Evacuation planning for occupants with disability

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TABLE OF CONTENT

Evacuation Planning for Occupants with Disability
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EXECUTIVE SUMMARY

In 1996, the Institute for Research in Construction (IRC) at NRC published the IRC Internal Report 712 entitled “Review of Evacuation Strategies for Occupants with Disabilities”. For that report the literature review was conducted up to 1995. It was felt in early 2002 that a new literature search should be conducted and an update of the report published which is this actual document. The report contains most of the information initially published in IRC Report 712 with a thorough update of the references, concepts and strategies currently discussed to plan the evacuation of occupants with disabilities in office, residential and public buildings.

There is a growing interest in planning fire safety procedures for buildings at large where some of the occupants may have disabilities. This paper reviews the different strategies presented in the literature and discusses various approaches being considered in Canada. One of the suggested options is the use of refuge areas in a building. This option implies that occupants with disabilities do not have to evacuate during a fire; rather they move to an area of refuge where they protect-in-place and will be rescued later. Another option being considered is the provision of safe elevators in highrise buildings. Most of the technical problems required to ensure that such elevators can be operated safely in a fire emergency have been addressed, however, there are still some outstanding human factor issues. A third option is to develop specific evacuation procedures for people with disabilities. The "buddy" system, for example, identifies one or a few persons who have the responsibility of looking after or reporting the presence of a person with limitations in case of an emergency. Another system is to have an available list, for the responding firefighters, of the people who may have problems evacuating. These special evacuation strategies assume that the people with disabilities will be carried out by hand or by using special devices.

In assessing the effectiveness of these various life safety strategies for occupants with disabilities, the general opinion is that there is no single life safety option that will solve all of the problems. Most likely, a combination of different options will be used to ensure an acceptable level of life safety for all occupants in a building. The physical layout of a building, the type of occupancy and the characteristics of the occupants are important parameters that should be considered when determining how to provide life safety for all occupants.

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1.0 INTRODUCTION

In 1996, the Institute for Research in Construction (IRC) at NRC published the IRC Internal Report 712 entitled “Review of Evacuation Strategies for Occupants with Disabilities”. This report received substantial interest and numerous requests for copies by managers, educators, researchers and students, as well as members of the general public. In the year 2000, the English report and a French version were placed on NRC’s website and could be downloaded for free. Since the initial literature review was conducted in 1995, it was felt that a new literature search should be conducted and an update of the report published. This update was initiated in early 2002 and the current report contains most of the information initially published in IRC Report 712 with a thorough update of the references, concepts and strategies currently discussed to plan the evacuation of occupants with disabilities in office, residential and public buildings.

Accessibility to buildings for occupants with physical disabilities has been solved with the introduction of elevators, lifts and ramps to most buildings [1]. The accessibility of perceptually-impaired people has also been facilitated by changes such as the use of raised or Braille characters for the blind on elevator buttons and the introduction of simple signs and pictograms for the hearing-impaired. Although universal accessibility to all buildings is not yet a reality in Canada, most buildings designated for the general public offer some level of accessibility.

Considerable focus has been given in the last few decades to accessibility while “egressability” has not received as much attention. The concept of “egressability" does not imply that the means of egress should be the same for everyone, but that there should be an equal level of life safety for everyone. In Canada, federal and provincial human rights legislation require safe access and egress from buildings for people with disabilities.

The last Canadian Census available for data on people with disabilities dates back from 1991. The 1991 Census reveals that 15.5% of the population had a limitation of some type in Canada, and of those, 93.7% lived in private households [2]. Thus, disabled people represent a significant percentage of occupants visiting a variety of buildings and all of them can expect an environment with an acceptable level of life safety. Not all disabled people are the same, and there should not be an attempt to necessarily solve everyone's individual problem with one ideal solution [3]. Partial data from the 2001 Census were published in March 2002 [4]. This data shows that in Canada, 12.7% of the population is 65 years old or older and this proportion of elderly Canadians is likely to increase with the aging of the baby-boomers. It is expected that many elderly have some form of limitation that may have an impact on their capacity to independently evacuate a building during a fire. The risk of dying in a fire increases dramatically with age [5, 6, 7, 8].

Four main types of disabilities are discussed in this report: mobility, visual, auditory and intellectual impairments. Each of these limitations leads to specific problems related to the occupant capacity of evacuating buildings. In looking for a solution, it is important to keep in mind that a solution that is acceptable for one group

may impede others. Ideally, the chosen solution should benefit more than one group or at least not impede the safety of any other.

Standards have been set in the UK in the Disability Discrimination Act and in British Standard 5588, Part 8 [9, 10] and in the USA following the Americans with Disabilities Act [11,12,13]. In Canada, the National Building Code and National Fire Code of Canada [14, 15, 16] present the minimal fire safety requirements. All of these documents provide general guidance for designers, builders and fire safety engineers.

A number of options for the evacuation to a safe location of disabled people have been detailed in the literature [17]. Solutions such as areas of refuge, safe elevators, buddy systems and stroboscopic alarms are among those that exist. This report reviews the wide body of literature available on the subject as of early 2002. Approaches and methods that appear to be the most feasible to implement in buildings designated as accessible to the general public are described.

