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APPROXIMATION OF THE TIME TO INITIATE THE EVACUATION OF PERSONS AT LARGE GROUP EVENTS IN OUTDOOR ENVIRONMENTS IN CASE OF A FIRE

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Review article

Abstract: One of the basic prerequisites for securing the safety of people at large group events is to ensure their evacuation in case of emergencies. This article deals with the approximations of time to initiate the evacuation of persons in case of a fire at large group events organized in outdoor spaces. The solution is based on the principles of determining the period to initiate the evacuation of persons in terms of international ISO standards. Considering the specificities of the given outdoor space and possible related security measures, the article recommends the relevant sufficient amount of time to initiate an evacuation.

Keywords: Evacuation, fire, meeting event, outdoor environment.

Introduction

Large group events are characterized by essential features and conditions that accompany their course (Wang, 2014). Incidents during these events are not common, but their consequences can be significant. Examples include the following events that have occurred during mass events in outdoor environments.

Incidents of extraordinary nature regularly occur during sporting events in stadiums. Some of these incidents are also associated with fires. One example is the fire that broke out in the main wooden seating area at Valley–Parade Stadium, which took place in May 1985 in Brandford, England. During this fire incident, 56 visitors were killed and 265 visitors were injured (Fletcher, 2015).

Another significant event that occurred in an outdoor environment is the disaster that happened in July 2010 at the Love Parade in Duisburg, Germany. On that tragic day, the event was attended by approximately 485 000 people. Due to panic caused by overcrowded streets, 21 people were killed more than 540 persons were injured. In subsequent years, at least 6 people committed suicide because of the prolonged emotional stress they suffered as a result (Helbing, 2011), (VFDB, 2010).

In terms of security when holding large group events in an outdoor environment, the primary viewpoint is to ensure *the safety of the participants* (material values are usually of minor importance). They safety of participants is directly related to the creation of appropriate conditions to ensure a possible evacuation.

This article aims to present one possible procedure for approximating the time to initiate the evacuation of people at large group events in an outdoor environment in case of a fire.

Materials and methods

The classification of large group events

Large group events can be distinguished by a number of aspects, e.g. in terms of their:

- Focus:
  - social,
  - sports,
  - educational, etc.
- Spatial (construction) arrangement:
  - indoor (a space limited by building structures along the perimeter and from above),
  - outdoor (a space not enclosed along the perimeter or from above, but defined by building structures, surrounding grounds or the natural environment).

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- Height:
  - determining the meeting space category according to its height placement within the building, e.g. according to ČSN 73 0831 (ČSN, 2011), respectively regulations dealing with assembly events (LAW, 1985).
- The number and density of the participants:
  - determining the meeting space category according to the number (density) of people, e.g. according to ČSN 73 0831 (ČSN, 2011), respectively regulations dealing with assembly events (LAW, 1985).
- Time course:
  - short-term (hours),
  - long-term (lasting for perhaps days).
- Accessibility:
  - public events (open to the public),
  - private events (i.e. events only for members).

The type of event fundamentally affects the evacuation of people in case of emergencies.

Threats to people at large group events

The basic risks affecting evacuees in case of a fire mainly include:

- The loss (decline) of visibility;
- The existence and influence of high temperatures;
- The influence of heat and heat flux;
- Exposure to toxic, irritant and asphyxiating substances;
- Reduction in oxygen concentration (Kučera, 2014).

When assessing the risk to persons, selected risks or all the risks are taken into account. The risks determine the time t_x, i.e. the time available for securing the evacuation of people.

Within meeting areas, described fire concomitants may lead to a Domino effect of additional risks. This primarily relates to the possible panic or blockage of evacuation flows due to very high concentrations of people (at a density greater than 3.8 persons per m^2) (Folwarczny, 2006).

In the case of outdoor meeting areas, however, there are factors that significantly mitigate the threats to persons during a fire. They primarily include high visibility (lucidity) in these areas and the ability to "easily remove and disperse" any accompanying phenomena. The risk of reducing the concentration of oxygen is practically meaningless. Risks described above usually endanger only people in close proximity to the source of a fire.

