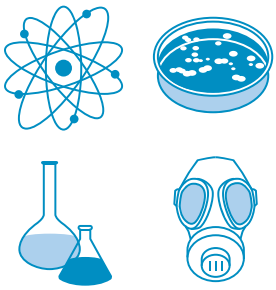

Collective Protection in Buildings

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The collective CBRE protection in buildings aims at the protection of persons in aboveground structures against the effects of chemical, biological, radiological and explosive substances (CBRE). Spiez Laboratory has been working out conceptual principles for the selection and evaluation of concrete protection measures to this end. The methodology was validated in practice, and in the case of four civilian buildings, Spiez Laboratory has undertaken the hazard and risk analyses. The methods for the evaluation of hazards and the assessment of risks can be applied successfully and result in practical recommendations for cost effective protective measures.

Underground protective structures offer good protection against the effects of weapons. When needed, they will be occupied as a precautionary measure. Incidents as well as attacks by terrorists or extremists however, most of the time take place with no or only short advance warning. In such cases, moving into emergency shelters is often not possible. As a complement to the classical shelter construction there is therefore a need for appropriate and practical concepts for collective protection of persons in aboveground buildings.

The National Risk Analysis of the Federal Office for Civil Protection FOCP covers the hazards and risks caused by NBC disasters as well as natural hazards at the national level. With regard to CBRE collective protection in buildings, the focus is on the specific analysis and evaluation of protective measures for a particular building (figure 1).

Hazard and risk analysis

To undertake hazard and risk analyses, reference scenarios are used that describe the possible CBRE hazards for persons in buildings. These scenarios are based on the *Hazard*

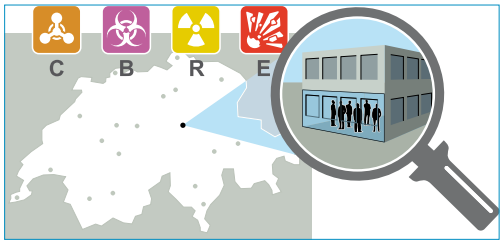


Figure 1: The focus of CBRE collective protection in buildings is on the individual assessment of buildings

Catalogue and the *Reference Scenarios CBRN* issued by the Federal Office of Civil Protection.

The hazards and risks for persons in buildings are determined based on these reference scenarios. The approach taken for the development of such object-specific and situational hazard and risk analyses is shown in figure 2.

The relevance of the reference scenarios is assessed using the object-specific *hazard analysis*. In case of scenarios assessed as not being relevant, no further analysis is required. Reference scenarios that have been assessed as relevant can be adapted with regard to the CBRE substances and their amounts considered. The plausibility and magnitude of the reference scenarios are assessed using object-specific *risk analysis*. Scenarios that lack plausibility can be discarded. The risks of possible incidents are situationally adapted by taking account of the structural characteristics, utilisation and operation of the building and the actual hazard potential present.

