion to reduce time-increasing and individuals' safety-decreasing man–man interactions, such as counterflow movements along the evacuation paths or high-density crowd conditions [38,59].

3.3. RMRSs by Access Control and Surveillance

"*Access control*" is a paramount strategy for hard targets or in case of mass gathering events due to its strongly deterrent character for terrorist attacks [9,29,32,46]. Safety personnel are often employed to manage such controls by following specific management procedures. If combined with safe perimeter solutions (i.e., heavy barriers), they constitute the most invasive solutions [8]. However, novel technologies could be employed to speed up the access controls and to make them less invasive, such as body scanners, metal detectors and optical devices for counting people. The use of video surveillance systems (CCTVs), distributed across the overall BE, can support the investigations of intelligence authorities to prevent possible terrorist attacks and to detect the perpetrators after the event. In addition, the effectiveness of these two RMRSs are strictly influenced by: (1) the application of reliable *coordination* actions; (2) the robustness of the infrastructure which collects and disseminates data between the First Responders and the LEAs [11,29].

In addition to these two main control and surveillance RMRSs classes, "*illumination*" represents a real and psychological deterrent for continuous or periodic observations by an aggressor, as well as a low-cost solution [46]. Different illuminance conditions can be designed to be increased over time, while site lighting can be helpful as a response to different levels of alert or to support users in attack-affected conditions (e.g., proper illuminance of the *emergency layout*). Finally, security illumination tools should be combined with CCTV since the cameras may need high intensity, low intensity, or infrared light for proper operation.

3.4. RMRSs by Safety and Security Management

"*Security personnel*" mainly include LEAs, Security Forces, and other surveillance bodies in soft targets. They should perform all the actions mainly related to security issues [7,44] that are: (1) before the event, to mainly deter and detect possible attackers; (2) during the attack, to mainly support First Responders in "*first aid*" operation in the immediate aftermath and to detect the assaulters. In a "*coordination*" perspective, they should be adequately trained to face effective conditions, and they also require the implementation of effective access control and surveillance RMRSs [32,42,44,60]. From a procedural point of view, while responding to the attack conditions, RMRSs concerning "*security personnel*", "*first aid*" and "*coordination*" should also be strongly supported by the *emergency plan* and *emergency layout*. In addition, tools to estimate the damage caused by the attack itself by including both direct fatalities due to the event and crowd-related and behavioural-based phenomena (e.g., crushing effects in the crowd) can support the combined planning of such RMRSs [38,40,44,61].

In view of the above, it is important to underline the role of two main RMRSs. Firstly, the "*emergency plan*" becomes a key element in management oriented RMRSs. This is the sum of subsequent indications for emergency personnel and users about the employment of the predisposed emergency facilities. Therefore, emergency plans have to be strictly related to the other RMRSs and able to organize and create interactions among them. Emergency coordinators and designers should have the capability to comprehend every key aspect and potentiality of each emergency measure and to take advantages from them by putting each RMRS into communication, to prevent and discourage the attack and to work jointly after the attack. Emergency plans have to take into account the main features of soft target typologies, which depend on their intended use. In particular, they have to face with the possibility that specific activities take place, and, in the case of mass gathering events, with the expected number of people (which can sensibly vary in soft targets and, especially, in outdoor areas).

It is worthy of notice that such measures are well codified in the literature when they are referred to a single part of the BE (e.g., a single building) or to the BE as a whole during specific events, such as organized mass-gatherings, festivals, and so on. In the case of "daily" use of the BE, it cannot be possible to define an overall system for safety and security management. Nevertheless, it is important to evidence how future efforts in defining common action plans between all the BE stakeholders will improve the coordination of counterterrorism measures in this sense. Secondly, the "user's involvement" concerns all the actions aimed at improving the awareness, the preparedness and the correct response of citizens to the risk of possible terrorist attacks, as for other kinds of SUODs [44]. In fact, the promotion of "educative" initiatives (e.g., booklets or guidelines) to common people can improve their awareness and preparedness in case of necessity (before the event) [62]. Some European countries (i.e., Belgium, United Kingdom, Germany) have supported the development of counterterrorism measures for individual devices (mainly smartphone applications). Some of these apps constitute a tool to provide detailed indications of the right behaviours to perform linked to the types of terrorist attack, such as the virtual platform iNFO-R!SQUES.be (available at: https://www.info-risques.be/fr; last access: 30 September 2020). Other apps inform users about ongoing terrorist attacks, integrating the alert message system to the users' location thanks to the Wireless Local Area Network for smartphones, such as the KATWARN mobile application (available at: https://www.katwarn.de/en/system.php; last access: 30 September 2020).

