Analysis of Fire Scenarios in Order to Ascertain an Acceptable Safety Level in Multi-Functional Buildings

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ABSTRACT

The construction of multifunctional buildings has increased over the last years as well as the threat level considering antagonistic events. This presents challenges for the fire safety in these types of buildings since the protection objectives needs to be more focused on the functions the buildings are providing. Further the antagonistic exposures might present more challenging fire scenarios. A structured method how to determine fire scenarios in order to ascertain an acceptable safety level in multifunctional buildings has been developed and is based on the SFPE Engineering guides *Fire Risk Assessment* and *Performance-Based Fire Protection*. The method provides guidance on how to determine assets worth to preserve, protection objectives, exposures and finally the fire scenarios for multifunctional buildings. Previous accidents and events are discussed and serve as a background to the additional considerations needed for multifunctional buildings (compared to general buildings) and related to antagonistic exposures when determining fire scenarios. This article is a part of the project SAFE Multibygg that focuses on a methodology to identify fire risks with respect to antagonistic attacks in multifunctional buildings and to define fire safety solutions.

INTRODUCTION

Over time buildings in different parts of the world have become more multifunctional. These buildings are characterized by the multiple functions within the facility. Frankfurt airport e.g. hosts air, bus and train traffic; Scandinavium in Gothenburg hosts event arena and restaurants. The buildings are often associated with a large number of visitors and functions are often important to society, contributing to the overall complexity, vulnerability and potentially unacceptable consequences to society should an accident occur. An accident in such a building can result in large consequences due to death, property damage and impaired functions essential to society or a business/operation.

In addition since these types of buildings quite often host large numbers of people and critical functions they are more likely to be selected targets for an antagonistic attack since the attack is likely to inflict significant emotional and/or economic damage [1]. There are a number of examples where attacks have occurred in such buildings, e.g. the subway fire in Korea 2003 [2], the riots in Denmark 2008 [3] and France 2005 [4] all involving arson fires, the underground explosion in the UK 2005 [5] and the gas attack on the subway in Japan 1995 [6].

Multifunctional buildings are often large and it is difficult for visitors to get an overview of the building. Visitors are generally unfamiliar with the environment and/or evacuation routes and there might also be a variety of people e.g. children and disabled. All of this complicates evacuation. The ability to safely evacuate a building is also dependent upon smoke and fire spread and the ability to maintain structural integrity throughout a fire. Therefore the ability of the structural frame to withstand the experienced impact and the complex way smoke may spread in multifunctional buildings will need to be considered in the light that the building at the same time needs to be safely evacuated.

Traditionally, building codes in many countries such as Sweden focuses on life safety [7] due to accidental fire events and limited consideration is given to property protection and continuity of functions. When including protection of functions as well as antagonistic threats the potential fire scenarios could be considerably different from those generally designed for. However, depending on the severity of an antagonistic attack, a building designed according to code might be adequately protected against such a fire, this depends on e.g. location and magnitude of the fire. Fire and smoke spread in complex buildings presents challenges since many different operations result in multiple protection systems that need to function together hence increasing probability of failure. Methods have been developed to analyze smoke spread within a building as an isolated problem [8] and at the same time fire safety design using different risk analysis methods have been developed [9]. However, the rapid development and complexity of these buildings, together with an increased threat and a large variety of possible scenarios create a demand for analyzing the safety level from a holistic perspective in order to determine if an acceptable safety level for both life and functions is achieved. It is therefore important that carefully chosen fire scenarios addressing the complexity are analyzed and there is a need for a structured method to develop scenarios.

DEVELOPMENT OF FIRE SCENARIOS FOR MULTIFUNCTIONAL BUILDINGS

The overall process to determine fire scenarios is illustrated in figure 1 and is a modification of the process given in the SFPE Engineering Guide *Fire Risk Assessment* [10].

