ELEVATOR USE FOR EGRESS: THE HUMAN-FACTORS PROBLEMS AND PROSPECTS

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ABSTRACT

Elevator use for egress is an increasingly discussed topic in the technical and regulatory literature; however, human factors issues are barely addressed. In a comparative approach covering selected U.S. and British developments, the departure from a long tradition of prohibiting elevator use for egress is discussed in terms of attitudinal impediments, public policy toward people with disabilities, evacuation capability or mobility demographics, information needs and human behavior generally in emergencies, and life safety options including egress and refuge.

NOMENCLATURE

Although the authors come from both sides of the Atlantic the paper uses North American terminology. For example, the term "elevator" is instead of "lift." Similarly, "egress" is used in place of the British term "escape." "Exit stair" is used in place of "protected stair." Generally, instead of widely used terms such as "the handicapped" or "the disabled," we prefer to say, "people with disabilities." Better still are specific terms such as "person using a wheelchair," or "person unable to use stairs." These preferred conventions properly identify the fact that we are dealing first with individuals and only secondarily with their *specific* functional adaptations or disabilities.

PURPOSE

The objective of this paper is to help balance the Symposium's likely emphasis on technical information about physical aspects of elevators and fire with information and ideas on certain human factors that interact with the physical aspects. Among the human factors considered are:

- Attitudinal impediments to greater reliance on elevators for egress,
- Motivations and capabilities of people to accomplish various life saving behaviors, and
- The information needs of people during emergencies in which elevator use might be important.

A major goal of this paper is presentation of some elevator use procedures or logistics in the context of the overall emergency response, including evacuation and refuge facilities plus activities. While it cannot provide a complete treatise on these topics, the paper should encourage much-needed discussion and technical development.

INTRODUCTION

There is little technical literature, from the U.S., addressing how emergency egress using elevators can be handled logistically and how such egress relates to more-conventional emergency egress by exit stairs. This might be due to widespread professional concern about, and

[1] Although all co-authors contributed information and ideas for the paper, the opinions expressed herein are those of the lead author.

traditional prohibition of, elevator use for egress during fire emergencies.

Even in the context of this Symposium there might be some participants who will be unhappy if they perceive an undermining of decades of their effort to convince building users and others that egress by elevator is *not* a workable, safe, or permitted option. Strenuous opposition (to proposed regulatory changes involving such elevator use and related refuge concepts) might come, for example, from some fire service representatives. Here it should be noted, however, that the Life Safety Code, NFPA 101-1988, Appendix A-7-4.1 states:

> "The use of elevators for emergency evacuation purposes where operated by trained emergency service personnel (building personnel, fire personnel, etc.) should be utilized in the building evacuation program." (Underlining added.)

A similar note, differing mainly through a specific reference to ASME/ANSI A17.1 where the underlining is shown, has been in the appendix of NFPA 101 since 1981. Part of the confusion or dissension over elevator use for egress arises because of inadequate specification of the expected conditions of elevator operation. Is it automatic or supervised? What is the nature of the fire incident? Has there been an activation of a smoke detector in an elevator lobby or elevator machine room, the important criterion used in ASME/ANSI A17.1, or is there a (small) event elsewhere in the building that does not (yet) endanger the elevators? Also, are elevators and lobbies adequately protected?

Problems of Elevator Use

Although not the major goal of this paper, it is hoped that the Symposium, generally, will clarify the physical conditions in which elevators are considered usable for egress.

Many publications have touched on the dangers of elevator use, either for egress by building occupants or for rescue and suppression activities by firefighters during fires. Such publications note all or most of the following concerns.

(1) Unreliable power supplies and control systems (e.g., call buttons and solid-state circuitry) in fire conditions;

(2) Vulnerability of elevator shafts to smoke and limited escape opportunity when people using the elevators become trapped between floors;

(3) Vulnerability of elevator controls and brakes to water;

(4) Difficulties due to excessive air pressures on doors under some conditions with smoke management measures; and

(5) Concerns about human behavior, often purporting likelihood of hysteria, panic or unreasonable demand for elevators with resulting disruption of their operation.

The objections by public officials to the use of elevators for emergency egress were just as strong and just as valid in Britain as those in North America. Moreover, the hazards were perceived to be similar regardless of the geographical differences.

Public Policy Implications

To some extent, in both Britain and North America, authorities also faced demands, from many people with disabilities, to be permitted to use an elevator for egress. Although not heard so much today in North America, there were often references to a policy loosely called "right to risk." In the U.S., especially, much attention was given by some accessibility advocates to simply getting access to building facilities and services; the question of how life safety was to be achieved was left unanswered and was considered secondary to access. While only recently formally and widely recognized in the U.S., the need to consider life safety simultaneously with accessibility was central to the development of British standards. The "right to risk" argument was viewed, in Britain, as something that a responsible society cannot accept. Neither could it be contemplated that public officials charged with safety enforcement would be improperly influenced by such arguments. The Foreword to the British Standard, BS 5588:Part 8: 1988, "Code of practice for means of escape for disabled people," (BSI, 1988) states:

> "A basic tenet of building law is that access provision has to be linked to egress provision, and it is on this account that this code has been prepared."

nterpreting what is actually required, under British law, requires professional judgement by the enforcement officer, taking into account the structure, hazards and occupancy of a building and based on requirements, for example, in the Fire Precautions Act, that the building be "provided with such means of escape in case of fire as may be reasonably required in the circumstances of the case."

While on the topic of public policy, it is also important to describe a basic difference in ideology, in Britain and in the U.S, regarding accommodation of people with disabilities. In Britain, concern for these people has been generally viewed as a public welfare issue. In the U.S., the concern has been seen more as a matter of civil rights. This basic public policy difference between the two countries has been described by Goldsmith (1983) and is reflected in the recent landmark civil rights legislation known as the Americans with Disabilities Act (ADA) of 1990 (Public Law 101-336 signed in July 1990).

Human Behavior

Regarding the concern about inappropriate human behavior in emergencies (stated as item 5 above) it seems clear, on the basis of evidence from general behavior in fires and other life-threatening events plus evidence on people's evacuation behavior with stairs, that the fears about inappropriate behavior are largely unwarranted. This is especially true if people are provided — both before and during the emergency — with realistic information about their options and about the conditions related to those options. Although disasters can be physically and psychologically harmful to people, we can see some truth in the opinion expressed by some investigators of disaster behavior: "Disaster brings out the best in people" (Bryn, 1973). The term "best" refers, for example, to altruistic responses which often characterize coping behavior. Furthermore, these experts often emphasize that the greatest need, of people in emergencies, is for useful information.

Nonetheless, despite findings from studies of actual behavior in emergencies, it will be difficult to change some long-held attitudes about behavior of people in emergencies (item 5 above). One reason is that there has been little if any research in the last few years on the general matter of behavior of people in fires (i.e., work subsequent to that reviewed by Bryan, 1988). Neither has there been work on the particular topic of evacuation logistics plus behavior when elevator use is an option. Apparently, not since 1977 has the technical literature (in the U.S.) even addressed simulation of egress by elevator from a logistical perspective (Bazjanac, 1977; Pauls, 1977). Even this literature is not well known in the firesafety field.

It is especially important to hold realistic attitudes about human behavior in emergencies when we are dealing with emergency egress, including that on stairs and in elevator systems. Some problems, such as inappropriate overcrowding behavior with elevators, are likely to be more perceived than real. The reality has been, and is expected to continue, that people tend to take each other's needs into account to at least the same extent as is normally the case. Indeed, altruism is even more marked in emergencies. This characteristic complements that of information-seeking behavior, a topic again addressed later in this paper.

History of Concern about Life Safety for People with Disabilities

The literature on human behavior and on elevator-based evacuation logistics largely predated the marked, recent growth of concern about egress, refuge, and life safety generally for people with disabilities. Even with the increased concern over the last few years in the U.S. and Britain, about emergency egress for people with disabilities, nobody has picked up the incomplete work on evacuation logistics. Moreover, for noninstitutional buildings, little has been done to spell out the details of operational aspects of refuge concepts. A notable exception is the British Standard, BS 5588:Part 8: 1988, in which details of operational aspects are provided (BSI, 1988).

Much of the history of the concern, research, and regulatory developments on life safety for people with disabilities has been reviewed in publications and presentations by Pauls and Juillet (e.g., the article, "Recent social and technical developments influencing the life safety of people with disabilities," Pauls and Juillet, 1990). There has been an international scope to the work of these authors. However, with current developments, their focus is on the U.S. scene, especially with regard to proposals recently processed through the National Fire Protection Association (NFPA) Life Safety Code (NFPA 101, 1991 edition), the International Conference of Building Officials (ICBO) