Accessibility and Evacuation Planning – Similarities and Differences

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Abstract Twenty–twenty four percent (20-24%) of the world population are people with disabilities. This population has special access needs for performing activities of daily living. This is especially important in case of an emergency. The evacuation concept for a building must take people with disabilities into consideration by means of including specific parameters as an integral aspect in the evacuation simulation model.

This paper presents the accessibility parameters to be considered in evacuation simulations. Examples of tools used in the two disciplines (evacuation and accessibility planning) are provided for illustration: The PedGo evacuation simulation package [Kluepfel, 2003], a model which does only implicitly take into account disabilities; and a decision support system for evaluating accessibility of facilities [Bendel, 2006] illustrates the accessibility approach to facility planning.

Recommendations for integration of accessibility and evacuation analysis summarize the paper.

Introduction

Twenty–twenty four percent (20-24%) of the world population are people with disabilities (U.S. Census Bureau, 2005; Australian Bureau of Statistics, 2004; EU commission, 2003). This population has special access needs for performing activities of daily living. This is especially true and important in case of an emergency. The evacuation concept for a building must take this into account. Planning should not assume that individuals with obvious physical disabilities are the only ones who will have difficulties evacuating. Individuals with a range of medical conditions — hidden disabilities including asthma or heart conditions — or any occupant who is recuperating from an injury or surgery might have difficulty using steps.

Despite of its importance, most current evacuation simulation models do not take into consideration many aspects of evacuation specific to people with disabilities and the elderly [Pelechano, 2008]. And they do not adequately address individuals with disabilities in their simulated populations Christiansen [2008]..

The "Time" Factor in Accessibility and Evacuation

Evacuation is not the same as accessibility, as the 'time'-factor plays a more restrictive role in the case of evacuation. There is an available safe egress time ASET, which defines the upper limit for the required safe egress time RSET (RSET < ASET) Nevertheless, evacuation and accessibility have much in common and they complement each other. For example, the spatial configuration and occupancy of rooms, obstacles, route marking as well as other factors related to various types of disabilities need to be explicitly taken into account in both fields.

This paper presents the accessibility parameters to be considered in evacuation simulations. The PedGo evacuation simulation package [Kluepfel, 2003] is used as an example for a model which does only implicitly take into account disabilities. In comparison to the simulation, a decision support system for evaluating accessibility of facilities [Bendel, 2006] will show the similarities and differences between evacuation and accessibility.

Anthropometrics, Ergonomics, and Pedestrian Movement

The physical, sensory and mental fitness of the populations in western society changes, as well as the age distribution. Age, as well as other factors like obesity, medical conditions etc. have an impact on the walking speed. These factors also affect accessibility needs as well as evacuation performance. Therefore, the special needs as well as the predicted demographic changes have to be taken into account for pedestrian planning and design.

Accessibility and Evacuability

Accessibility and Evacuability correspond to and complement each other. Nevertheless, the two fields have remained quite separate in the past.

Accessibility is a general term used to describe the degree to which a product (e.g., device, service, or environment) is accessible by as many people as possible. Accessibility is strongly related to universal design when the approach involves "direct access." This is about making the environment accessible to all people (whether they have a disability or not).

However, accessibility is often used to focus on people with disabilities (including people with mobility sensory and mental impairments) and their right of access to entities on an equal basis with the rest of the general population. In order to achieve barrier free environment, accessibility standards and regulations were created. The standards focus on minimum requirements to create an architectural and communication barrier free environment

Emergency evacuation on the other hand is the immediate and rapid movement of people away from the threat or actual occurrence of a hazard.

Laws and regulations regarding evacuation focus on life safety codes including fire protection. However, individuals with disabilities are disproportionately affected by conditions in the built environment especially during an evacuation event (US Fire Administration, 1999). An accessible facility by definition should provide for improved evacuation routes and procedures, therefore it is essential to address as many as possible accessibility elements in the evacuation evaluation models.

Accessibility elements which have an impact on evacuation:

In many countries evacuation regulations are included to some extent in the accessibility standards or guidelines. There is much similarity among the guidelines in the different countries. The main differences are in the details required for specific elements for example door width in one country must be minimum 80 cm, while in another country the minimum required is 75 cm of clear width. In this paper we'll use as an example the ADA Accessibility Guidelines (ADAAG, 2002) in the USA.