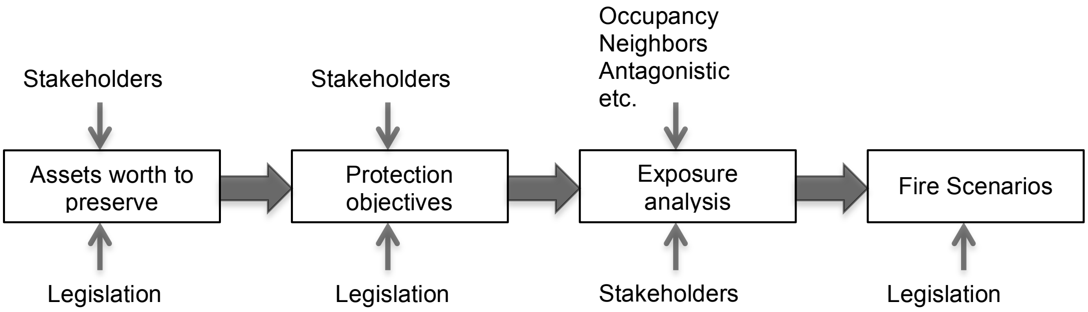

Figure 1. *Overall process for development of fire scenarios in multifunctional buildings.*

Due to the complexity of multifunctional buildings as described above performance-based design (PBD) for fire safety is necessary. The National Board of Housing, Building and Planning (Boverket) in Sweden has recognized this by demanding the fire safety be verified with PBD for buildings in large need of protection [11]. In many cases multifunctional buildings have this need due to high occupant density and a variety of functions. The need for PBD is governed by the complexity of the evacuation situation and the consequence in case of collapse [11]. This approach implies that the Swedish code mostly considers life safety and only to some degree property protection since it is only considering the worst credible property damage consequence of a fire event, i.e. collapse, this focus is also recognized by e.g. Klason et al [7]. The approach to mainly focus on life safety does not capture the entire complexity of safety in multifunctional buildings, not even from a societal perspective, since the loss of a building with important societal functions might cause unacceptable disturbances in the society. In addition these are more prone to antagonistic attacks than general buildings [1]. These types of events have generally not been considered by building codes [12] or other authorities and it might be necessary to consider these threats.

Assets Worth to Preserve

The first step in the process of determining fire scenarios is to determine what should be protected, i.e. assets worth to preserve. An asset is a resource of value requiring protection [1] and this can be humans, facilities, the building itself, operations etc.. For the purpose of this method assets have been divided into five categories:

1. Functions:
   a. Functions important to society
   b. Support systems (e.g. electricity)
   c. Continuity of operations
   d. …
2. Life safety
3. Property
4. Environmental protection
5. Safety and protection sys. (e.g. fire pump)

The nature of multifunctional buildings is to host several functions, it might be a train station, restaurants and other public occupancies. However there might also be functions within such a building that are not readily visible, but a fire could result in loss of this function, which in turn could affect business or society. Examples of such functions are electrical systems, computer servers etc. where even a small fire could result in large consequences. Such fires are generally not considered by codes only focusing on safety of life, due to fire location.

People are naturally one of the assets worth to preserve. A fire by an accidental event such as an electrical fault or other "natural" cause should already have been part of traditional design. However if considering antagonistic threats such as arson or explosions the fire development might be considerably faster than that of a natural cause [13] and this might need to be considered.

Property includes the facility as well as its contents [10], it should also be noted that the loss of property might also cause interruption to important functions, as can environmental issues. A fire, due to contamination from smoke, water etc. might affect the environment, hence the authorities might forbid operation until environmental issues have been resolved.

The safety of the building is depending upon the protection systems provided within the building. If the systems fail in case of an accident the damages will most likely increase. When considering antagonistic attacks the integrity of protection systems become more important since the initiating event might impair the systems. An explosion damaging sprinkler pipes might render the system ineffective. During the bombing of the World Trade Center in 1993 the smoke management system and emergency lighting was damaged by the initiating event causing extensive smoke spread which aggravated evacuation [14].

Multifunctional buildings often have many different owners and businesses, hence many different functions might be important. In order to be able to determine the full scope of assets needing protection all stakeholders need to be involved during the design/evaluation of a building. Brown suggests a two-step method to ascertain that all assets are captured [1]. Step 1 is to define and understand the building's core functions and step 2 is to identify the building infrastructure. In this way, vulnerabilities are identified and focus is put on what a building does, how this is achieved and how various threats can affect the building [1]. The information needed to determine all assets needing protection might be comprehensive and so also the amount of people needed to provide input. It should be noted that the corporate of tenants, owners etc. should also be consulted if the interdependencies between functions demands it to get a full view of the exposure. The following stakeholders, obtained from [1] and [10], might need to be consulted (there might be more than the ones listed below):

- Building owner
- Tenants
- Facility staff
- Occupants
- Neighbors
- National Intelligence Service
- Municipality
- Regulators
- Police
- Designer
- Risk Manager
- Insurer
- Fire Brigade

Multifunctional buildings hosting functions important to society is of special interest since interruption to functions might have big implications on society's functionality. The Swedish Civil Contingencies Agency (MSB) has defined a function essential to society as having the following attribute: *loss or disturbance of the function would imply large risk or danger for life and health, the functionality of the society or its fundamental values* [15]. The agency lists some sectors where these functions might be present, e.g. energy supply, hospitals, transport and communication sector among others. From the broad examples of sectors it is implied that such functions could be located within many types of buildings. It is therefore not possible to list all types of buildings that need to be analyzed. If the building needs to be analyzed or not must be determined on a case-by-case basis.

