Optimisation of the Technical Building Evacuation through Adaptive Systems

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Abstract

Buildings are where people spend the most time in their lives. Add to this that the number of people in buildings at any given time is increasing to make the best economical use of the space provided. Further, the average population today is much more heterogenous as well as diverse in language and culture. And finally, the inclusion of people in our society; people with disabilities, sensory limitations, temporary or permanent mobility restrictions (injury, pregnancy), or otherwise vulnerable, means extra measures must be taken to protect all. In this paper, the concept of dynamic and adaptive escape routing will be presented and discussed. This concept focuses on achieving a technical solution for evacuation, that can finally adapt to the course of a hazardous event (e.g., fire). The objective to provide occupants with the best possible chance to leave the hazard zone in a fast, orderly, and stress-reduced manner. Technological developments have made such an approach today both available and affordable. This concept takes the two-sense principle into account. It means that for example a part of the population has sensory limitations in vision and/or sight. By providing emergency information and instructions through visual and acoustical means, such people have an increased chance to understand emergency instructions and initiate the respective measures towards self-rescue. An additional positive effect can be seen with people without limitations, when the same (collaborating) information is received through two channels.

Keywords: evacuation, adaptive, dynamic, two-sense, dynamic and adaptive escape routing

Introduction

The range of hazards that create requirements for the design of buildings is large. There are several factors that influence a building evacuation.

In case of danger (fire, amok, stop, etc.), all persons should be able to move to a safe area without any outside intervention [1].

Technical measures to support the evacuation of buildings are today mainly used for compensation when safety requirements cannot be met based on the building-specific conditions on the usual route. They can enable flexible design and help to avoid constraints (especially in the case of existing buildings) [2].

However, technology only achieves a high level of acceptance if it is economical. This requires applying case-specific, holistic concepts with a combination of structural, organisational, and technical measures being considered. Urbanisation in turn leads to ever larger and more complex building structures with many uninformed visitors, where these measures quickly reach their limits.

Technical measures can minimise the need to aid able people in the event of evacuation. The existing aid personnel can concentrate on those vulnerable groups of people who are less mobile, such as children, the elderly, the disabled and pregnant women.

Demographic trends show an increase the proportion of older people in our society. In addition, the number of overweight people is increasing [3]. In other words, mobility tends to decrease. However, relying on rescue by intervention forces (e.g., fire services) is a risk, because fire dynamics make the development of a fire unforeseeable. Hence it is not acceptable to wait until rescue arrives. Ensuring opportunities for sufficient self-rescue is therefore essential in all cases and is a top priority.

Early detection and warning are mandatory prerequisites for achieving protection of building occupants. Meeting protection objectives can be improved, by supporting the guidance of persons along escape routes that reduce the risk of disorientation and undesirable panic-like behaviour. The added value of the concept of dynamic and adaptive escape routing guidance results from the connection between different technical systems that react flexibly to the development of the danger situation.

A supporting factor is the inclusion of a two-sense principle, which addresses at least two human senses to warn and support the evacuation procedure. People who are impaired in terms of perception of environmental stimuli are often neglected, despite guidance as given by the Disability Equality Act in Europe ([4], cf. [5]). Limited perceptual capacity leads to delayed reaction and delayed self-rescue with serious consequences.

The needs of people with disabilities must be addressed when planning the evacuation. The two-sense principle also assists those without impairments.

Legal situation

Ensuring the self-rescue of building occupants in the event of danger (e.g., in the event of a fire, amok or terrorist attacks or other dangerous situations) is the primary protection objective for builders, building operators and planners. There is a legal obligation for builders or building operators to plan, build and operate their buildings in such a way that all persons in the building are unharmed in the event of any possible danger.

People must be able to leave the building as quickly as possible or escape to a safe area of the building as quickly as possible. The protection concepts, in particular the fire protection concept, must be defined and implemented in such a way that in general people can move to a safe area without assistance. The builder/operator may not base his planning on the assistance of external assistants in the rescue of his building users. The devastating Grenfell Tower fire has forced lawmakers to re-consider this approach in England.