Strategies discussed in this report are not intended for hospitals or nursing homes. The evacuation planning for health care occupancies is well documented and includes many good ideas for lift and carry techniques [18, 19, 20, 21]. There are major differences between the evacuation of health care patients and that of autonomous, disabled occupants. For instance, health care centres can rely on trained staff to guide or move patients to an area of safety, whereas office or apartment building occupants must rely on their families, neighbours or colleagues until the arrival of rescue personnel. Another difference is in the type of occupants; health care centres house patients that are, in most cases, highly dependent on the care personnel for any movement. In general, multi-level building occupants, disabled or not, are independent and self-sufficient when it comes to taking care of themselves and, under normal circumstances, most can easily enter and leave the building independently. Because of these differences, it should not be assumed that a solution that has been proven effective in a health care centre will be just as valuable in other occupancies.

There are two approaches in designing a fire safe environment for occupant with disability: the micro or macro approaches. In the context of egressability, the micro approach consists of finding solutions specifically for disabled occupants, and these solutions will likely be different from evacuation procedures for non-disabled occupants. On the other hand, the macro approach focuses on finding evacuation procedures that can be used by all occupants alike. Many experts believe that, in a fire situation, all occupants are impaired to some degree, for example, either by the presence of smoke, or the lack of familiarity with the building. Furthermore, almost everyone, at some point in life, is subject to mild or temporary disabilities, such as asthma, injuries or pregnancies that can affect their evacuation potential. As people age, limitations may appear [22]. From all these conditions being disabled is not a special case anymore. Researchers suggest that ideal solutions should facilitate the evacuation of every occupant, and not only of those traditionally designated as disabled [23, 24, 25].

2.0 PLANNING FOR FIRE SAFETY

A starting point in planning fire safety procedures for a specific building is to determine what the building already provides in terms of fire safety, as well as the needs

and capabilities of the building users [26]. Such information will help identify the areas needing improvement and the problems to be resolved.

For new buildings, cost-effective fire safety strategy should be incorporated fully into the design concept at the very start of the design process [27]. For existing buildings one of the first steps in planning for fire safety is to identify the occupant and building characteristics already in place. Table 1 provides a list of some of the elements that should be taken into account when developing a fire safety strategy. For example, knowing the profile of your occupants is essential in devising a plan; if your building houses mainly adult office workers, your plan will be different than if you have a day-care centre with 60 pre-schoolers.

The fire safety planning initially involves the definition of a strategy. The strategy should be developed in collaboration with the local fire department. It should take into account fire safety requirements imposed by regulations and by occupants limitations and needs as well as the building's possibilities and the feasibility of various options. Once the strategy is determined, a procedure can be defined. The procedure will describe the role and responsibilities of staff and occupants. It should include the precise sequence of actions to be taken in case of an emergency. Finally, a plan is devised based on the procedure and consists of clear and concise instructions intended for the occupants of the building. Copies of the plan are usually displayed in or near elevators, but can also be provided in employees' manuals or distributed when a person signs a lease for an apartment.

Defining the strategy will involve a decision between two options: protect-in-place or everybody-out [28]. The protect-in-place option implies that some or all occupants will stay in the building during a fire and will, therefore, need a fire and smoke-safe compartment where they can wait until firefighters control the situation or rescue them [29]. Such compartments are referred to as the refugee floor, areas of refuge or staging area, and include enclosed rooms and balconies. The everybody-out option refers to immediate evacuation of the full building or of the floors where the occupants could be affected by the fire. In this case, those with mobility impairments can either evacuate using safe elevators or be carried down the stairs.

For many highrise buildings, the everybody-out option, which implies total evacuation, may not be the best strategy. Evacuating all occupants of a highrise building could require considerable time, and could delay the evacuation of those who are in real danger [30]. Sequential evacuation, where floors are evacuated by priority, starting with the affected floor and those directly above, is often the best solution. In many cases, occupants on floors remote from the fire floor may not need to evacuate at all. Occupants on the selected floors to be evacuated can move down to ground level or can go to a safe floor below. This strategy implies that occupants with disabilities may have to be moved up or down a number of floors. Implementing a sequential evacuation procedure requires training and a good communication system. The protect-in-place option means that occupants will stay where they are or move horizontally to an area of refuge during a fire. It implies fire safety features, including a smoke control system, fire and smoke resistant walls, ceiling and doors, and possibilities for occupants to communicate with people outside if they need help.

Table 1: Occupant and Building Characteristics

Occupant Characteristics	Building Characteristics
Profile • Gender • Age • Ability • Limitation	**Occupancy** • Residential (lowrise, midrise, highrise) • Office • Factory • Hotel • Cinema • College and University • Shopping Centre
Knowledge and Experience • Familiarity with the building • Fire safety training • Other emergency training	**Architecture** • Number of floors • Floor area • Location of exits • Location of stairwells • Complexity of space/Wayfinding • Building shape • Visual access • Balcony
Condition • Alone vs. with others • Active vs. passive • Alert • Alcohol+Drug – Medication	**Activities in the Building** • Working • Sleeping • Eating • Shopping • Watching a show, a play, a film, etc.
Role • Visitor • Employee • Owner	**Fire Safety Features** • Fire alarm signal (type, audibility, location, number of nuisance alarms) • Voice communication system • Fire safety plan • Trained staff • Refuge area • Elevator • Sprinklers, Smoke control sys., Etc.

Decisions on the chosen strategy should be made based on the design of the building, fire safety features, modification possibilities and the costs involved. It is essential to consider if the strategy proposed has the potential of making the building less safe for some occupants [31]. If possible the strategy envisioned should be discussed with the disabled occupants to obtain their opinion. Since occupants with a disability have an important responsibility in being prepared to face a potential fire, they should be involved in the development of the evacuation plan [32]. For all buildings, the strategy will have to be explained to occupants using the plan and should be assessed through drills. In most highrise buildings, a communication system to inform occupants of the situation and provide instructions is essential.

Once a strategy has been selected, it should be incorporated in the building evacuation procedure. From that procedure, a plan can be defined and may vary between occupants depending on occupants' characteristics and needs. The plan should be discussed with the people concerned especially when different procedures are planned for specific groups [33]. Some instructions may apply to all occupants, including the mildly, temporarily or permanently disabled, following the macro approach.

Whatever the situation and procedures being considered, disabled occupants who will follow the plan must be comfortable with it. A procedure is only useful as long as people are willing and ready to use it. Obtaining disabled occupants' opinions in the early stages of the planning might facilitate the process and ensure that the procedures are accepted by the disabled occupants. It is essential that the details of the procedure be discussed with the local fire department to obtain their comments and suggestions, and to assess how their rescue procedure relates to the evacuation procedure developed.

It cannot be over-emphasized that the success of an evacuation procedure depends on the occupants' familiarity with it. In too many cases, the emergency provisions involve taking routes that are not commonly used, such as special emergency exit doors. Too often, if occupants have never used these exits, they will not think of using them during an emergency. Occupants may also not be willing to try a new route during an emergency, fearing it will not lead them to safety. Drills are valuable opportunities for occupants to become familiar with evacuation routes. Ideally, emergency procedures should make use of routes commonly used by occupants.

For many building users, especially in non-residential buildings, planning for an emergency is not a high priority [34]. Many occupants are not willing to spend endless time familiarizing themselves with complicated procedures. Keeping the procedures clear and simple is the best way to ensure that occupants will know how to react during an emergency. Training is an important factor in improving occupants' knowledge of fire safety procedures. Three stages of training should be planned. During the first stage, talk-throughs will describe the procedure to the occupants who can ask for explanations and discuss their specific needs and concerns. The second stage is to proceed with announced drills which put into practice the information received during the talk-through. Finally, surprise drills as a third stage should be used to assess the procedure and to improve the occupants' training. This three-step training procedure should be carried out every year. Drills are essential because they are the best way to assess the procedure and they offer an opportunity for actively training occupants [35].

Many managers are reluctant to carry out unannounced evacuation drills because they fear occupants will panic. The concern about people panicking during a drill is just as unjustified as the fear of people panicking during a fire [34]. Panic has never been shown to have an important influence on the behaviour of occupants during a fire. In fact, panic rarely occurs, even during a very serious blaze [36, 37]. The primary concern should be to motivate all occupants to participate in the fire safety education and training being provided. Training should not be seen as a burden or a waste of time, but should be seen as essential for a person's own safety and that of others. Drills, announced or unannounced, should never last much more than 10 min, which would be the time available in most buildings for occupants to reach safety during an actual fire.

3.0 BUILDING CHARACTERISTICS

The building characteristics include all components that are related to a fire safety procedure. Design and architectural properties of the building, such as the size and location of staircases and exits, will affect occupants' evacuation possibilities. Those factors should be taken into account when developing the fire safety strategy and procedure. Certain features can be implemented in a building specifically for emergency situations. These include emergency lighting, areas of refuges, safe elevators and sprinkler systems. Some other features can be used at all time such as communication systems and wayfinding signage. All of these features can, in most cases, improve fire safety not only for disabled occupants, but for all building users.

3.1 Areas of refuge

Areas of refuge, also known as safe areas, staging areas, areas of rescue assistance or areas of evacuation assistance, consist of an accessible space, separated from the rest of the building by fire-resisting materials and fire doors that limit the passage of fire and smoke. They are required by the Americans with Disabilities Act (ADA) in buildings where there are no sprinklers and no accessible exits [11]. Nevertheless, areas of refuge are better suited to sprinkled buildings where the activation of a sprinkler-head might obscure light and limit vision in the fire vicinity and occupants in that compartment or floor need to move to a safe area [38].

The area of refuge should offer the same protection and fire-rating as an exit staircase. Some buildings use staircase landings as their areas of refuge [39]. In these cases, the landing area must be large enough so that the staircase is not obstructed by disabled occupants waiting there, including wheelchair users. Some researchers believe that an area of refuge should be directly connected to an escape route, such as a staircase or elevator. Such areas are called areas of rescue assistance [40]. In situations where firefighters plan to use elevators to evacuate occupants, the elevator lobby can be designed to serve as an area of refuge, protecting occupants while they wait to use the elevators if leaving the floor is necessary [41]. If an area does not open directly onto a stairway or elevator, it should at least be situated close to one so that people seeking refuge are easily accessible for rescuers, should the need arise to evacuate them.

Other locations for areas of refuge include same-level connections between two buildings [3], where two separate buildings are linked by a passageway, through which occupants can move to the next building and use its elevators to egress. Another option is the horizontal separation of floors, where floors are divided into two or more sections, with fire and smoke resistant doors between each compartment [41]. In the event of a fire in one of the zones, occupants move to the other zone and wait there until the fire is extinguished or until they are rescued. Power-operated fire doors with specified fire endurance could be used to protect areas of refuge. Door holders and closers can be wired into the alarm, which would result in the closing of all such doors when the alarm is activated [42]. The evacuation flow would be disrupted in the whole building if all fire doors were to close at once. Alternatively, each door can be equipped with an integral smoke detector or be connected to zones which would close only the doors situated

close to the fire. Since someone in a wheelchair may have difficulty opening and closing fire doors, an automatic mechanism would be of substantial help.