Protection Objectives

Protection objectives need to be developed for the assets worth to preserve. The protection objectives will vary depending on the asset and some might be governed by legislation. Damage criteria for the asset need to be developed, and coupled to the protection objective, in order to quantify the exposure level causing the protection objective to be exceeded.

The protection objectives (e.g. no deaths) and associated damage criteria (e.g. loss of visibility) for life safety in case of fire is generally determined by legislation, see e.g. [11] and [16]. Depending on the scenario different protection objectives and damage criteria might be needed, e.g. in case of explosion an acceptable level of elevated pressures might be needed. Protection objectives may also be expressed as acceptable individual or societal risk.

Property damage objectives might be expressed as acceptable monetary value of loss or as an acceptable damage area. Environmental objectives are typically defined in terms of contamination of a medium [10]. Both damage to property and the environment might be associated with business interruption. However it is recommended that the cost of business interruption associated with a scenario is included when analyzing the function assets. This since property or the environment might not have been determined an asset worth to preserve.

The safety and protection systems are used to protect the assets from an event and naturally they need to be protected against the event. The protection objective for fire safety systems should be that there should be no damage to them due to an event requiring them.

Loss of functions is often associated with interruption to services, e.g. a business or important societal function. It is essential to determine how the facility fits into the "big picture", i.e. how critical the facility is to the organization's operation, after that protection objectives can be established [10]. One suitable way of establishing the objectives is to conduct a business impact analysis (BIA), often done for IT systems [17]. A BIA identifies a system's critical resources and each resource is then further examined to determine how long functionality of the resource could be withheld before an unacceptable impact is experienced [17]. The time identified is maximum allowable outage (MAO) and the balancing point between MAO and the cost for recovery establishes the Recovery Time Objective (RTO). This method can be applied to multifunctional buildings as well by establishing the impact on a function if loss occurs of a component. Recovery strategies together with protection should then result in a downtime less than the RTO. It might also be beneficial to include loss of customers due to prolonged downtime in this analysis. Damage criteria depend on the support systems or resources required to maintain the functions and could include equipment, personnel etc.

Exposure Analysis

The next step is to determine what hazards/threats could pose a risk that protection objectives specified for the assets are not met, i.e. to conduct an exposure analysis. Sometimes called hazard identification [10], the purpose of the exposure analysis is to support the development of scenarios. SFPE [10] defines a hazard as a condition or physical situation with a potential to cause harm. A physical hazard might be flammable liquids or combustibles, but if a hazard relates to a person or group it will normally be defined in terms of state of knowledge, attitude or belief that is characterized as human action within an event. For the purpose of this paper exposures are divided into two types of exposures, *accidental or natural* and *antagonistic*.

Examples of accidental or natural exposures may be an occupancy containing combustibles that are ignited by an electrical fault or hot work. These hazards are generally considered within the design process of a building, but as stated above the main asset considered is most often life safety. For multifunctional buildings a larger focus is needed on functions provided, which follows from the determined assets. For the accidental or natural exposures the method for hazard identification in the SFPE Engineering Guide *Fire Risk Assessment* has been adapted and a more detailed description can be found in [10]. When considering multifunctional buildings it is essential not to overlook any hazards/exposures to the determined assets. Some assets might be very sensitive to fire and even exposures generally thought to be minor might cause large consequences in terms of property damage or interruption to the function, e.g. equipment in a computer server room upon which all business rely.

Antagonistic attacks have become more apparent during the last years. The attack on WTC and the London bombings are events with large consequences. In December 2010 there was an unsuccessful suicide bomb attack in Stockholm Sweden. If the bomb would have exploded in the nearby shopping mall and caused a fire the consequences would however been much larger. All these examples are large-scale attacks that might be hard to protect against but there are also other antagonistic exposures of smaller scale, such as arson fires, but with large consequences. Examples are the Gothenburg fire 1998 where 63 persons died [18] another is the subway fire in Korea 2003 where 192 persons died [2], both these events started with antagonistic attacks, namely arson fires. An important factor here is to determine if all possible exposures, even the worst cases, should be included in design.