4. Challenges in a Holistic, Sustainable and Human-Centred Approach to Risk Reduction Strategies' Classification and Evaluation

The brought classifications of existing RMRSs are not enough to determine which RMRSs are more convenient to be applied to a specific case study. Therefore, the main challenges for risk mitigation and management solutions have to be assessed from a sustainable point of view as well. Hence, RMRSs should be oriented towards the following main sustainability criteria here synthesized [8,10,22,24,29,38–40,44,58,63]:

- Moving towards redundancy criteria of the resilient BE by combing different strategies to ensure that each of them could support the risk-reduction process (according to different operational procedures) in all the phases of the disaster;
- Selecting solutions to be effective for more than one terroristic threat/attack typology;
- Adopting a human-centred approach to include the behavioural reaction of the exposed individuals (especially in crowds) and of the terrorists, also in respect to the human–BE interactions (i.e., for the promotion of correct emergency behaviours);
- Including mass gathering conditions during strategy planning to ensure the safety and security aspects of different BE use situations;
- Considering the possibilities of connecting different BEs (at a local scale, e.g., indoor-outdoor; at a global/urban scale) to face the disaster;
- Promoting a psychological function of the strategies to ensure they are perceived as reliable by the citizen, to deter the terrorists but also to guarantee the liveability of the BE under normal use conditions.

A critical evaluation of such aspects is outlined through Tables 5 and 6, which focus on the general applicability, adaptability and costs approach issues. In particular, redundancy criteria and coordination criteria in Tables 5 and 6 are expressed according to the correlation in Appendix B (Tables A2 and A3, respectively). Furthermore, Tables 7 and 8 deal with human perception and evacuation simulations, according to the human-centred standpoint.

Table 5. Sustainability of RMRSs by the applicability, adaptability and costs approach (Design of the physical elements of the BE; BE layout).

RMRS	Redundancy about Attack Typology and Source (External/Internal)	Applicability to Indoor, Outdoor, Both	Coordination with Other RMRSs	Adaptable for Existing BE	Main Application Context (Intended Use; Overcrowding)	Costs
Design of the physical elements of the BE						
Safe perimeter	2/10—external	Outdoor: around buildings and specific targets, or to circumscribe areas in a wider open space	4/16	Adaptable, through punctual installations	For hard targets, because of its complexity level	Depending on adopted technologies and BE perimeter length
Building shape	4/10—external/internal	Principally outdoor but specific measures (i.e., escape routes, shelters) are adaptable in indoors as well	3/16	Not adaptable	Specific for public buildings with a high number of visitors	Sustainable for new BEs or full BE elements renewal
Façade protection	2/10	Protecting single buildings	4/16	Generally, solutions are related to new facades (which can alter the aspects of the original elements). Interventions on existing openings have a lower impact.	Specific for public buildings with a high number of visitors	New reinforced facades can be put in place with limited costs (depending on the building typology). Interventions on existing openings are encouraged due to their lower costs with respect to the protection increase advantages.
Structure	1/10	Indoor: relative to building's structural system	2/16	Preservation of historic buildings could be affected, unless there are focused interventions	Encouraged only for institutional public buildings with many visitors	Depending on intervention type, structural typology and building dimensions
BE layout						