In apartment buildings, balconies are often defined as areas of refuge. The balcony as a refuge area may not be appropriate during Canadian winters since the door to the balcony could be blocked by snow or ice and people could be forced to wait outside for a long time in very cold temperatures. In many apartments, occupants must move up or down one step to get from their apartment to the balcony, such a step would be difficult to negotiate for wheelchair users [24]. In the event of a fire, whether a balcony could be a safe area of refuge depends also on factors such as the fire location, the wind direction or the likelihood of the fire venting through exterior windows or openings.

The safety of areas of refuge depends on the details of the design, the type of fire exposure, the outside wind, the temperature conditions and the capability and reliability of the smoke control system. Without pressurization, areas of refuge can become dangerous [41, 43]. There is also some concern about areas of refuge without a second means of escape, as the area must allow escape and rescue [41]. Another fear is that some people may be unable to reach the area before the pathways become lethal [24, 41, 43]. From an owner's point of view, areas of refuge should not represent non-leasable space. Owners can therefore use existing areas, such as elevator lobbies needed in everyday operations but modified to serve this purpose in an emergency.

The acceptance of areas of refuge by occupants, as a safe place to wait during an emergency, is also dependent on design details: telephone, window, chairs, distance to exit, etc. A crucial aspect of the success of the area of refuge concept is the occupants' willingness to accept and use these areas during a fire [41]. The organizational and human behaviour aspects of the use of areas of refuge are more complex than those of the traditional total evacuation. Two-way communication should be provided in each area of refuge to allow occupants to signal their presence to rescue officers and to obtain information on the situation [44]. A close-circuit television system with a monitor in the control centre will allow rescuers to know exactly what is happening in the refuge [45]. Chairs should be installed since many of the people using the refuge area may not be in a wheelchair. Such occupants may be suffering from heart problems or rheumatism and may not be able to stand up for prolonged periods of time [46]. Windows looking either to the outside or inside of the building could prove to be a source of reassurance for occupants having to stay in refuge areas for a prolonged period of time. Areas of refuge must be clearly indicated as such, and suitable signs should be installed [47]. There is as yet no convention on a standard sign to indicate an area of refuge. A standardized sign would increase the familiarity and the acceptance of the concept.

Some firefighters are reluctant to rely on areas of refuge and still prefer the total evacuation of the building [47]. Co-ordination of the evacuation procedure with the fire department and other rescuers is essential, as the people in the area of refuge may need to be evacuated [41]. Depending on their size and location, the areas of refuge can be used either only for disabled occupants, or for all occupants. For example, a staircase landing cannot hold more than a few occupants, while a horizontal separation may allow all occupants to protect-in-place in the building to await further instructions.

3.2 Safe Elevators

The term 'safe elevator' refers to an elevator that can be safely used by occupants during a fire. In considering using elevators during a fire emergency, the building should be fully sprinkled and specific consideration should be given to the propagation of smoke throughout the building [48]. A number of technical aspects of the elevator components should be considered before elevators are used during a fire [26, 49]. For instance, the elevators should be protected from fire, heat, smoke, water damage and power loss [50]. Fire-resistant doors are needed, pressurization against piston and stack effect throughout the shaft is essential to control the smoke [3], dual power systems must be installed for reliability [3] and components that can function in a wet environment are also needed. Some options such as floor drains and sloped floors have been considered in an attempt to limit the water from entering the shaft, however, these have important architectural limitations and must be studied further. Finally, each floor should have an enclosed elevator lobby, such as an area of refuge, where occupants can wait for the elevator [10, 50]. The technology to ensure that elevators are safe is available but building owners want to see codes and standards requirements before installing safe elevators in their facilities [51].

The organizational aspects of using elevators for evacuation can be quite complex. First it must be determined if the use of the elevators during a fire will be restricted to disabled occupants only. If all able-bodied occupants use the stairs to evacuate, while only the occupants with mobility impairments use the elevators, the evacuation of those who cannot use the stairs will not be delayed [52]. If the elevators are to be used for the evacuation of a much greater number of people, the limited capacity of the elevators will require careful management of people, and some prioritizing will be essential, such as evacuating only specific floors unless the situation is threatening to all [52].

In many buildings, safe elevators for firefighters are available, but currently their use is limited to the rescue team during a fire. Fire safety procedures can be changed to accommodate disabled occupants, but it might be problematic if firefighters need the elevators to deal with fire suppression, while occupants are waiting to evacuate using the same elevators [24]. If the elevator lobby can serve as an area of refuge, the disabled occupants can safely wait until the elevator is free, or until the firefighters choose the best time to evacuate them [40]. The evacuation procedures should indicate clearly which of the occupants, the firefighters or a third party, has priority and the responsibility for operating the elevators. Regardless of who is in charge of managing and directing the elevators, disabled occupants should be able to contact a person in charge, or directly contact the elevator operator to identify themselves and communicate their status and location [52].

The signs installed should always provide clear and correct information about elevator use during a fire. For example, if safe elevators are provided, old signs indicating that occupants should not use elevators during fires should be replaced by signs indicating that these elevators can be safely used during an emergency and how and by whom they can be used. The use of elevators during a fire emergency will necessitate a complete re-education of occupants. Through the years, people have learned that in case of fire, they should not use the elevators. Reversing these instructions implies that people must be re-educated and must understand where and when elevators can be safely used in fires.