The chapter on *Accessible Means of Egress* (ADAAG 4.1.3(9), 4.3.10) includes minimum number of egress routes required to be accessible (based on life safety code requirements). Means of egress is defined as:

> "A continuous and unobstructed way of exit travel from any point in a building or facility to a public way. A means of egress comprises vertical and horizontal travel and may include intervening room spaces, doorways, hallways, corridors, passageways, balconies, ramps, stairs, enclosures, lobbies, horizontal exit, courts and yards."

The egress routes must comply with the criteria for accessible routes. An accessible route does not include stairs, steps, or escalators

Accessibility elements to be considered:

<u>**Accessible routes**</u>: i.e.; **Length** of route (Travel distance**)** **width**, **Passing Space**, **Head Room**, **Surface Textures** (such as carpet, slippery surface, uneven surface etc), **Slopes**, **doors** (i.e. not revolving doors, including elements such as clear width, maneuvering clearances at doors, two doors in series, thresholds at doorways, door hardware: handles, pulls, latches, locks, door closers, door opening force, automatic doors and power-assisted doors and the **treatment of elevation changes**: a curb ramp, ramp, elevator, or platform lift respectively. Elevators, the standard means of access between floors are typically taken out of service in emergencies for safety purposes. ADAAG addresses this situation through re-

quirements for **areas of rescue** assistance with two-way communication devices (voice and visible signal requirement such as a button that lights) or **horizontal exher**. (ADAAG 4.1.3(9), 4.3.11).

Evacuation elevators, which are recognized by the model building codes although are not included in the current ADAAG, offer an additional solution. These are elevators that are specially designed to remain functional in emergencies. Possibly also emergency personnel may be able to operate standard elevators in certain emergencies. Meaning the route to the elevator must be considered as well as means of egress, as well as the specifications for accessible elevators (i.e., automatic operation, call buttons, hall lanterns (visible and audible signals), door protective and reopening device, door and signal timing for hall calls, door delay for car calls, and the floor plan of elevator cars.

Stairways although steps and stairs are not considered accessible means of egress, they can be used for evacuation by various types of people with disabilities for example visually or hearing impaired and some mobility impaired who are not wheelchair users. Therefore specifications for stairs mentioned in the accessibility guidelines must also be considered: i.e. width, number of steps, treads and risers, nosings, handrails, detectable warnings at stairs.

Alarms ADAAG (4.1.3(14), 4.28) provides specifications for emergency alarms so that they are accessible to persons with disabilities, including those with sensory impairments. i.e. audible and visual features which address intensity, flash rate, mounting location in all general usage and common use areas including meeting and conference rooms, classrooms, cafeterias, employee break rooms, dressing rooms, examination rooms and similar spaces

Signage (ADAAG 4.1.3(16), 4.30): i.e. character proportion, character height, raised and brailed characters and pictorial symbol signs (pictograms), finish and contrast, mounting location and height, symbols of accessibility, illumination levels, especially of information and directional signs.

Most of these elements may have an impact on the evacuation and the movement speed of evacuating a facility.

Many of these specifications are part of the building design, and therefore can be addressed more easily in the design based evacuation simulation model. However, elements which mostly do not appear in the building design such as surface textures (carpet, slippery surface), door hardware, signage, alarms etc. should be also included.

Evaluating accessibility

All accessibility elements in the built environment must be analyzed in order to determine the level of their compliance with the accessibility standards. The standards are the minimum requirements to enable people with different types of disabilities to use the facilities in general and in case of an emergency and need for evacuation in particular. A thorough accessibility survey not only will identify barriers to access but will highlight emergency evacuation problem as well. Accessibility evaluation is needed during the planning stage of a new building as well as for existing facilities to identify required modifications. Defining accessibility in the built environment is complicated. Many details are needed to meet the needs of people with a wide range of disabilities. Each detail does not stand alone; therefore, the sum of the non-compliant items is not always an indication of accessibility. For example, the general width of a corridor may meet only the minimum requirements, the door width and the opening direction of the doors (in direction of the corridor) comply with the guidelines. Yet the corridor may still not be accessible due to the combination of the two complying elements (door and corridor). In this case when the doors are open they may cause an obstacle, as well as decrease the width of the corridor, especially when there are many doors involved. The decision support system for evaluating accessibility of facilities [Bendel, 2006] presents a computerized audit tool and a decision support system model for evaluating accessibility of existing public facilities, and grading them. The system focuses on the interaction between the individual and the environment, as well as possible combinations between the different elements of design. This system highlights items in the facility requiring adaptation or upgrading to better meet the user's needs. The decision support and grading system operates on formulae and equations for data analysis to define accessibility grades. The equations consist of Boolean operators ("and", "or", "not") combining the accessibility components.