Table 5. *Cont.*

RMRS	Redundancy about Attack Typology and Source (External/Internal)	Applicability to Indoor, Outdoor, Both	Coordination with Other RMRSs	Adaptable for Existing BE	Main Application Context (Intended Use; Overcrowding)	Costs
Standoff	2/10	Distances applied to the outdoors can be adapted for some indoor conditions	5/16	Possible massive impact, if applied together with Safe Perimeter. Otherwise, adaptable to the historical layout using management actions.	Specific for strategic buildings but extendable to soft targets with visitors and temporary mass gatherings	Depending on land use issues to guarantee the distances in case of new constructions. In existing BEs, costs concern the space use management
Sheltering	6/10	Shelters can be placed inside buildings or constitute a safe area in the outdoor BE	4/16	Adaptable if limited to the definition of shelter areas and their accessibility (management issues); incompatible considering interventions on building facades and structures.	Considering attacks to single and strategic buildings with something/someone to protect	Low costs if limited to existing shelter areas; elevated cost otherwise
Area division	5/10	Both	6/16	The adaptability is related to the area configuration and dimension	Specific for mass gathering events in open spaces	Low costs associated with physical solutions (e.g., open space perimeter), but management and operational issues should be evaluated (e.g., organizing activities in the spaces and their relation; access controls)
Emergency layout	5/10	Outdoor or within strategic buildings and hard targets	8/16	Adaptable for each situation	Adaptable in each event typology	Depending on the extension of the emergency area in relation to the BE activities

Table 6. Sustainability of RMRSs by the applicability, adaptability and costs approach (Access control and surveillance in the BE; Safety and security management of the BE).

RMRS	Redundancy about Attack Typology and Source (External/Internal)	Applicability to Indoor, Outdoor, Both	Coordination with Other RMRSs	Adaptable for Existing BE	Main Application Context (Intended Use; Overcrowding)	Costs
Access control and surveillance in the BE						
Access control	7/10	Applicable to circumscribed areas in open spaces/inside a building	7/16	Adaptable for existing BE because of the possibility to circumscribe areas (i.e., outdoor perimeter)	Adaptable for events with considerable crowding conditions (mass gathering events)	Depending on the number of access/control points and to the employed technologies/personnel
Security service	6/10	Employable in indoor and outdoor conditions	6/16	Adaptable for existing (including historical) BEs through not invasive installations	Adaptable to private and public buildings, and also in open spaces and mass gatherings	Depending on the BE dimension to monitor and on the adopted technologies
Illumination	4/10	For outdoor spaces; in indoor, mainly for scarce luminance condition of buildings	3/16	Adaptable for existing (including historical) BEs with possible restrictions at technological level (e.g., systems integration/installation)	Adaptable both to private and public buildings, both in open spaces and mass gatherings	Depending on the number of installed devices, and their operational and maintenance issues
Safety and security management in the BE						
Security personnel	7/10	Employable in indoor and outdoor conditions	8/16	Adaptable in each condition	Personnel could support an emergency in whatever building. It is strongly recommended in mass gathering events, especially outdoors	Depending on building dimension and floors. In mass gatherings, depending on event area extension and number of participants
Coordination	10/10	Always recommended	7/16	Not dependent on the BE typology	Necessary in each case; it requires special consideration for some hard targets or mass gathering events	Low-cost improvement of performances is possible, but costs could be related to the employed technology
First aid	9/10	Always needed; support from external rescuers' actions	7/16	Adaptable in each condition	Mandatory for mass gathering and in hard targets of the BE	Low costs by considering the direct possibility to save lives

Table 6. *Cont.*

RMRS	Redundancy about Attack Typology and Source (External/Internal)	Applicability to Indoor, Outdoor, Both	Coordination with Other RMRSs	Adaptable for Existing BE	Main Application Context (Intended Use; Overcrowding)	Costs
Emergency plan	10/10	Always needed	11/16	Adaptable in each condition	Recommended in any cases, especially in mass gathering events and in hard targets of the BE	Depending on management and operational phases; they could be elevated considering case by case (e.g., cost of personnel considering their number)
Users' involvement	10/10	Users should be involved in the same manner for both indoor and outdoor scenarios. However, the provided data will be different	7/16	Not dependent on the BE typology	Users should be formed to face disaster both in BE normal use and in case of events with overcrowding conditions	Financing informative campaign can be considered as an investment on citizen safety; costs for users' involvement are also related to evacuation guiding tools for mobile devices (e.g., apps)

Table 7. Sustainability of RMRSs by a human-centred approach (Design of the physical elements of the BE; BE layout); N.A. stands for "not assessed".