What should be designed for and what is an acceptable level of risk is a difficult question. However, Det Norske Veritas has suggested risk criteria for individual risk between 10^{-5} and 10^{-7} and between 10^{-4} and 10^{-6} per year for N=1 for societal risk [19]. Stewart suggests that the probability for a terror attack on a US commercial building is between 10^{-6} and 10^{-7} [20]. Since the acceptable criteria and determined frequencies are of the same order of magnitude antagonistic attacks might need to be taken into account. This conclusion is also based on the fact that multifunctional buildings might be more prone to experience an antagonistic attack. Another issue reinforcing the need to analyze antagonistic threats is the long-term effect of such an event on society. As an example Rubin et al concluded that the population reduced their use of public transportation system in the London area 8 months after the London bombings in 2005 by 19% [21] and Handley et al conclude that 45% of persons directly affected by the bombings reported disabling travel anxiety that had interfered with their everyday life [5]. Further Thompson and Bank discuss that since the terrorist attacks of 2001 in the US the anxiety level and the perceived risk of occupants of buildings have increased and that the perceived risks are not necessarily limited to terrorist attacks but could also be e.g. catastrophic fires [22].

Richards suggests that around 15% of all fires in New Zealand are deliberately lit and in crowd buildings (retail shopping, cinemas etc.) the number is as high as 40% [13]. Hall concludes that 6% of all fires in structures in the US are intentional fires [23]. The statistics show that a large percentage of fires is intentional indicating that, at least where consequences might be large such as in multifunctional buildings, these events should be considered.

Brown and Lowe give a broad list of antagonistic threats that should be considered and the fire related threats are explosions and arson/incendiary fire [1]. Explosions are divided into subcategories: vehicle, mail, thrown or placed explosives and for arson/incendiary fires the extent of damage is depending upon the accelerant and quantity. Thompson and Bank suggest terrorism-related hazards for buildings and of importance to consider especially regarding fire are arson, fire as a secondary effect to a blast, attacks on load-bearing members, attacks on fire suppression systems and attacks against staircases, elevators etc. that slow down evacuation [22]. These become important for multifunctional building due to a large amount of people and the importance of support systems to the functions. A well-informed attacker might know exactly where to place a fire or how to bypass fire suppression systems. This indicates the interaction between safety and security, i.e. if a car cannot enter the building the amount of explosives or accelerants that can be brought into the building might be limited and the exposure less severe. The difference between the terms safety and security is not clear and there are a lot of different attempts for definitions, see e.g. [24, 25]. The meaning for the purpose of this paper is found in the beginning of the paper.

Table 1. *Key points for antagonistic exposure analysis, modified from [1].*

Step	**Examples of things to consider**
Existence	Who is hostile to the assets, organization etc. and might they be present at the location?
Capability	What methods, material, means etc. do the aggressors have? Is the material available at the building or do they need to bring it?
History	What has the aggressors done in the past? Where have they done it? Is there any history of such events in the area?
Intention	What do the aggressor hope to achieve? (vandalism, political, excitement etc.)
Threats	Explosion, arson, electrical supply, fire protection systems etc.
Security	Surveillance, access limitation, site perimeter, lighting, security personnel etc.

Brown and Lowe state that terrorism attacks are conducted because the aggressors seek publicity for their cause, monetary gain or political gain through their actions [1]. Richards lists reasons for arson as vandalism, excitement, revenge, crime concealment, profit and extremist beliefs [13]. To determine the exposure to a specific building input from different stakeholders are needed. Tenants and owners might know if they have experienced attacks before, the police or fire department may have information on vandalism in the area etc. Brown and Lowe state the significance of understanding who the people are that want to cause harm, their means and resources [1]. However, the matter of what incidents should be protected against is a difficult question, especially when considering low probability high consequence events such as a large-scale terrorist attack, i.e. extreme events. Extreme events for a building are any incidents that exceed the design level event and are therefore beyond the design objectives [26]. For antagonistic threats, extreme events are clearly possible. However, the more secure the building is and the better designed it is to resist an antagonistic threat, not only will the damage probably be less severe but the building is also less likely to be picked as a target [1]. Table 1 presents steps to go through to determine antagonistic exposures and is based on the method by Brown and Lowe [1]. It should be noted that the process is somewhat iterative. Sometimes you might e.g. start with the aggressor and its capabilities, sometimes with possible scenarios and then determine who has that capability.

Fire Scenarios

Credible fire scenarios are developed based on the exposure analysis with the assets worth to preserve in mind so that the fire scenarios challenge the protection objectives, see figure 1. At this stage the description of the fire scenarios are still qualitative and the development of a fire scenario is described with qualitative characteristics, e.g. initial heat source, fire spread to secondary rooms etc. [10]. The amount of possible fire scenarios is probably unmanageable and the scenarios need to be merged into clusters [10]. From each cluster, design or trial fire scenarios are chosen, these should be representative for all the fires in the cluster in terms of challenging the protection objectives. The term design fire scenario is used when designing a new building and trial fire scenario is used when analyzing an existing building. Once the design/trial fire scenarios have been chosen they need further specification, e.g. heat release rate. The general approach for quantifying this scenario is given in figure 2. The process is based on the working method presented by Staffansson [27] and the SFPE Guide [28]. Factors affecting the scenario need to be defined and should at least include building, occupants and fire characteristics [28]. The characterization (determination of heat release rate, evacuation etc.) of the design/trial fire scenarios for a multifunctional building in general follows the regular process as described in e.g. [28, 10, 27]. The remainder of this section will discuss specifics for multifunctional buildings and considerations regarding antagonistic threats.

Importance of availability and reliability of fire safety systems

The first step of quantifying a design/trial fire scenario is to determine the worst credible consequence. For this purpose the scenario is evaluated assuming all active protection systems are impaired. This provides an indication to how important active fire protection systems are and if they are needed to meet the protection objectives. If active fire protection systems are needed to meet the objectives an availability and reliability analysis should be conducted [28] to ascertain functionality in case of fire. It might also be necessary to study failure of individual systems depending on the criticality of each system. All protection objectives should be evaluated and for property this event could be compared to what is often referred to as Estimated Maximum Loss (EML).

Impairment of fire safety systems due to the event

The initiating event has a large impact on the subsequent development of the fire scenario. Of special importance is if the initiating event is impairing passive or active fire systems and how that affects the scenario development. The airplanes crashing into the WTC immediately affected several fire compartments, damaged the fire protection of the steel structure and damaged sprinkler piping rendering the system ineffective. The explosion in WTC in 1993 caused a power failure damaging both primary and back-up sources leading to failure of smoke management and emergency lighting with a large amount of casualties as a result from the fire following [14]. The fire in Gothenburg 1998, where an arson fire was started in a stairway led to a fast developing fire, blocking one out of two emergency exits with 63 casualties [18]. In this case a failure of human protection system or human factor plays an important role but even an attacker can place the fire load in the evacuation route with similar consequences. Another issue associated with antagonistic threats is the degree of planning of an attack; it may include bypassing fire protection [13]. The examples are all associated with antagonistic threats and when such a threat is identified in the exposure analysis special attention to the impairment of systems is needed. However even natural or accidental exposures might cause impairment to the systems, e.g. an explosion in a flammable liquid mixing room bringing down a fire rated wall or sprinkler main. If the protection systems are essential to meeting the protection objectives means to improve the availability and reliability and protection of the systems against the scenario (e.g. isolation of the fire pump, access control, redundancy) itself is necessary.