As an example, to avoid liability in the event of damage, the German Federal Court of Justice has developed the principle based on engineering procedures, whereby the client or building operator must consider all objectively recognisable risks, and thereby take appropriate measures, (technically available and economically reasonable) to contain or, if possible, eliminate them ([2], [6] and [7]). This requires a risk-oriented approach to the planning and realisation of a building. “Objectively recognisable” is what a court-appointed expert in the proceedings for damages later presents to the court as “recognisable” at the relevant date, often years ago. The subjective considerations of the persons involved in the construction are not pertinent.

The requirement that liability also depends on the solutions available on the market introduces a dynamic element. What was technically impossible yesterday or could not be implemented at reasonable costs and therefore could not be legally demanded, is now economically feasible due to technological developments. This gives rise to a legal obligation to reconsider and realise the identifiable risks with a view to a technically possible and economically reasonable solution.

Each building operator must regularly check his/her site-related risk situation. The "right of continuance" (preservation of the status quo) is not grounds for exemption of liability. “Economic adequacy” is again a relative measure, which must be assessed in relation to the importance of the asset to be protected. However, when the protection of people's lives and health is at issue, case-law deems even high demands and efforts to be “still reasonable”.

For the fire protection planning of a building, this results in a legally concrete task and obligation, which is predetermined by the building supervision and recommended for the avoidance of liability. The client and the architects and specialist planners must plan a combination of structural, technical, and organisational measures in such a way that the protection objective of self-rescue (without any outside intervention) of occupants to a safe area is achieved.

General distinction between the components

A distinction must first be made between the individual components or technical products and systems used for escape routing guidance. Evacuation technologies can be grouped into either visual (also called optical) or acoustical.

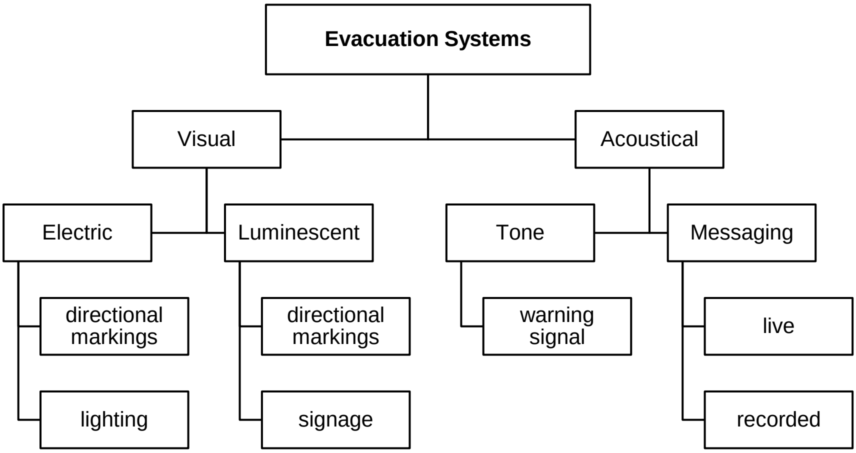

Fig. 1. Overview of products and systems for escape routing guidance.

Visual signalling for escape route guidance has been in use for decades in the event of a fire. In most cases, emergency lighting as well as emergency exit signs (often illuminated) are used, and they can display various escape routes/directions. But escape route indicators can also indicate closed routes by means of red crosses. In an event, the signalisation is activated, e.g., by a fire alarm system. The information received about the danger is evaluated and on this basis escape routes are specified, and the escape directions are indicated.

Acoustic signals have also been in use for decades to notify of hazardous situations. The most common devices are bells (almost out of use today), sirens, horns, and sounders that are attached to the fire detector. In Europe, the use of voice alarm systems is increasing; a praxis long applied in countries such as Canada, United States and Great Britain. They have significant advantages over classical devices such as horns or bells because they provide building occupants with clear instructions on what they must or must not do. This shortens the reaction time and thus the necessary evacuation time – especially in buildings with uninformed visitors [8]. The use of voice alarm systems allows the broadcasting of situational and targeted instructions for escape route direction, closing windows, or avoiding certain areas of the building just to mention a few examples (cf. [9] and [10]).