Time of evacuation

An evacuation can be considered safe if the *required safe escape time* t_c is less than or at most equal to the *available safe escape time* t_x, i.e. the time to reach critical conditions. Therefore, the following applies (Kučera, 2014):

$$t_c \leq t_x \quad (1)$$

The required safe escape time consists of the partial time intervals that are shown in Fig. 1.

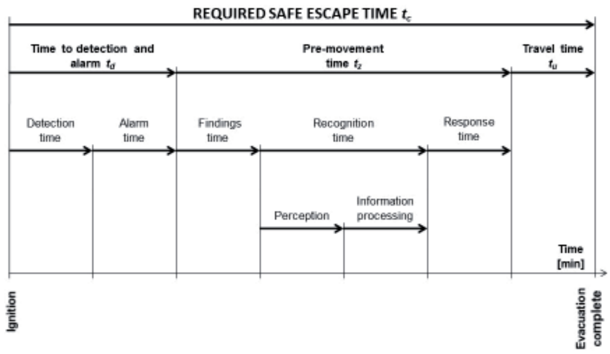

Fig. 1 The required safe escape time (Kučera, 2012)

The required safe escape time t_c consists of partial time intervals (Kučera, 2014), (DiNenno, 2008), (ISO, 2009), (ISO, 1999):

$$t_c = t_d + t_z + t_u \quad (2)$$

where t_c required safe escape time [minutes]; t_d time to detection and alarm [minutes]; t_z pre-movement time [minutes]; t_u travel time [minutes].

For a further description in this article, the time to initiate an evacuation is considered time t_{dz}, which includes the time required for detection and alarm and other steps needed to initiate the evacuation:

$$t_c = t_{dz} + t_u \quad (3)$$

where t_{dz} time to initiate the evacuation of persons including the time to detection and alarm and other steps needed to initiate the evacuation [minutes].

The available safe escape time t_x can be determined as the time to reach critical values of the risks affecting the evacuees (Kučera, 2014):

$$t_x < t_{kr} \quad (4)$$

where t_x available safe escape time [minutes]; t_{kr} time to reach critical values [minutes].

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Results

The method for determining the time to initiate the evacuation of persons

The range of approaches that can be taken to determine the time to initiate the evacuation of persons is substantial. The most common method is the principle described in literature (ISO, 1999), (HOSSER, 2009) that can be characterized as a "tabular classification method".

The reaction time, i.e. the time to initiate an evacuation, depends mainly on the following factors:

- Design behavioural scenarios and occupancy types (awake/sleeping/other factors affecting readiness), their knowledge of the building and density;
- Alarm system quality;
- Building complexity;
- Fire safety management (ISO, 1999), (HOSSER, 2009).

Factors affecting the time to initiate the evacuation of people are shown in Fig. 2.

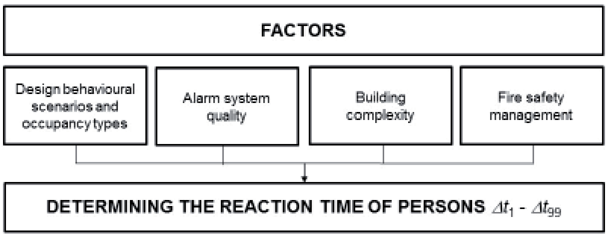

Fig. 2 Factors affecting the time to initiate an evacuation

Factors and their sub-parameters are shown in Fig. 3.

FACTORS	SUB-PARAMETERS
Design behavioural scenarios and occupancy types A, B, C(x), D, E	- awake / sleeping / other - familiar / unfamiliar (environment)/ with care (supervision, treatment) - low/high (density)
Alarm system quality A1, A2, A3	- fire detection system with an immediate alarm in the affected area (A1) - fire detection system with a delayed alarm in the affected area (A2) - no or only local fire detection (A3)
Building complexity B1, B2, B3	- simple, single-storey, rectangular (B1) - simple, several rooms (B2) - a large extensive building (B3)
Fire safety management M1, M2, M3	- familiarized users, support staff, training, independent examination (M1) - smaller proportion of trained staff, without an independent examination (M2) - security management meets relevant standards (M3)

Fig. 3 Factors and their sub-parameters affecting the time to initiate an evacuation

Individual factors create categories and subcategories of methods used to determine the time to initiate the evacuation of persons (see Tab. 1).