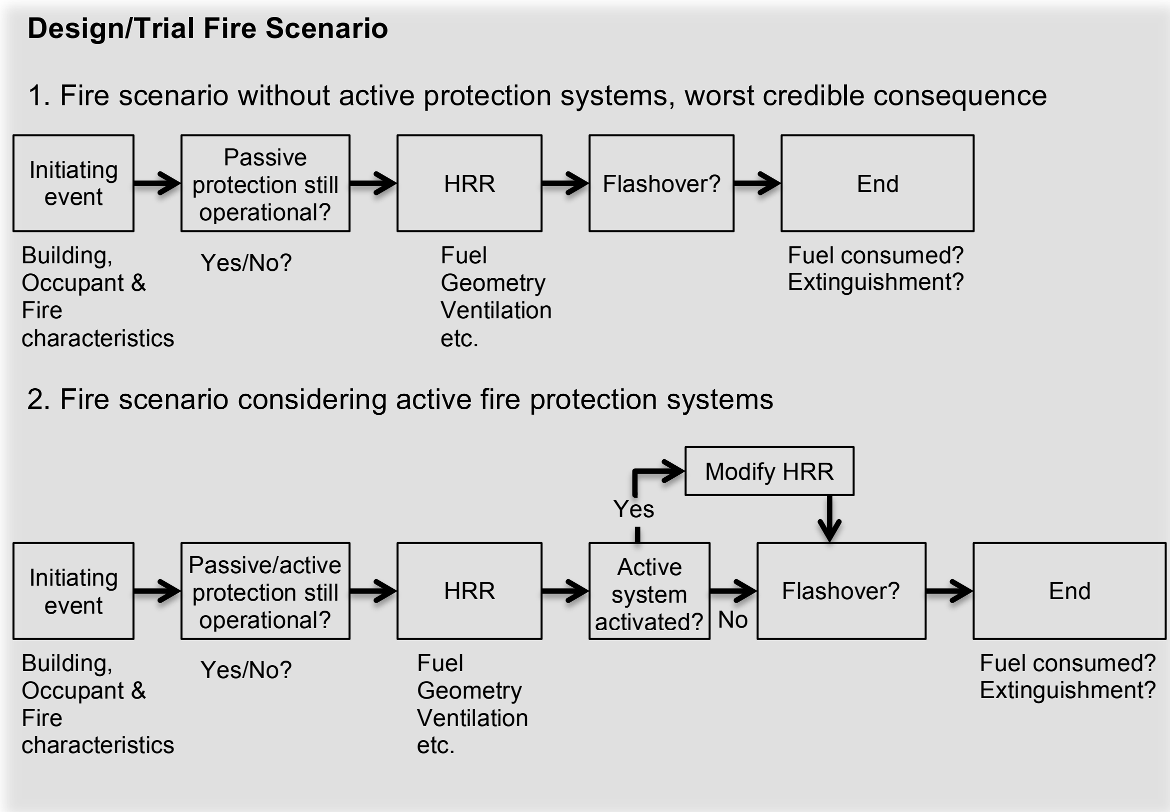

Figure 2. *General process for development of fire scenario.*

Effectiveness of fire suppression system

If the fire safety systems are not impaired due to the event, or for some other reason, there is still the question whether they effectively will control or protect against the event. How different active systems affect the fire development in a building with an occupancy it is designed for and with a general fire initiation can be found in e.g. [29, 30, 16, 31]. However the effectiveness needs to be determined against the stated protection objectives and the anticipated fire hazard the system was designed for. If the fire hazard for some reason is higher than what was designed for or if the protection objective concerns e.g. contamination, then the suppression system might be ineffective. A fire in an electrical room e.g. might be adequately controlled by a sprinkler system to not spread further within the building but the protection objective for functional performance of e.g. a computer system might be exceeded due to interruption for a prolonged time. One example where the fire protection system might be overwhelmed and rendered ineffective is the initiation of multiple fires, i.e. multiple fires started at different locations within the same building within a short time period [13]. Richards also discusses that multiple fires might block evacuation routes, overwhelm smoke management and sprinkler systems and might reduce the time to flashover [13].

One problem for multifunctional buildings is the many tenants and owners of the building, making it hard for every business to have knowledge about the fire safety systems installed and their capabilities. This might result in storage configuration or occupancy exceeding the design limits of the suppression systems. In addition there might be a high turnover of tenants and the occupancy might change considerably resulting in inadequate fire suppression systems. Another situation that might need to be considered is a fire involving flammable liquids. A fire deliberately lit in rack storage using accelerants might e.g. result in such a rapid fire growth that it overwhelms the suppression system. Another example might be the use of large amounts of flammable liquids causing a large burning area overtaxing the sprinkler system. This is of special importance when antagonistic exposures have been identified.

Fire size and location

In multifunctional buildings more protection objectives are needed to ascertain good protection for all assets worth to preserve including operation, property etc. than in general buildings. The fire location should reflect assets worth to preserve, protection objectives and exposure analysis. This means that fire locations that often are omitted due to small concerns for life safety might need consideration. A fire in a control room could e.g. be associated with lengthy interruption, even if the fire size is small and never spreads outside the room. Klason et al state that for school buildings, the code generally considers fires occurring inside a building and ignores external fires [32]. However, if an antagonistic exposure has been identified the likelihood of a fire occurring against e.g. the façade might be high, in New Zealand 8% of deliberately lit fires were started at the façade [13]. In a school in southern Sweden e.g. an incendiary fire started against the façade. No persons were injured but the fire impaired teaching functions, shopping facilities and a health care center [33]. When considering antagonistic threats security becomes important in order to limit the exposure. This goes not only for the site perimeter and external fires but also planned attacks with a specific target such as main components in a system, e.g. electrical or network distribution. Richards suggests e.g. that around 5% of deliberately lit fires in crowd buildings are started in support rooms [13].

In addition to the location, when considering antagonistic threats such as arson, the magnitude (growth rate, heat release rate etc.) of the fire might be larger than what usually designed for. In general buildings are not designed for incendiary fires [13] and the fire in the subway system in Korea [2] and the fire in Gothenburg [18] both enforces this. The fire in the subway system in Korea resulted in 192 casualties and this fire was started with only four liters of flammable liquids [2] as primary fire. Clearly the safety systems were not designed to handle fires like those and there may be many other reasons. Maybe the exposure was not foreseen, the code did not demand that such events should be designed for, the fire characteristics were poorly understood, routines were not followed etc. The Swedish building code today stipulates that a building hosting many people should be designed for a maximum heat release rate of 10 MW with a growth rate of 0.047 kW/s^2 [16]. If there is a sprinkler system that activates before the heat release rate reaches 5 MW the heat release rate is to be reduced and if above 5 MW the heat release rate is to be kept constant [16]. For antagonistic exposures these design fire curves might not be representative. Richards suggests e.g. that the peak heat release rate for a 1-liter Molotov cocktail is reached after around 12 s and the peak heat release rate is around 1 MW [13]. The growth rate could be compared to what is demanded for a crowd building in the Swedish code where 1 MW is reached after approximately 150 s. In addition the fire might be much larger when the sprinkler system activates later than what it was designed for. It is not easy to determine what scenarios are accounted for by the code since it depends on the fire development after the initiating event. If an antagonistic exposure has been identified it is likely that there are more severe fire scenarios than what is usually designed for. In a design phase these more severe fire scenarios need to be designed for and in an evaluation stage these severe scenarios need to be considered.

Load bearing members

Fire design of load bearing members is often prescriptive in terms of an hourly rating according to a standard fire curve see e.g. [34]. Often structural elements will not be affected until the later stage of the fire. It is therefore necessary to analyze the full time scale of the fire including the possibility of a post-flashover development. The effect of a collapsing building due to fire was witnessed in the attack on the twin towers 2001 and some literature suggests that the experienced fire scenario would have caused collapse even if the impact load by the airplanes was neglected [35, 36]. Structures are generally designed for one accidental load at a time, see e.g. [37]. However, a fire following an explosion cannot be ruled out, see e.g. [14] regarding the bombing of the WTC 1993. When considering antagonistic exposures such as explosion one possible event following might be fire and as such maybe two accidental loads should be considered. This however needs further investigation.

CONCLUSIONS

A first framework for development of fire scenarios for multifunctional buildings has been presented and the following conclusions reached:

- There is a need for a structured method for development of fire scenarios for multifunctional buildings considering protection of functions as well as antagonistic exposures, otherwise an acceptable safety level cannot be ascertained.
- Buildings with multiple functions have more assets worth to preserve than regular buildings resulting in more protection objectives and different exposures. Therefore additional and different fire scenarios than what is usually designed for need to be evaluated. Often location and severity of the fire differs.
- To be able to capture all assets input from a large variety of stakeholders is essential.
- Antagonistic threats cannot be ignored for multifunctional buildings and the exposure generally results in more severe fire scenarios needing further analysis.
- Antagonistic events pose a higher probability for domino effects, e.g. first an explosion and then a fire following, and failure of active or passive protection system.
- The methods presented in the SFPE engineering guides [10, 28] appear to be suitable for evaluating multifunctional buildings. However this need further validation.

DEFINITIONS

Multifunctional building: One or several connected buildings hosting several functions or occupancies (e.g. office, restaurant) where the facility and its functions is one integrated whole. The definition also includes underground facilities.

Antagonistic attack: Manmade attack, against a specific target to which the aggressor bear hostility, with the intention to cause harm as a consequence of the attack, e.g. terrorist attack such as an explosion or arson fire.

Security: Security is protection aimed towards limiting access such as perimeter fencing, CCTV, watch service, locking etc.

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