There are two sets of formulae. The first set is formulae defining the accessibility of each specific element or space in the building separately (i.e. parking, entrance, offices, staircase etc.), with different equations each one relating to the four major types of disability groups: wheelchair users, users of crutches or walkers, individuals with visual impairments and individuals with auditory impairments. In other words, the elevator's accessibility is graded specifically for the visually impaired, for the wheelchair users etc. Therefore the grade for the visually impaired, for example will be a combination of all elements of the elevator which are relevant to this group, i.e. specifications of accessible signage, availability of tactile elements in front of the entrance door and on control buttons audible signage, etc. The accessibility of the elevator for wheelchair users will integrate elements such as door opening, size of compartment, height of control buttons etc. The second set of formulae defines weighted grades of the whole facility according to the type of the building/site and to the type of disability. As behavior of people in public buildings is related to the type of service given in the building, the usability of the building is analyzed accordingly. Therefore, the formulae for a bank, for example, will differ from those of a sports facility. The relative importance of each element and the connection between elements are considered in the definition of the formulae. For example the toilets are an element with high relative importance for people who visit a sports facility, but of low relative importance for banking. The overall weighted grade of the building's accessibility for each type of disability is computed based on all the services available and the building environment, using the grades of each element as described above.

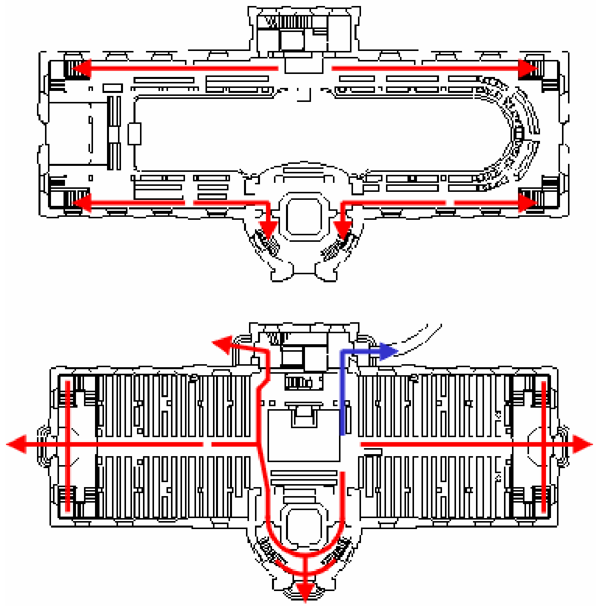
Evacuation Model for Persons with Disabilities

The BUMPEE model Christensen [2008] is an evacuation model taking persons with disabilities explicitly into account. This is a person-based simulation classifying the built environment according to environmental characteristics and simulating a heterogeneous population according to variation in individual criteria representing the diversity and prevalence of disability in the population.

However, the impact of the building design as a whole and integration of the different elements of the building i.e. location of elements, direction signs, direction of doors etc. as well as behavior under pressure, behavior that have an impact on others are not used in the model.

Evacuation Simulation

Figure 1 shows the layout of the building used for the sample evacuation simulation. There are altogether 1019 persons in the building, five of them being wheelchair users.



Gallery:

Seated:	202
Choir:	24

Ground floor:

Seated:	788
Wheelchairs:	5

Figure 1: Layout of the two-storey building. The evacuation route for the persons with disabilities (wheelchair users) is shown in blue (via the ramp).

Each person possesses individual parameters. The following parameters are used in this example: Velocity (V_{max}): The maximum free walking speed; Patience: The maximum time a person stands still (e.g. in a congestion) before changing her route and attempting to find another escape route; Sway: The accuracy, with which a person follows the gradient of the potential; Reaction: The duration a person needs to respond to the evacuation signal, e.g. start moving (= pre-movement time); Dawdle: The probability, for a person to reduce his walking speed, e.g. to stand still for the rest of a sub time step; Inertia: The force with which persons try to continue on their walking direction, i.e. resist change of current walking direction.

The parameters of the standard population are shown in the following table.

Table 1: Population parameters (Standard Population)

	Min	Max	Mean	Std.-Dev.	Unit
Velocity	0.8	2.0	1.2	1	m/s
Patience	5000	5000	-	-	s
Sway	1	5	3	2	
Reaction	0	60	30	300	s
Dawdle	0	30	15	5	%
Inertia	1	5	3	2	%

The next table only provides the parameters that are different for the persons with special needs. All other parameters are as in **Table 1**.