Elevators are already planned to be used for fire evacuation by occupants in some special buildings. Some historical mid-rise buildings which were not designed with two stairwells but usually contain one stairwell and one elevator have sometimes no other option than planning to use the elevator as a second means of egress. In such cases it is the authority having jurisdiction and the local fire department who can give their approval for such means of egress to be used. Some new structures have been designed and built with the plan to use the elevators as a means of egress [53, 54]. It is the case for instance at the Stratosphere Tower in Las Vegas where the primary means of evacuation is by elevators. At the top of the four-leg structure located at 236 meters above ground there is a 13-storey pod, which contains restaurants, conference facility and fun fair. A maximum of 2,650 occupants, controlled by turnstile can be in the pod at any one time. The evacuation plan of the pod combines the use of refuge areas and the use of 4 express elevators to evacuate the tower which also has a single stairwell [55].

3.3 Sprinkler Systems

It has been said that "the operation of a properly-designed sprinkler system eliminates the life threat to all occupants" [41]. This might be true theoretically, but sprinklers are not a perfect solution, for instance; they may not be triggered during a smouldering or a shielded fire. Furthermore, sprinkler systems need regular care and maintenance and can be negated by human error [40]. As well, even a sprinkled fire can generate significant quantities of smoke that could endanger the life of occupants.

All occupants should therefore be provided with some means to be separated from the area of the fire, even in a building equipped with sprinklers. Setting up areas of refuge could prove to be an excellent complementary solution.

Properly designed and maintained, sprinklers will, in most cases, limit the fire to the compartment of origin, which could reduce the need for complete evacuation. The need to move some occupants to another area, however, may still be present. Thus, even if sprinklers are 95% reliable at limiting the fire to the area of origin, as reported in the literature, a backup plan for disabled occupants is a priority [3].

3.4 Communications

The evacuation plan provided to occupants should specify the type of alarm that is used during fire emergency, whether it will be a slow-whoop, a continuous bell, or the new Temporal-3 pattern is important to know for occupants to recognise the signal. Until all buildings upgrade their alarm sounders to the Temporal-3 requirement, it is essential to specify in the emergency plan which fire alarm sound is used in the building, to help occupants recognize the fire alarm [56]. If information will come through a P.A. system, it should also be mentioned in the plan.

It has been said that, during an emergency, what occupants need most is useful information [52]. For example, the location of the fire could influence the choice of egress route, and a P.A. system could be an effective way of keeping occupants informed about the unfolding situation [52]. It is important to provide occupants with information on the fact that there is a fire, where the fire is located, and what is the best course of action [57].

As well, communication among occupants or between the occupants and the rescue team during an evacuation should not be overlooked. Occupants with disabilities have distinct needs in terms of communication, which vary from one person to the other, depending on the nature of their limitations and on the fire safety procedure intended for them. Communication needs should be determined on a case by case basis.

Throughout an evacuation, the alarm can seriously inhibit communication if the sound level is very high [58]. It is suggested that alarm sounders be installed in living and working areas rather than in circulation areas such as corridors or staircases, where the sound of the alarm may prevent essential communication between occupants during an emergency. It is also important to interrupt the alarm while messages are given through the P.A. system to ensure their audibility [14]. When firefighters arrive at a building, they sometimes turn off the alarm, even if the situation is not entirely under control. This procedure can lead occupants to believe that the emergency is over and they may decide to return to their initial location. To maintain the alert mode while allowing communication between people, it would be useful if the firefighters could switch the alarm to a pulsing tone. This continuing signal would keep occupants aware that the situation is still under investigation and that they should remain in a safe location. Disabled occupants, unfamiliar with evacuation procedures, are very likely to need more information than most occupants, and the loud noise of the alarm may increase their anxiety over a long period of time, while preventing them from communicating with each other.

4.0 COMPLEMENTARY PROCEDURES

Three systems can be implemented to complement a fire safety procedure. The first one, the fire warden system, can benefit all occupants. The other two, the list of occupants in need of assistance and the buddy system can be especially useful for disabled occupants. None of these systems constitutes a fire safety procedure in itself. Means of reaching safety must be determined independently, however the implementation of these systems is a key element in improving the efficiency of various evacuation procedures.

4.1 Fire Wardens

Many office buildings have a system of fire wardens. Generally, one employee, working in each section of the building on every floor, is designated as a fire warden. Fire wardens usually receive some training and should be well aware of the evacuation procedure. They are also expected to inform occupants of the evacuation procedure and to make sure that everyone reaches an area of safety during an emergency. This kind of system seems to work well because it ensures that one person will take a leadership role during an emergency, informing the others and directing them to safety. It may create problems if the person chosen as the fire warden is not a person with a position of authority in everyday operations since during an emergency, others might not be willing to listen to the instructions provided by a warden who is usually in a subordinate position. Also, the warden should not be a person who frequently has to work outside the premises, because that person may well be absent during an emergency. Alternate wardens have to be identified to replace fire wardens who may be away for holidays, sick leave or other reasons.

It is more complicated to implement a fire warden system in apartment buildings. In an apartment building, it is not reasonable to expect a resident to ensure that everyone has evacuated a section of the building; this person would need to have access to all the private apartments under his or her responsibility to make sure that all occupants leave. Identifying the appropriate person for the role could also be difficult. The person must be willing to take on the duty, should be physically able to help or to find help, and should not be someone who is often away from the building. It is felt, however, that the role of fire warden could be modified to accommodate the needs of apartment buildings. The responsibilities could be limited to providing fire safety information to other occupants, to knock on all doors in the event of a fire, to be aware of the occupants who may need assistance and to report the location of occupants in need of assistance to the firefighters or rescue officers. Since the fire warden cannot be expected to be in his or her apartment at all times, there is no assurance that the warden will be there to help during a fire. Identifying more than one fire warden could resolve that problem, increasing the chances that at least one of them would be present during an emergency.