Tab. 1 Main categories of operations used to determine the time to initiate the evacuation of persons (PD, 2004), (HOSSER, 2009)

Main categories	Characteristics
Category A	awake and familiar
Category B	awake and unfamiliar
Category C(a)	sleeping and familiar
Category C(b)	residential facilities with care
Category C(c)	sleeping and unfamiliar
Category D	people in buildings with medical care
Category E	people in traffic (bus and railway stations, airport halls)

Factors for classifications into categories according Tab. 1 are discussed in Fig. 2 and 3.

The evacuation of the first persons is initiated soon after the setting off of a fire alarm. The beginning of the reaction time is considered the moment when 1 % of the persons begin to evacuate (Δt_1). The time interval from the initial reaction to the end of the reaction time indicates the state when 99 % of people are moving (Δt_{99}). Values between Δt_1 and $\Delta t_1 + \Delta t_{99}$ are chosen for individual reaction times (ISO, 1999), (HOSSER, 2009).

According to the described method, the time to initiate an evacuation ranges between 1.5 minutes and more than 40 minutes.

Although the described tabular classification method was derived for buildings (closed buildings) during fire events, we can also basically assume its general use for outdoor spaces.

Application of the tabular classification method, results

The described method was applied to *large group events in outdoor spaces*. The time to initiate the evacuation of persons was approximated for events of a general nature (cultural, sports, etc.). Specific conditions unique to particular events are not taken into account.

The principles for determining the time to initiate an evacuation are shown in Fig. 4.

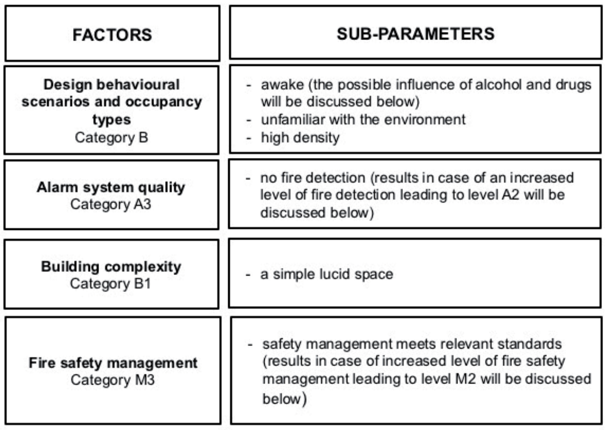

Fig. 4 Determining the time to initiate the evacuation of persons from outdoor meeting areas

The time to initiate the evacuation of persons from outdoor meeting areas can be determined using Tab. 2 (awake persons familiar with the environment).

Tab. 2 Reaction time for persons in category B (ISO, 1999), (HOSSER, 2009)

Scenarios (main categories and subcategories)	**Δt_1 [minutes]**	**Δt_{99} [minutes]**
Category B: awake and unfamiliar		
M1 B1 A1 – A2	0,5	2
M2 B1 A1 – A2	1	3
M3 B1 A1 – A3	> 15	> 15
B2: add 0.5 minutes to Δt_1 due to worse orientation		
B3: add 1 minute to Δt_1 due to worse orientation		

Based on the factors classifying outdoor meeting areas (B, A3, B1, M3; see Fig. 4) and reaction times for the given category (see Tab. 2), it is possible to determine the time to initiate evacuation Δt_1 > 15 minutes and Δt_{99} > 15 minutes. The total time to initiate the evacuation of persons exceeds 30 minutes.

Discussion

The determined time to initiate the evacuation of persons, longer than 30 minutes, is considerable. It is possible to expect that this time can be significantly reduced in some cases.

First, we will discuss the possible effects of the presented method leading to more favourable results and then the factors that are not included in this method primarily focusing on closed buildings.

To achieve more favourable results, it is necessary to improve the quality of the alarm system (moving from A3 to A2 category) and fire safety management (moving from category M3 to M2).

The *alarm system* includes the *time to detect the incident* and the *time required for warning people*. At events in an outdoor environment, the time to detect the incident can be influenced by increasing the number of people involved in fire supervision (e.g. organizers, fire prevention patrols). Supervising persons must be familiar with the environment, the nature of the event and safety conditions. It is difficult to assess the extent to which the persons providing supervision can replace electrical fire alarm systems. However, we can realistically assume that increasing the number of these trained persons will significantly reduce the time to detect an incident. For repeatedly (permanently) organized events, fire supervision can be supplemented by technical devices (e.g. cameras).