RMRS	Interactions with Behavioural Issues	Perceived as Reliable and Slightly Invasive for Citizens	Employable for Mass Gathering Conditions	Possibility to Be Represented in Crowd Evacuation Simulators
Design of the physical elements of the BE				
Safe perimeter	Barriers should be designed by considering the users' perception and the behaviours in an emergency (e.g., in evacuation), being correlated to emergency layout and plan strategies	Barriers offer a reliable perception, while their invasive aspect or not depends on their different typology	Emergency layout elements (e.g., gathering areas/evacuation paths) can be additionally protected by such measures	The BE geometry and obstacles for attackers can be represented in a virtual environment. Moreover, such data can also influence the pedestrians' evacuation dynamic
Building shape	By constituting temporary shelters, hiding places, and recovery areas	Not generally invasive since it is still included within the general architectural features of the BE	N.A.	Plan geometry of each building in the simulated BE
Façade protection	N.A.	Not generally invasive if related to new constructions but it could be in the case of intervention on an existing building in relation to the employed technology	N.A.	Effects (i.e., damages) of the attack on the BE elements
Structure	N.A.	N.A.	N.A.	Attack damages reduction possibility on buildings
BE layout				
Standoff	N.A.	It could be perceived as a negative element in relation to area division, due to the modification/definition of the particular fruition mode of the BE	Standoff distances in the positioning of hazardous facilities or equipment	Plan geometry of the BE
Sheltering	Shelters are designed considering users safety and eventual necessities during the emergency	Yes	Safe areas should be predisposed where to direct the evacuation	Safe places play an attractiveness role where to refuge

Table 7. *Cont.*

RMRS	Interactions with Behavioural Issues	Perceived as Reliable and Slightly Invasive for Citizens	Employable for Mass Gathering Conditions	Possibility to Be Represented in Crowd Evacuation Simulators
Area division	Area division is defined in the function of crowd dynamics and human behaviours	Area division is often heavily perceived with a negative impact	Area division is mandatory in some regulations in relation to the entity of the event	Plan geometry of the BE, maximum crowd capacity, main intended use and related hosted users' typologies/activities affecting the evacuees' behaviours
Emergency layout	The emergency layout is planned by considering the supposed number of users, their typologies and their behaviours (e.g., by using evacuation simulators)	Users should be aware of the safety measures and emergency facilities	The emergency layout is strongly recommended, especially in mass gathering events, because of the higher impact of crowd conditions on the emergency (i.e., evacuation) process	Input data for the environment definition (e.g., available evacuation paths, safe areas according to the emergency plan)

Table 8. Sustainability of RMRSs by a human-centred approach (Access control and surveillance in the BE; Safety and security management if the BE).

RMRS	Interactions with Behavioural Issues	Perceived as Reliable and Slightly Invasive for Citizens	Employable for Mass Gathering Conditions	Possibility to be Represented in Crowd Evacuation Simulators
Access control and surveillance in the BE				
Access control	Access control is aimed to discourage the attackers	Access control could be strongly invasive in relation to employed tools and users' fruition modes (e.g., because of access timing) but perceived as a positive protective measure	It is strongly recommended or mandatory in relation to the event entity	As an element to control input data related to the simulated pedestrian's presence in the environment
Security service	Employable to discourage attackers and to detect suspected behaviours	The solution can be visible or invisible depending on the employed technology generally perceived as positive	Video Surveillance could give an important contribution to monitoring the situation in mass gatherings	Integration of monitoring tools in the emergency to simulate "intelligent" solutions application (i.e., input data for emergency detection and evacuation management)

Table 8. *Cont.*

RMRS	Interactions with Behavioural Issues	Perceived as Reliable and Slightly Invasive for Citizens	Employable for Mass Gathering Conditions	Possibility to be Represented in Crowd Evacuation Simulators
Illumination	Employable to discourage attackers and to detect suspected behaviours	A visible solution, non-invasive and perceived as positive	Necessary for control and emergency purposes (access/egress points and emergency facilities), but it should be compatible with specific events (e.g., entertainment with specific illumination requirements)	Effects of illumination degree on the motion of individuals and on the selection of specific paths, also during the emergency and evacuation process
Safety and security management if the BE				
Security personnel	Employable to discourage attackers and to intervene in case of suspected behaviours	A visible solution, non-invasive and perceived as positive	It is strongly recommended or mandatory that its number depends on the amount of hosted people	Personnel constitute a source of instructions able to modify pedestrian's evacuation
Coordination	N.A.	N.A.	The efficiency of emergency response is sensibly improved	Simultaneous and coordinated employment of different countermeasures
First aid	Adequate to users' typologies and number	Solution perceived as positive. Generally also visible before the emergency.	It is strongly recommended or mandatory in case of mass gatherings	Representable as a reduction in victims' amount and as rescuers' motion towards specific areas
Emergency plan	Emergency plans should be developed by considering possible human behaviours and actions (e.g., by using evacuation simulators)	It should be known by the users	It is strongly recommended or mandatory in relation to the event entity	It can constitute the amount of data that can be assessed preventively and considered as an input to the emergency simulation
Users' involvement	Indications issued to users should be related to their spontaneous reactions performed in hazard situations	People that know what to do in case of emergency will feel safer	Users' proper behaviour could support the evacuation decisions from a bottom-up approach, to support the rescuers and the emergency staff	Capabilities of the users to perform right behaviours

Some remarks on research objectives, future challenges and design/policy/planning perspectives can be summarized according to this critical overview of RMRSs and their classification.

Firstly, according to this work's aims, the proposed classification critically reviews, for the first time, current consolidated RMRSs, filtering them through the different elements composing the BE and its management. The proposed classification succeeds in evidencing the complex relation system between all the physical and management-related elements composing the BE (outdoor and indoor spaces). This result is achieved by considering solid regulatory frameworks and guidelines. The findings highlight how the BE and its users have to be considered not as the attack's background, but as an integral part of the RMRSs themselves. In fact, safety planners should coordinate (1) the BE layout design, which can support space organization in normal fruition (i.e., standoff distances; area and access control by the stakeholders) and in emergency conditions, with (2) BE-oriented interventions to establish safe perimeters and adopt constructive solutions for the protection of buildings' parts, façades, and structures (to limit the terrorist acts' effects).

The organization of RMRSs, depending on the elements composing the BE and its management, can represent a unique and easy-to-use list of solutions for safety planners and decision-makers. Thus, such a list can increase their awareness in respect to the implementation of such solutions in the BE in a sustainable and quick manner, additionally pursuing a high-level of liveability of the BE. Finally, analyses on the combination/coordination of RMRSs to contrast a terrorist act can support safety planners and decision-makers, also in view of the use of behavioural-based simulation tools, as remarked by Tables 7 and 8 [8,13,31,37].

Furthermore, the proposed classification list can be used to collect data from real-world BEs. Such an action will define recurring conditions in RMRSs' implementations depending on the frequency of RMRSs implementation. Widespread data collection in national and international contexts will support the definition of typical BE scenarios depending on the applied RMRSs.

Secondly, the proposed classification and the human-centred principles codified in Tables 7 and 8 support the combination of RMRSs to manage specific emergencies, especially related to actions carried out by the BE users. In fact, they can sustain the organization of future regulatory frameworks which can manage terrorist risks for the BE under different scenarios of use of open spaces and facing buildings. In particular, in the case of open spaces where mass gatherings can occur, the results remark how the access points should be controlled, adopting security services through trained and adequately coordinated personnel.

In this sense, future challenges in RMRSs' definition and assessment will move towards a human-centred perspective, as for other kinds of SUOD such as fires, so as to check how the BE users' control and support can be achieved in all these different scenarios of BE use. Current RMRSs solutions to increase people's safety against terrorist attacks are limitedly based on data nearer to reality [40,44,64–66]. On the contrary, many simulation models were developed in the past, and they also included the effects of the terrorist acts on the BE, but most of them adopted general purpose behaviours (e.g., those related to fire egress) and only a few of them were based on effective evacuation scenarios from terrorist acts [40,67–70]. Such modelling issues can beneficially assume microscopic approaches due to the possibility of representing the interactions among attackers, attack actions and occupants over time and space (e.g., by pursuing a social-force based [67,70] or a cellular automata [66,69] approach, also integrating agent-based models [71]). Thus, further efforts to provide reliable databases on terrorist act-related emergencies are urgently needed and they should include the possibility of simulating the effects of the adopted RMRSs [33]. In this way, these studies could fully include a human-centred approach into RMRSs' planning practices to support decision-makers [31,40,66]. The database outcomes could be used for preliminary activities related to the development, evaluation and validation of behavioural emergency evacuation simulators for terrorist attacks in the BE, especially if