4.2 List of Occupants in Need of Assistance

Many highrise buildings have what is sometimes called a "fire list", which contains an up-to-date account of disabled people, a description of their limitations and their respective locations in the building. The list system, if kept up-to-date, is useful in quickly identifying the people needing assistance, and can be consulted by rescue officers when they arrive on the scene. It should be stored where it can easily be accessed by arriving firefighters.

The fire list, unfortunately, is not always a complete listing of all the occupants with disabilities. Visitors with disabilities will not be on the list. Occupants with a disability who are regularly in the building may refuse to be on the list for privacy reasons or may not come forward and ask to be listed not knowing that such a system exists. Some others may have a disability that they refuse to acknowledge or which they feel does not impact their capacity to react during an emergency [59]

The main problem with fire lists is that often, they are not kept updated. If the list is not accurate, firefighters may waste valuable time attempting to rescue occupants that have moved out of the building. For a fire list to be a useful tool, someone has to be given the responsibility for updating every 3 to 6 months, making sure the latest version is available to firefighters (for example, by placing it in the fire alarm control panel, which is one of the first locations firefighters will investigate on arrival.)

4.3 Buddy System

Many office buildings where disabled occupants are present have implemented the buddy system. Each person with a limitation is paired with one or more people with no limitations. It is suggested that a person with a visibility or hearing impairment be assigned one buddy, and that a person with mobility impairment be assigned two buddies [47]. Others suggest that every person with a limitation be assigned two buddies in case one is absent during a fire [3]. This system cannot be used if the person with a limitation does not want to be identified as such or does not want to receive special treatment.

The buddies should be selected carefully. The buddy and the person with a disability have to be able to quickly make contact with each other in case of an emergency. If a buddy is untrained or inappropriate (e.g., not strong enough if the person must be carried), the system becomes ineffective. If the buddy appears untrained, it is unlikely that he or she will inspire the confidence necessary to motivate the disabled person to evacuate. In most cases, the disabled person should be able to determine if help is really needed and, if so, what form of help is desired [24].

The buddy is expected to remain with the person throughout the evacuation. If moving to another floor is necessary, some suggest that the buddy and the person with a limitation should wait until others are gone and the stairwells are free to evacuate [47]. This should depend on the type of evacuation technique used. For example, a deaf person can easily evacuate with the occupants' flow, at the same speed as other occupants, while carrying a person in a wheelchair down the stairs could block the entire staircase and, therefore, should be performed after most occupants have evacuated [30]. Whatever the procedure agreed on, it should be practised ahead of time so that both the buddy and the person with the disability are familiar and comfortable with this procedure.

The buddy system could also be implemented in apartment buildings, but is not as convenient when neighbours do not know each other very well. Some people with disabilities could feel that having a stranger designated to help them and having to practice the procedure goes against their need for privacy. It should be reassuring, however, for the person with the disability to have someone who knows how to help in case of an emergency. The buddy system should not be seen as a burden by either party if the buddies are carefully paired off. A person who is constantly away from the apartment or office building would not be a good choice of buddy. Assigning more than one buddy to each disabled person could prevent such situations.

Assigning a buddy ensures that a least one person is willing to take the responsibility of helping the disabled person. If no one is designated as a buddy, there is a risk that all occupants will assume that someone else is going to help the disabled person and, meanwhile, this person could be left without help. The buddy system is especially useful for disabled occupants living alone.

5.0 OCCUPANTS' CHARACTERISTICS

The nature of each occupant's disability will determine the best evacuation procedure for that person. Egress capabilities varies enormously among people with disability [60]. Fire safety issues for occupants with mobility, visual, auditory and intellectual impairments are discussed.

5.1 Mobility-Impaired Occupants

Mobility impaired occupants include those with any type of limitation on movement, and not necessarily just wheelchair users [61, 62, 63, 64, 65]. In fact, mobility-impaired occupants can be classified in different categories; the two most common are semi-ambulant or non-ambulant people, based on whether they can walk to

some degree, or not [25]. Because of these differences, evacuation procedures should not necessarily be the same for all mobility-impaired occupants.

In the case of semi-ambulant occupants, research has shown that if they have some capacity to walk by themselves, they generally move faster without any direct help [66, 67]. The best way to help them is to ensure that they are free to move and are not caught in crowded corridors or staircases. The design of the building and the evacuation route layout can have a major impact on the evacuation capability of the occupants [68]. People prone to frequent spasms, however, are more likely to benefit from help [67]. Non-ambulant people are those who cannot walk by themselves in any way, and must use a wheelchair or be carried. They are the people for whom the question of egress is of greatest concern. There are, however, options to provide them with satisfactory life safety measures.

5.1.1 Lifts and Transfers

If the evacuation plan favours the everybody-out option and, assuming safe elevators are not available, everyone will have to evacuate using the stairs. One option for the non-ambulant occupants is to be carried down the stairs. However, most people with mobility impairment prefer the option of horizontal evacuation to the outside of the building or to another compartment [69]. Usually the decision to carry down a mobility-impaired person is the last option that should be considered [70].