Concepts for escape routing guidance

There are different types of escape routing management that depend on the concepts and the components used.

First, there are ***passive signalling or signage***, which are installed in the building and indicate the escape and rescue routes. They are always in the same status, regardless of the existence of a hazard. Examples of this are signs, illuminated or backlit escape routing markings in continuous operation.

In the case of ***active escape routing guidance***, the components are activated (turned on) in the event of a request, such as emergency lighting or the broadcasting of a pre-recorded announcement. The direction indicator of an exit sign is not variable. Such products make it possible to react to a hazardous situation, but they do not allow any changes in the information they display during activation.

The ***dynamic escape routing guidance*** offers the possibility of a one-time selection in direction and instruction. The information provided on the danger situation, triggers this selection. This can guide people to the shortest possible way out of the danger zone and to a safe are via the remaining escape routes. All elements for escape route guidance, adapt only once to the danger situation at the beginning of the evacuation and maintain their condition until deactivated.

Adaptive escape routing e guidance offers the possibility of diverting people based on continuous escape routes monitoring and allowing a possible change in escape guidance during the event, i.e., it permanently follows developments. In such a concept/system, both the detection of hazards and the management of the escape route signalling (visual and acoustical) must be possible to react to changes in the danger situation including the status of the evacuation.

In adaptive escape route guidance, escape routes are constantly monitored for their accessibility and ability to allow unrestricted escapes. The adaptive system detects when an escape route is no longer accessible (e.g., smoke, gases, obstacles) and automatically adapts the escape route visual and acoustic signalling to achieve the best possible (safest) escape options for occupants.

Modern technological developments such as indoor positioning systems, simulation software for escape route planning, as well as the integration into other building systems such as suitable elevators, escalators, building automation, access control, and video systems can greatly support adaptive escape route guidance.

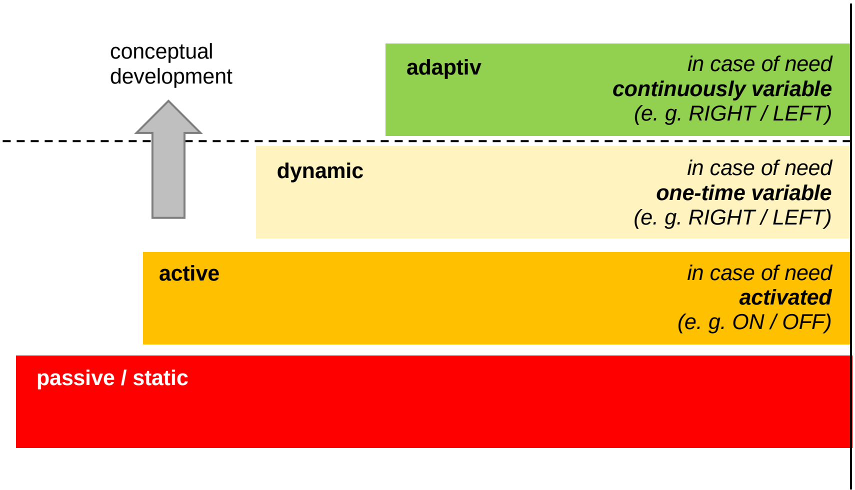

Fig. 2. Distinction between escape route guidance concepts.

The following table gives an overview of the different parameters and concepts of escape route guidance and illustrates the difference between active, dynamic, and adaptive escape route guidance.

Table 1. Overview of the technical concepts of escape route guidance.