related to specific case studies. The results of future simulations will allow us to evidence the possible interactions among the effects of the attack (and the attackers, too), the RMRSs adopted, the BE and its modifications, the crowd and the first responders in view of such an emergency [40]. Pedestrians' evacuation flows will be combined with analyses on the evacuation time and the causalities' number to evidence the effects of such interactions and to inquire about the effectiveness of proposed RMRSs, thus improving community resilience aspects in specific scenarios. Simulation tools could also be applied to typical BE scenarios organized depending on the RMRSs analysis in real world contexts. They will define recurring conditions in the emergency phases, depending on the BE features (e.g., morphological-constructive features), the BE use and crowd presence, the type of attack and the implemented RMRSs. These activities will move towards a parametrization of risk levels and evacuation conditions in significant scenarios, thus being a quick support for preliminary effectiveness evaluations from decision-makers.

Thirdly, the RMRSs discussion through sustainability criteria is based on redundancy, adaptability, coordination, and costs, and seems to trace which RMRSs can be more convenient in relation to the obtained effects, as also remarked by Tables 5 and 6. In particular, the combination between safety and security management strategies and access control and surveillance seems to lead towards the highest sustainability levels, thus being a possible focus for effective RMRSs in the future, in each kind of BE. Such an approach will support decision-makers while organizing plans on terrorist act mitigations to be extensively applied in different urban BEs. Nevertheless, one of the greatest challenges for policy planning concerns the overcoming of limitations due to the combination of public-oriented actions and classified risk management strategies. As for other kinds of disasters, such as fires, earthquakes or floods [33,34,36], strategies based on risk awareness and preparedness should be shared with the BE users to increase their safety [32], but they should be arranged in respect to the reliability of security measures. In fact, these security measures widely concern intelligence activities and should be hence protected by public and uncontrolled accesses. The decision-makers can use simulation tools to evaluate the acceptable threshold for such safety-security measures concerning: (1) pre-disaster actions in terms of the spreading of emergency plans, which could also be known by the potential attackers; (2) and the emergency response actions to support the population during the event and the evacuation process. The level of shared information will be managed to limit the possible support to terrorists in collecting sensitive data, but it will demonstrate the level of safety of the BE they would attack, thus also becoming a dissuasive element in terrorism fighting.

Finally, the sustainability and holistic perspective-oriented criteria discussed in Tables 5 and 6 could also be adopted to provide the bases of key performance indicators to assess the RMRSs feasibility and reliability in BE application. According to the Tables 7 and 8 insights, the introduction of typical factors relating to the levels of support to BE users in emergencies and to the mass gathering conditions in the BE will boost this assessment process. From this point of view, the proposed approach also represents the first step towards the organization of holistic BE resilience metrics to also be applied to other disasters affecting the urban BE. However, they will be based on the elements composing the BE and its management, and they will adopt the same sustainability and human-centred key factors. In this sense, a combined analysis of the BE under several threats will be pursued by using common key performance indicators, in accordance with the goals of the wider project this paper is part of [41]. However, the next works should provide quantitative indexes for merging them by considering different priority levels depending on each proposed criterion.

5. Conclusions

Terrorism acts have become a more frequent menace for society nowadays. Attacks mainly occur in the open spaces of our cities which are habitually frequented by inhabitants. Thus, measures able to face such sudden onset and man-made disasters have to

be organized in strict relation with the Built Environment features. This work traces a critical review on existing and consolidated Risk Mitigation and Reduction Strategies (RMRSs) based on the codified regulations that risk-prone countries have adopted in the last few decades.

Classifications of RMRSs are provided according to main literature-based criteria and involve consolidated regularity frameworks. In particular, the analysis provided a distinction between hard and soft BE targets, where active and passive actions can be applied by considering their level of visibility in respect to possible aesthetic and preservation issues of the BE. The identification of the main attack typologies is supported by the RMRSs' effectiveness depending on time and space, since different attacks imply different effects on the exposed individuals and modifications of the BE. A layer-based discussion of RMRSs' implementation in the BE evidences the roles of perimeter elements, open spaces in the BE (and their furniture) and building components/buildings as the inner level of safety.