Many reports have been published explaining techniques to carry people down stairs. One conclusion is very clear: no one lift is ideal for every situation [71]. Each type of lift has advantages and disadvantages that must be carefully weighed when selecting an appropriate lift. The non-ambulant person is often able to indicate which method is best suited to him or her.

Each type of lift requires that the carrier and non-ambulant person receive training to be used efficiently [44]. Carrying a non-ambulant person requires movement that can be strenuous and risky. Untrained people can easily injure themselves or the non-ambulant person in attempting to lift another person. Without appropriate planning and training of the potential carriers, it is unlikely that non-ambulant persons can participate in a total building evacuation where only stairs will be used [67].

Further biomedical assessment is needed to determine appropriate lifts for different situations. For example, previous studies have found that the traditional "fireman's carry" should not be used as it compresses the chest of the person being carried. The choice of lift depends on the characteristics of the person to carry: weight, disability, flexibility, muscle strength. It also depends on the characteristics of the person(s) carrying him or her and on the building design and area in which the lift is being performed: width of the staircase, number of floors to travel, etc.

If a person is being carried down the stairs without his or her wheelchair, it is strongly recommended that someone follow carrying the wheelchair. Non-ambulant occupants spend most of their time in wheelchairs. They will feel much more comfortable and secure once they have reached safety if they can get back into their wheelchair as soon as possible. Without their chairs, they lose their autonomy and are completely dependent on others to move around.

Rather than simply carrying a non-ambulant person to safety, there are techniques to carry the person while sitting in a chair. Some techniques are used to carry someone seated in a conventional straight chair (e.g., kitchen chair, office chair), while other techniques are used to carry someone in a manual wheelchair. In general, motorized wheelchairs and scooters are much too heavy and cannot be evacuated with the person. People can only be carried in straight chairs and wheelchairs if the width of the staircase allows it [71]. As well, numerous manuals and videos are available on carrying techniques [44, 67, 71, 72, 73, 74, 75].

5.1.2 Evacuation Chairs and Other Devices

Some evacuation chairs have been designed specifically to take people up or down stairs in an emergency. Different models have been tested and are available in some buildings [74]. Typical models have a number of auxiliary wheels that easily step over stair noses to provide a smooth ride during descent. Most are also equipped with brakes, belts, kickstands and footrests to ensure the security of the rider.

During an evacuation drill in a highrise building in Montreal, firefighters used such a chair to evacuate two mobility-impaired occupants. It was found that training improved the efficient use of such a special chair. Even though the second person was evacuated down a staircase that was narrower than the first, the time to evacuate was less during that second trial. The speed of descent and the manoeuvrability of the chair increased significantly with practice. Carrying the empty chair up the stairs was somewhat of a problem because it was heavy and did not have a handle that would have made it easier to carry. The chair also had a tendency to open while being carried up the stairs, which was inconvenient and slowed down the firefighters' ascent.

Due to the width of most staircases, it is unlikely that someone can be taken down the stairs using an evacuation chair, while able-bodied occupants are still evacuating through the staircase without causing major congestion [30]. Mobility-impaired people will usually have to wait until other occupants have evacuated and the staircase is free [76]. It is important that there is an appropriate waiting area for mobility impaired occupants. Depending on the building design, the staircase landing may serve as a waiting area.

The decision to purchase such chairs requires considerable thought. The disabled occupants should be consulted to determine their willingness to be evacuated with an evacuation chair. Fire safety officers must decide how many chairs are needed and where the chairs should be kept. Since a number of different models are available, it will also take some time to consider the advantages and disadvantages of the different chairs. Finally, people who use evacuation chairs to evacuate disabled occupants must be identified and properly trained.

5.2 Visually-Impaired Occupants

There is a wide range of visual impairments. Even for those falling in the category of the “legally blind”, many variations are observed. In fact, only a few of those considered legally blind have absolutely no visual perception. Most visually-impaired people have some visual perceptions even though their eyesight is limited in terms of acuity or visual field, such as in the case of people with light vision or tunnel vision. Visually-impaired people can suffer from a variety of conditions such as macular

degeneration, cataracts or glaucoma. Most visually-impaired people, if they don't have any other disability, will be able to participate in an evacuation with a minimum of help.

Familiarity with the building is the paramount factor in the evacuation behaviour of occupants with visual impairments. Occupants who are familiar with the building normally have few problems using their usual exit route, unless this exit is inaccessible or unsafe. In the case where such occupants have to take an unfamiliar route to evacuate, or if they are not familiar with the building, they need guidance to reach safety and avoid obstacles. Visually-impaired people can usually travel in the stairs at speeds comparable to others, especially when the steps follow a consistent pattern. People accompanied by guide dogs should also have no problem evacuating the building by the stairs with the evacuation flow. However, if the evacuation is conducted under emergency lighting, the occupants with visual impairments who rely on their visual residue to move around could travel in the stairs at a speed 50 to 80% slower than sighted people [77]

Many visually-impaired persons rely heavily on the surrounding sounds to orient themselves in a building. The alarm sounding may very well prevent them from hearing most of the ambient noise, consequently depriving them of one of their means of orientation [58, 67, 78]. A lower alarm sound in the circulation area could help them use auditory cues to move around. They also rely on their other senses; for example, if smoke were present in the staircase, they would not see it, but would likely be able to smell it and feel the heat on their face and hands.