	Signalisation control			
Concept	**can be activated**	**direction is variable**	**direction can be changed**	**Comment**
adaptive				feedback loop to adjust signalisation accordingly
dynamic				signalisation set once with no changes during event
active				signalisation is activated (from a deactivated standby)
passive				signalisation with or without continuous lighting

Benefits of dynamic and adaptive escape route guidance

In contrast to static, active, and dynamic escape route guidance solutions, adaptive escape route guidance offers the advantage that the guidance of occupants in danger can be changed in the event of danger in accordance with the development of the danger situation. Due to the oft unpredictable development of a hazard such as a fire, initially safe escape routes and stairwells can become impassable. In this case, occupants must be diverted around the newly created danger spots towards alternative escape routes or stairwells.

Adaptive escape route guidance is automated, providing time critical, relevant, and clear visual and/or acoustic orientation to occupants. This generates a time gain for the persons concerned to act in a timely fashion towards performing their self-rescue. With the support of an adaptive system, an augmented walking pace can be achieved because stalls and delays at suddenly occurring danger points can be better managed/avoided.

In addition to the danger of fires, there are numerous other natural and man-made threats such as terror attacks, bombs, shootings, or earthquakes, floods, storms, etc.

These can be roughly categorised into two possible reaction scenarios: a) swift exiting of the building or b) retreat to a safe refuge in the building. Certain hazardous situations can require evacuation from the immediate danger zone, but not always from the building. Adaptive escape route guidance can react quickly to the situation and lead occupants in danger to safety in time.

As a further benefit, adaptive escape route guidance can reduce panic-like behaviour. It should be noted that personality as well as the social and cultural environment influence people's behaviour and reactions.

Advantages of using the two-sense principle

When people enter a building, a floor, a corridor, or room, it is not in the nature of most to note where emergency exits are. Further, it cannot be assumed that regular occupants – let alone visitors – have specific knowledge of the building architecture; more specifically which exit routes exist and how to get to them. For this very reason, emergency exits on airplanes are pointed out and explained on each flight. This is not viable in a building.

In addition, the existence of sensory limitations such as vision or hearing in building occupants poses a risk to their ability to comprehend emergency signals such as sirens, strobes, or voice alarms promptly and appropriately. For this part of the population, measures must be taken to compensate for these limitations, to lower the risk to them.

To address both the above circumstances, the two-sense principle (also called two-sense communication) is the basis for barrier-free design of buildings. For building occupants with sensory limitations, the chance of self-rescue is greatly improved. To explain, the two-sense principle makes information simultaneously available to two of the three human senses, namely vision, hearing, and touch:

- instead of seeing, hearing and touching
- instead of hearing, seeing and touching

When the two-sense principle is applied in an alarm situation, guidance to and along the escape route is provide in at least two ways. The senses addressed depend on the specific situation, with visual and acoustic solutions currently dominating. Approximately 85 percent of information is usually absorbed through "seeing", with about 10 percent through "hearing", and the rest through "touch" [11] [12]. The two-sense principle is also an advantage for people without disabilities, and it is used in everyday life, e.g., mobile phone (ringtone and vibration alarm at the same time) or pedestrian traffic light (red/green signal and beep). Incorporating the two-sense principle into adaptive escape route guidance provides the following further advantages:

- increased safety for all groups of people
- accelerates orientation also for people without disabilities
- barrier-free use of buildings, facilities, and meeting places
- reduced reliance on organisational measures

Conclusion

In this paper, the authors have outlined the existing concepts and technologies for escape route guidance, being passive, active, dynamic, and adaptive. Technological advancements make the application of adaptive systems both technically and economically more attractive. In the foreseeable future, the use of adaptive escape route guidance will increase safety and security for occupants in buildings. For new builds, and very much for existing building owners confronted with heightened fire safety requirements (e.g., additional escape routes) during renovation, this approach can be significantly more effective and certainly lower in cost. With a view to the Renovation Wave of the EU (Energy Performance of Buildings Directive [13]), millions of building renovations will be required in the next years. Further to the above, the value, and above all, the importance of incorporating the two-sense principle into an adaptive system decreases the time needed to orient and guide people out of a danger zone to a safe area. People with sensory limitations are safer by being able to receive and act on the information broadcasted through the two “sensory channels” for example vision and hearing used. And for people without disabilities, getting the messaging through both channels reduces the time to comprehend and act.

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