Subsequently, a properly designed acoustic solution for a given event (or other measures) can significantly reduce the time required for warning people. It is usually possible to use the principle of automatic or manual alarms accompanied by successive actions (e.g. shutdown of the current program, switching on the lights).

With the proper inclusion of the measures described, the quality of a alarm system can be classified as category A2.

Another issue discussed is *fire safety management*. To move to a more favourable category M2, persons should be familiar with the environment, should undergo training and should be supported during an evacuation by highly qualified and trained staff. Such conditions usually do not correspond to the actual situations of large group events in outdoor environments. Attendees of such events are not thoroughly familiar with the environment and do not undergo training focused on safety. In outdoor spaces, however, the possible exposure of persons to fire concomitants is significantly lower than in closed buildings for which the presented tabular classification was compiled (see the part labelled Threats to people at large group events).

Similarly to the alarm system, the quality of fire safety management can be improved by increasing the number of professionally trained persons involved in fire supervision or by other organizational measures.

With the proper incorporation of the measures described, fire safety management can be classified as category M2.

Given the fact that the described tabular classification method was primarily developed for closed buildings, it ignores the importance of the high lucidity of outdoor environments (especially during daylight hours) in combination with the human quality "to imitate the behaviour of others in case of emergency". It is likely that during the evacuation of some people, others will follow their example. The described effects will reduce the time to initiate an evacuation.

During the large group events, people sometimes consume alcoholic drinks and other intoxicating substances. Participants at these events may be somewhat indisposed. Despite these influences, however, such people cannot be assessed as persons "with limited mobility" or "incapable of independent movement". The discussion can also refer to the number of indisposed persons, which greatly depends on the nature of the event. Ailments caused by alcoholic beverages or other drugs are not further addressed in this article.

When incorporating the measures described and other measures taking into account the specifics of any given event, based on the above arguments, it is sometimes possible to adjust factors classifying outdoor meeting areas into B, A2, B1, M2, and the reaction time to initiate evacuation Δt_1 = 1 minute and Δt_{99} = 3 minutes (see Tab. 2 and Fig. 5). Under these conditions, the total time to initiate the evacuation of persons is 4 minutes.

FACTORS	SUB-PARAMETERS
Design behavioural scenarios and occupancy types Category B	- awake - unfamiliar with the environment - high density
Alarm system quality Category A2	- fire detection system replaced by persons providing fire supervision
Building complexity Category B1	- a simple lucid space
Fire safety management Category M2	- safety management replaced by persons providing fire supervision

Fig. 5 Determining the time to initiate the evacuation of persons from outdoor meeting areas when considering the measures discussed

Depending on the incorporation of appropriate organizational measures, the time to initiate the evacuation of persons within outdoor areas in case of a fire ranges from 4 to over 30 minutes. The range of specific measures is necessary to propose in relation to the character of the specific action. For specification measures may be useful also laws that deal with mentioned issues (e.g. LAW, 1985).

Conclusion

In terms of ensuring safety at events where several people gather, the evacuation of people is the primary issue. Such events are unquestionably accompanied by emergencies, including fire. The time to initiate the evacuation of people represents a significant portion of the total time of evacuation. In some cases, the time to initiate an evacuation may even exceed the actual time of required for the movement of people during the evacuation and thus becomes one of its most essential parts.

One basis for determining the time to initiate the evacuation of persons are the principles described by international ISO standards. However, those standards are intended for normal buildings, not for outdoor areas, and cannot take into account certain specific factors (positives) that outdoor areas provide in case of a fire. At the same time, it cannot be assumed that outdoor areas will be equipped in the same way as indoor spaces in terms of safety. The reason is obvious; it is not necessary. The principles laid down in ISO standards for indoor spaces must be adequately adjusted for outdoor spaces.

The outputs of this article present the time interval in which we can realistically expect the time to initiate the evacuation of persons at large group events in outdoor spaces in case of a fire, depending on the incorporated safety measures.

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