In view of the above, the collection of the main paradigms regarding physical and management-oriented aspects in the BE can summarize all these issues from a holistic standpoint. It provides the basis for the discussion of consolidated RMRSs based on sustainability and human-centred criteria, which essentially encompass redundancy, adaptability, coordination, costs and BE users' support in emergency conditions. Filtering RMRSs by the elements composing the BE and its management provides the basis for the future organization of these solutions from a parametric standpoint, which depends on the effective scenario where they will be placed. Meanwhile, among the adopted criteria, the human-centred ones highlight how simulation-based approaches could play a pivotal role in assessing the effectiveness of RMRSs, also including emergency management topics, due to the significant impacts of man–man and man–environment interactions in the immediate response phase.

Future works will have to improve the dimension of the sample of the documents concerning the RMRSs by including those from other countries prone to terrorist acts. This action will allow detecting if additional measures can be included in the RMRSs classification, according to local experiences and other codified policies. At the same time, a deeper focus on case studies from real-world BE applications could support the delineation of a general theory for RMRSs' selection and evaluation. The proposed BE-oriented classification criteria of RMRSs could be applied to real-world scenarios. These activities could delineate common implementation strategies in real contexts. Furthermore, the response of each deployed RMRS before and during the attack could also be assessed if considering BEs affected by terrorist acts. Thus, stakeholders and researchers could move towards experimental-based analyses on their effectiveness to be compared with feasibility, risk assessment and simulation-based evaluations.

Appendix A

Table A1. Documents selected in this work for the risk mitigation and reduction strategies analysis, by organizing them by country and identifying each document according to a specific identification code (ID code) used in the following results and discussion sections.

Country	Number of Documents	Document: Institutions and/or Authors (Year) Title [Language], Other Identification Data including Website
Australia	3	Live Performance Australia (2019) *Audience and Crowd Management Hazard Guide* [English]
		Commonwealth of Australia (2017) *Australia's Strategy for Protecting Crowded Places from Terrorism* [English] ISBN: 978-1-925593-95-2
		Australian Institute for Disaster Resilience (2018) *Safe and Healthy Crowded Places* [English] Handbook 15
Czech Republic	1	Soft Targets Protection Institute/Kalvach, Z., et al., (2016). *Basics of Soft Targets Protection—Guidelines (2nd Version)*, https://www.mvcr.cz/cthh/soubor/basics-of-soft-target-protection-guidelines.aspx
France	3	Ministère de la Culture et de la Communication (2016) *Vigilance Attentat: les Bons Réflexes-Guide à Destination des Organisateurs de Rassemblements et Festivals Culturels* [French] https://www.culture.gouv.fr/Actions-de-renforcement-et-de-surveillance-des-lieux-culturels
		Ministère de la Culture et de la Communication (2016) *Vigilance Attentat: les Bons Réflexes-Guide à Destination des Dirigeants D'établissements Culturels Patrimoniaux* [French] https://www.culture.gouv.fr/Actions-de-renforcement-et-de-surveillance-des-lieux-culturels
		Ministère de l'Intérieur, de la Culture et de la Communication, Secrétariat général de la Défense et de la Sécurité National (2017) *Gérer la Sûreté et la Sécurité des événements et Sites Culturales* [French]
India	1	National Disaster Management Authority (2014) *Managing Crowd at Event and Venues of Mass Gathering* [English]
Italy	3	Ministero degli interi (2017) *Circolare 7/6/17 n.555/OP/0001991/2017/1* [Italian]
		Ministero degli interi (2017) *Direttiva 28/07/2017 n. 11001/110(10)* [Italian]
		Ministero degli interi (2018) Direttiva 18/07/2018 n. 11001/1/110/(10) [Italian]
UK	3	Home Office in partnership with the Department for Communities and Local Government (2012) *Crowded Places: The Planning System and Counter-Terrorism* [English] ISBN: 978-1-84987-392-5
		Pool Re/Julian Enoizi (2017) *Terrorism Threat & Mitigation Report* [English]
		Home Office in partnership with the Centre for the Protection of National Infrastructure and the National Counter-Terrorism Security Office (2012) *Protecting Crowded Places: Design and Technical Issues* [English] ISBN: 978-1-84987-393-2
United States	5	Joint Counterterrorism Assessment Team (JCAT) (2018) *Planning and Preparedness Can Promote an Effective Response to a Terrorist Attack at Open-Access Events* [English]
		Homeland Security Science and Technology (2018) *Planning Considerations: Complex Coordinated Terrorist Attacks* [English] Homeland Security Science and Technology (2009) *Handbook for Rapid Visual Screening of Buildings to Evaluate Terrorism Risks* [English] FEMA 455
		Homeland Security Science and Technology (2011) *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings* [English] FEMA-426/BIPS-06/Edition 2
		U.S. Department of Homeland Security (2006) *Safe Rooms and Shelters Protecting People Against Terrorist Attacks* [English] FEMA 453