Table 2: Population parameters for persons with disabilities (wheelchair users).

Velocity	0.8	0.8	-	-	m/s
Sway	1	1	-	-	
Dawdle.	0	50	25	250	%

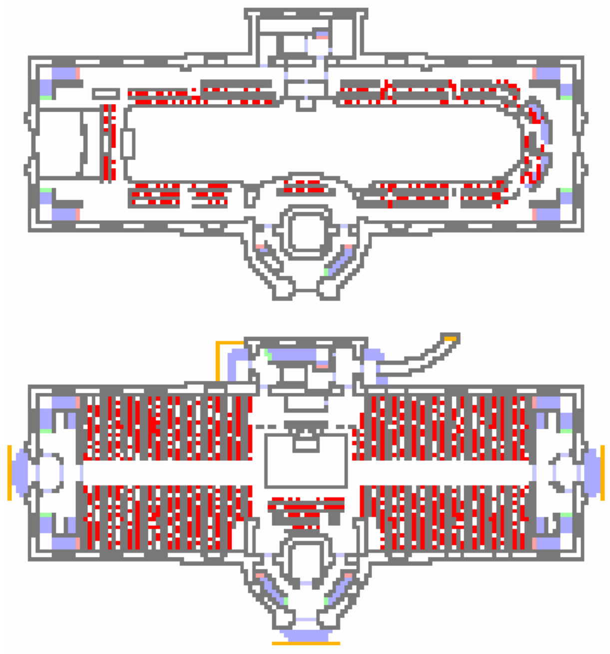


Figure 2: Initial distribution of persons.

The wheelchair users had been assigned a maximum free velocity of 0.8 m/s, whereas the abled population has a normally (Gaussian) distributed range from 0.8 m/s to 2.0 m/s. The initial distribution of persons (red dots) is shown in Figure 2.

For this project, several scenarios had been defined with different availability of exits and routes. For the sake of this paper, we focus on scenario 1, where all exits are available (this is the reference scenario, cf. Figure 1).

Based on this distribution and the parameters stated above, the evacuation of the building is simulated. As can be seen from the evacuation curve (number of persons evacuated versus time, cf.), the evacuation of the wheelchair users which are seated close to the ramp in the ground floor (cf. Figure 1) is faster than for the general population. This is mainly due to the fact that there are only five wheelchair users and they are seated close to the exit which is used specifically for them.

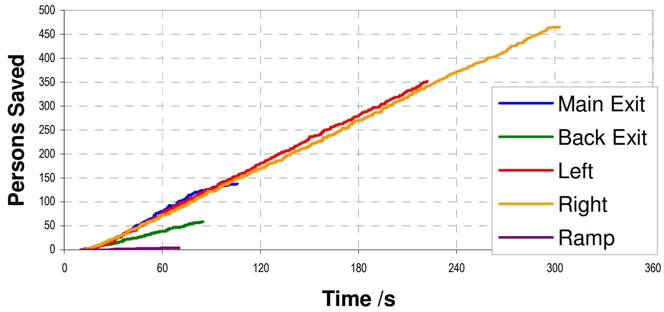


Figure 3: Results for the evacuation of standard and wheelchair population.

Summary, Conclusion, and Recommendations

In this paper we presented a summary of the similarities and differences between accessibility and evacuation. In general, a universal building designed will also perform well in an evacuation scenario. The main difference is the RSET < ASET requirement, i.e. the available safe egress time determined by the hazard (e.g., a fire) must be longer than the required safe egress time. This criterion is usually not required in the case of access to a building, whereas the simulation model is not based on the interaction and integration of the building elements which view the building as a whole unit.

Recommendations for integration of accessibility and evacuation analysis:

- Information items should be added to the CAD plan, for example location of signage to reduce trial and error behavior during evacuation.
- The accessibility grades – the results of the accessibility analysis should be incorporated in the simulation model. This would allow taking into account accessibility parameters in a straightforward manner.
- Accessible facilities therefore should also have an impact on parameters used in the PedGo evacuation simulation model presented above

The demographic factors mentioned in the introduction will inevitably change the composition of societies of many if not most countries in the world. A prominent example is the need for rest during the evacuation of high-rise buildings. Furthermore, many mobility impaired persons are not able to evacuate a building. One consequence will probably be the use of elevators for evacuation. The field of accessibility or barrier free planning and design has a lot to offer for the field of evacuation planning.

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