The 1995 National Building Code of Canada requires that raised characters be placed in elevators and on staircase access doors on each floor to indicate the floor number [14]. The Americans with Disabilities Act (ADA) requires that raised and Braille characters be placed on exit doors; these measures are useful but can only be used for occupants who know where the doors are located [11].

5.3 Auditory-Impaired Occupants

In 2001, it was estimated that 10% of the Canadian population or one person in 10 was suffering from a significant hearing loss. As reported on the Canadian Hearing Society website: "Accurate statistics on hearing loss are very difficult to obtain. Most of the research and statistics gathering rely on self-identification and an inconsistent use of terminology and definitions. It is very common for people to deny their hearing loss. In addition, many hard of hearing people who have adapted well to their hearing loss, their hearing aids and other assistive listening devices may report that they have no difficulties hearing and are therefore excluded from the statistics" [79]. It is expected that this proportion of people with hearing loss will increase over years with the demographic trend of our aging society.

Hearing impairment can be congenital, acquired or associated with normal aging (in the latter case it tends to be more prevalent in men). People suffer from auditory impairments to varying degrees. Some people have problems hearing specific ranges of the sound spectrum; for example, many older people may have difficulty hearing sounds at frequencies over 2000 Hz while they can very well hear sounds at 500 Hz or less, such as normal speech. Since most smoke alarms and fire alarms are emitting signals in the mid to high frequencies, many people with hearing loss may not perceive such signals [80, 81]. To account for this variety of impairments, evacuation procedures must

be adapted to accommodate occupants with hearing loss. First, and most important, since the fire alarm providing an auditory warning may not be perceived, a plan to alert hearing-impaired occupants must be prepared. Secondly, instructions during an emergency must be provided to them through means that they can hear or understand.

In their daily lives, people with hearing impairments use a number of visual signals to compensate for their hearing problems. For example, flashing lights are coupled to auditory signals to inform them of a phone or doorbell ringing. Such lights could also be used to signal a fire alarm. Research has been carried out on visual alarms and on their success rate in waking sleeping occupants [82]. Visual alarms studied included strobe flash and incandescent lights. Researchers found that visual alarms are as effective in waking hearing-impaired people as audible alarms are at waking hearing subjects. They have also determined that strobe lights were much more effective than incandescent bulbs.

There was concern in the past that strobe lights were capable of triggering seizures in people suffering from epilepsy. This problem has been corrected with alarms flashing at frequencies between 1 Hz and 3 Hz [11]. Such issues must be considered when installing visual fire alarms. The question of the number and location of the visual alarms must also be evaluated in relation to their visibility, installation and maintenance costs. The presence of visual alarms, when supplementing auditory alarms, can also benefit hearing occupants, especially in areas where the background noise level is very high, such as casinos, arcades or discotheques.

Telephone devices for the deaf (TDD) and teletypewriters (TTY) are now widely used. Such systems could be used to give information to the hearing impaired that would otherwise be given over a P.A. system. Telephones with captions can provide essential information. Provision must be made to ensure that TDD's move with a hearing-impaired occupant, should they move about in a building. To counteract this problem, some hearing-impaired workers at Public Works and Government Services Canada are equipped with a small vibrating pager, which they carry when they move about in the building. The pager is combined with a small liquid-crystal display on which short messages can be read. These pagers and displays are used for daily instructions; emergency warnings can also be sent via this means. A number of other devices are available for the hearing-impaired and may also offer valuable solutions [67].

When providing fire safety information or training for the hearing-impaired, the method of communication must be adapted. Many of those who have had a hearing impairment since birth have weaker language skills than the average person [83]. Using simple words and simple sentence structures should make it easier to get the message across. Seldom used words such as “Evacuate”, can be replaced by more common phrases such as "Get out" while still conveying the correct message.

5.4 Intellectually-Impaired Occupants

Limited research has been conducted on evacuation procedures for intellectually-impaired occupants. Most research on this subject presents specific case studies, where a person with an intellectual disability has been trained to evacuate a building under various stimulus conditions using reinforcement [84]. Long-term training and constant reminders appear to be the best approach for this group. It is likely that most intellectually-impaired individuals found in highrise or public buildings will either be

accompanied, or if they are by themselves, will only be slightly impaired. Individuals with serious intellectual impairments are generally under supervision or care in special care facilities.

According to the literature available on the subject, intellectually-impaired individuals can be trained to respond to a fire alarm by evacuating the building. Many trials are needed, however, to achieve appropriate behaviour. Training must be repeated periodically to ensure that the procedures learned are not forgotten [84]. Further it would appear that evacuation skills acquired through daytime training do not effectively transfer to nightime evacuation scenario [85]. It is also of some concerns if skills developed for a specific environment are transferable by the person to other buildings.

6.0 CONCLUSIONS

The risk of fire cannot be completely removed from modern buildings. Many alternatives, however, are available at a reasonable cost to ensure an acceptable risk-to-life for all occupants, including occupants with disabilities. The first step should be to decide on a philosophy: either all occupants exit the building, or safe areas are designed so that some or all occupants can find refuge during an emergency. Once an approach is selected, a procedure must be established, clearly defining evacuation actions to be performed by all occupants. The life safety measures implemented in buildings involve all occupants, whether disabled or not. At one point, anyone may be affected by an impairment, or be called upon to assist someone who is disabled, so it is imperative that everyone be aware of the procedures. To convey the information to the occupants, the emergency plan should be posted in the building and distributed to occupants. Regular training and practice for all occupants is an essential part of any successful fire safety procedure.

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