Appendix B

Table A2. The evaluation of redundancy of each RMRS related to the possibility to face more than one attack typology. Matches are indicated by "X". The total match number is provided on the total attack typologies.

	Bombing Attack	Armed Assault	Attack with a Cold Weapon	Vehicle Running into the Target	Arson	Unmanned Aircraft Systems	CBR Attacks	Hostage Taking	Crowd Attack	Facility Attacks	Total
Safe perimeter	X	-	-	X	-	-	-	-	-	-	2/10
Building shape	X	X	X	X	-	-	-	-	-	-	4/10
Façade protection	X	X	-	-	-	-	-	-	-	-	2/10
Structure	X	-	-	-	-	-	-	-	-	-	1/10
Standoff	X	-	-	X	-	-	-	-	-	-	2/10
Sheltering	X	X	-	X	X	X	X	-	-	-	6/10
Area division	X	X	X	X	-	-	-	-	X	-	5/10
Emergency layout	X	X	X	X	-	-	-	-	X	-	5/10
Access control	X	X	X	-	X	-	X	X	X	-	7/10
Security service	X	X	X	-	X	-	-	X	X	-	6/10
Illumination	X	X	X	-	-	-	-	-	-	X	4/10
Security personnel	X	X	X	X	X	-	-	X	X	-	7/10
Coordination	X	X	X	X	X	X	X	X	X	X	10/10
First aid	X	X	X	X	X	X	X	X	X	-	9/10
Emergency plan	X	X	X	X	X	X	X	X	X	X	10/10
Users' involvement	X	X	X	X	X	X	X	X	X	X	10/10

Table A3. The evaluation of possible coordination of each RMRS with the others to improve their effectiveness. Matches are indicated by "X". The total matches number is provided on the total RMRSs. The intersection between the same RMRS is marked by the grey cells with the diagonal lines.

	Safe Perimeter	Building Shape	Façade Protection	Structure	Standoff	Sheltering	Area Division	Emergency Layout	Access Control	Security Service	Illumination	Security Personnel	Coordination	First Aid	Emergency Plan	Users' Involvement	Total
Safe perimeter	▨	-	-	-	X	-	X	X	X	-	-	-	-	-	-	-	4/16
Building shape	-	▨	X	X	-	X	-	-	-	-	-	-	-	-	-	-	3/16
Façade protection	-	X	▨	X	X	X	-	-	-	-	-	-	-	-	-	-	4/16
Structure	-	X	-	▨	-	X	-	-	-	-	-	-	-	-	-	-	2/16
Standoff	X	--	X	X	▨	-	X	-	X	-	-	-	-	-	-	-	5/16
Sheltering	-	X	-	X	-	▨	-	-	-	-	-	-	-	X	X	-	4/16
Area division	X	-	-	-	-	-	▨	X	X	-	-	X	X	-	X	-	6/16
Emergency layout	X	X	-	-	X	-	X	▨	X	-	-	X	-	X	X	-	8/16
Access control	X	-	-	-	X	-	X	X	▨	-	-	X	X	-	X	-	7/16
Security service	X	-	-	-	-	-	-	--	X	▨	X	X	X	X	-	-	6/16
Illumination	X	-	-	-	-	-	-	-	X	X	▨	-	-	-	-	-	3/16
Security personnel	X	-	-	-	-	X	X	-	X	X	-	▨	X	X	X	-	8/16
Coordination	-	-	-	-	-	X	X	X	X	X	-	X	▨	X	-	-	7/16
First aid	-	-	-	-	-	X	X	X	-	-	-	X	X	▨	X	-	7/16
Emergency plan	X	X	-	X	X	X	X	X	X	-	-	X	X	X	▨	-	11/16
Users' involvement	-	X	X	-	-	X	-	-	-	-	-	-	X	X	X	▨	7/16

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