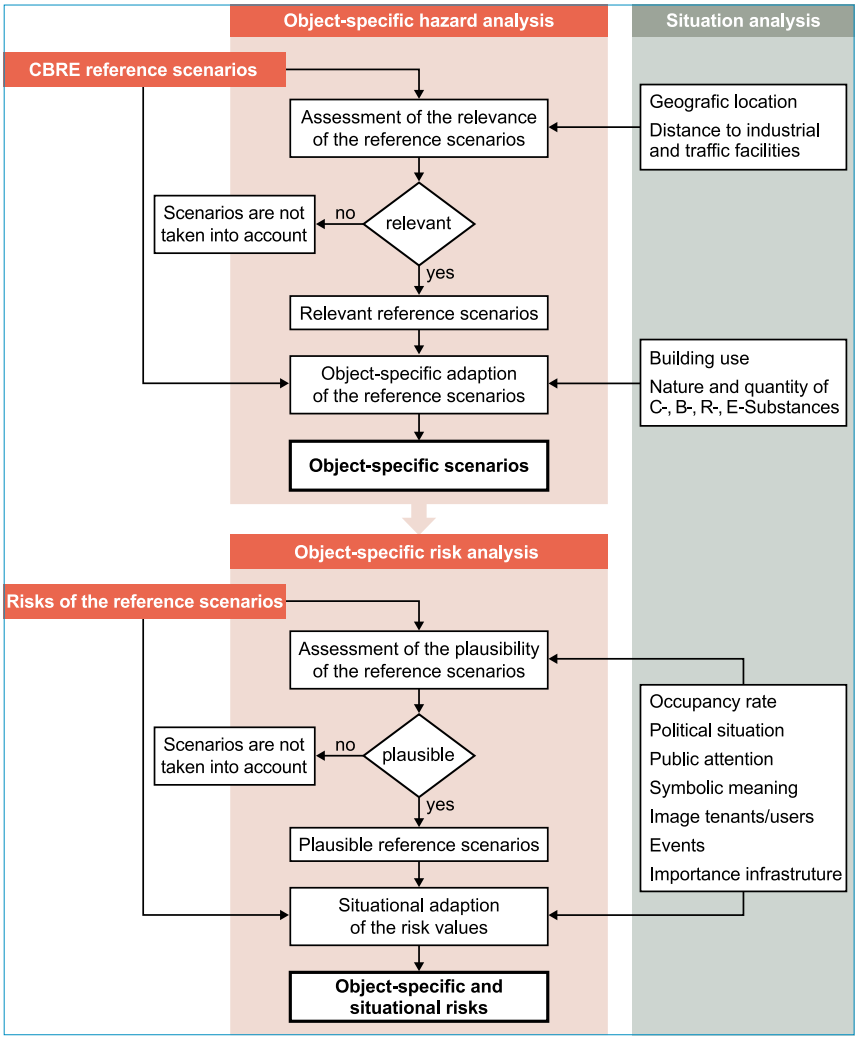


Figure 2: Approach to the object specific hazard and risk analysis

Risks of the reference scenarios

The risks considered in the reference scenarios are set out in the conceptual principles. They have been developed using the methodology that was developed by the Federal Office for Civil Protection in the framework of the National Risk Analysis. Because these CBRE risks are individual risks related to single buildings, they are much smaller for most scenarios than those associated with disasters and emergencies in Switzerland.

In contrast to statistically recorded accident events, scenarios that have a terrorism or extremism background can be described only with difficulty using frequentist statistics. Therefore, for such scenarios subjective probabilities and the related frequencies are estimated, from which is derived the plausibility of the occurrence of the scenario. For the qualitative risk estimation, six classes with regard to both plausibility and damage are defined, as shown in figure 3:
As a semi-quantitative support for the estimation of the *plausibility* of the scenarios, the probabilities are given for the occurrence of a scenario related to a building over a period of 20 years, as well as the corresponding return period of the scenario.
The estimation of the *damage* is done primarily based on the expected personal and financial damage. The estimation of the financial losses takes into account the damage to property, consequential losses and reputational damage, as well as losses due to business interruptions.

The representation of the risks in matrix format with plausibility and damage enables a visualised comparison of different risks. Figure 4 shows the risks of the CBRE reference scenarios.

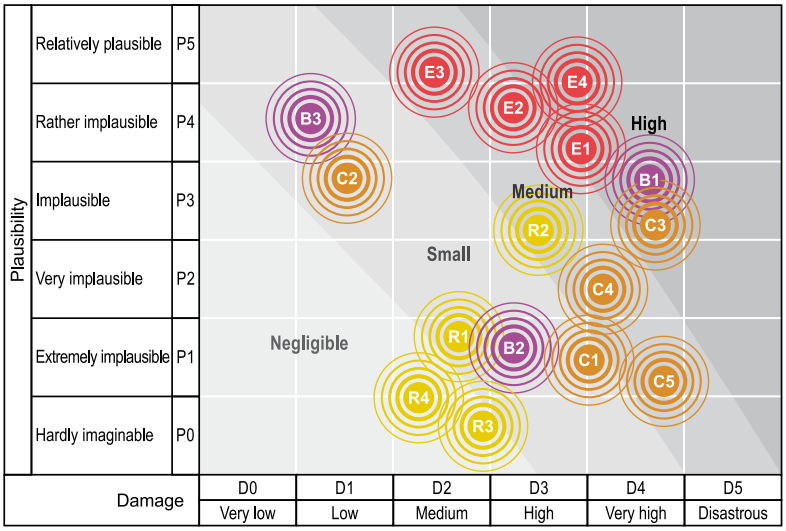
Protective measures

Figure 5 provides an overview of the protective measures that can be adopted for CBRE collective protection in buildings:
The *design and arrangement* of buildings relates to the most advantageous array of sensitive building elements such as ventilation

Plausibility		Likelihood of the scenario within 20 years		Return period of the scenario
P5	Relatively plausible	likely	≥ 10%	< 200 years
P4	Rather implausible	relatively likely	≈ 5%	200 - 1‘000 years
P3	Implausible	rather unlikely	≈ 1%	1‘000 - 5‘000 years
P2	Very implausible	unlikely	≈ 0.2%	5‘000 - 20‘000 years
P1	Extremely implausible	highly unlikely	≈ 0.05%	20‘000 - 100‘000 years
P0	Hardly imaginable	extremely unlikely	< 0.01%	> 100‘000 years

Damage		Personal damage	Monetary damages incl. consequential and reputational damages
D0	Very low	No personal damage	< 100‘000 CHF
D1	Low	1 - 20 Injured	100‘000 - 750‘000 CHF
D2	Medium	1 Fatality / 10 - 50 Injured	750‘000 - 5 Mio CHF
D3	High	2 - 9 Fatalities / ≈ 100 Injured	5 Mio - 50 Mio CHF
D4	Very high	10 - 50 Fatalities / ≈ 500 Injured	50 Mio - 500 Mio CHF
D5	Disastrous	> 50 Fatalities / > 500 Injured	> 500 Mio CHF

Figure 3: Plausibility and damage classes of CBRE scenarios



C-Scenarios
C1 Attack/Accident on transport with toxics
C2 Accident in a chemical plant
C3 Attack with toxic chemical (TIC)
C4 Attack with chemical warfare agent (CWA)
C5 Chemical weapon attack to a city

B-Scenarios
B1 Attack with biological toxin
B2 Attack with pathogen virus
B3 Attack with anthrax

R-Scenarios
R1 Accident in a nuclear power plant
R2 Radiological attack (“dirty bomb“)
R3 Use of nuclear weapons near the border
R4 Attack on a transport

E-Scenarios
E1 Attack with VBIED
E2 Attack with PBIED
E3 Arson attack
E4 Attack with small arms

Figure 4: Risks of the CBRE reference scenarios

openings, the creation of stand-off distances or the construction of shelters.
With regard to the *building services*, hazards caused by toxic gases, aerosols and ionising radiation are relevant. Important in this context are the detection of hazardous substances, the processing of the detector signals and the use of filtering systems.
Security measures are technical/organisational measures such as controls, surveillance and guarding which prevent an incident. *Safety* measures include measures that reduce the impact of an incident. They include alert systems, evacuation as well as fire protection.
Construction measures include amongst others perimeter protection. By limiting access to a building, incidents can be prevented. With a sufficient distance between perimeter and building, the effects of an incident (e.g. the impact of explosions) can be reduced. Construction measures and hardening that improve the robustness of buildings or structural building elements are typical examples for construction measures that reduce the consequences of incidents.

Cost effective planning of measures
The conceptual principles of CBRE collective protection in buildings describe a risk-oriented approach for the assessment of protective measures that is based on marginal costs.
In this approach, the expenses required for the measures are contrasted with their effectiveness. The relation between costs of the measures and achievable risk reduction quantifies their efficiency. For cost effective measures, the expenses for the protective measures are less than the costs incurred by the risks.

Protective measures reduce risks, which is associated with decreasing risk costs. An increased expenditure for protective measures does however lead to increases safety costs. Expenses for protective measures are at an optimum when the total costs of safety costs and risk costs are minimal (figure 6).

Validation of the conceptual principles
The applicability of the principals for collective CBRE protection in buildings were validated in practice by Spiez Laboratory. To this end, the object-specific CBRE hazards and risks were evaluated for four different buildings and facilities. The buildings selected for this validation project differed profoundly with regard to size, geographical location, utilization and occupancy rate. The methods for hazard and risk analysis as well as the evaluation of the protective measures were applied to an office building, a bus depot of a public transport enterprise of a city, the datacentre of a bank, and

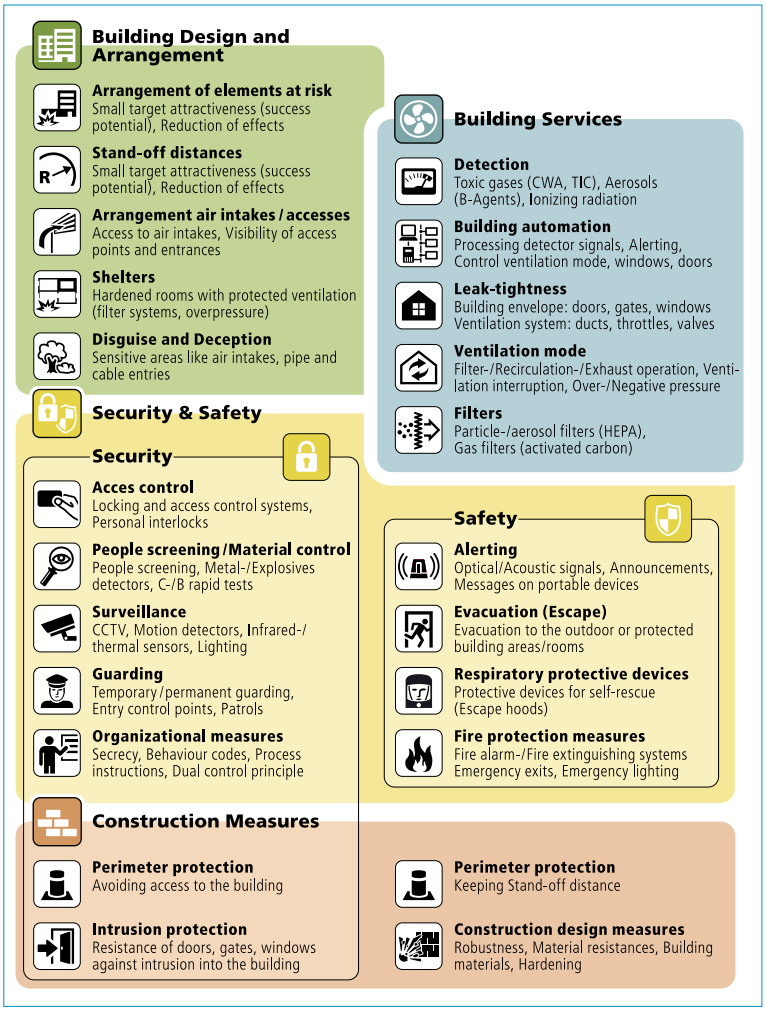


Figure 5: Technical areas and protective measures

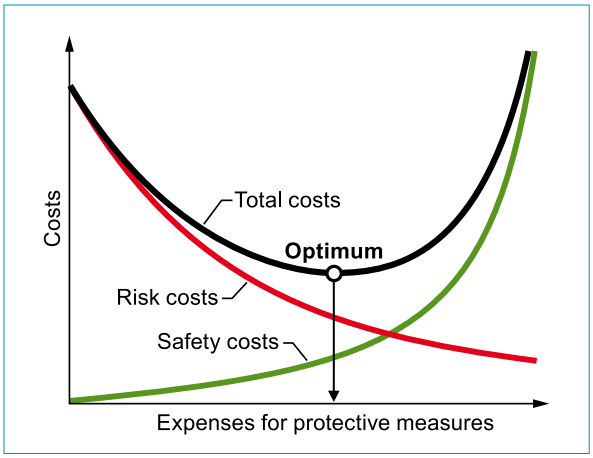


Figure 6: Optimum expenses for protective measures at minimum total cost (schematic)

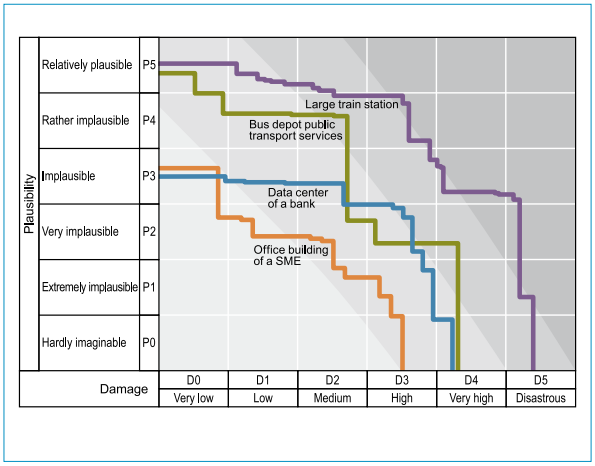


Figure 7: Risk profiles (cumulative curves) of the objects studied in the validation project

a large railway station. The analyses were conducted with the help of specialists who contributed their particular competencies to the resolution of the different problems. Stakeholders who were familiar with the building, security experts and facility managers as well as external risk experts and CBRE specialists participated in the expert groups (Delphi survey).

The results of the four risk analyses are shown in figure 7, in a comparative manner. As is common in safety engineering, the risk profiles of the buildings are shown as so-called cumulative curves. A comparison of the risks shows that the highest risks are present at the railway station whilst the lowest ones are found for the office building. The comparatively large risks at the railway station result from the large public exposure as well as the general vulnerabilities related to the operation of a railway station. For all buildings, the E scenarios (attacks with explosives or small arms) contribute the largest share of the overall risk whilst the risk contribution of C scenarios is generally small. The risks associated with an attack using a radiological bomb ("dirty bomb") are significant for the railway station as well as the bus depot. The analysis of the datacentre yielded small risks because security and safety measures are already implemented and because the bank operates a redundant datacentre.

The validation of the conceptual principles for the CBRE collective protection in buildings was able to demonstrate that the methodology for the conduct of hazard and risk analyses can be used for very different objects and, consequently, that the evaluation of cost effective protection measures is possible.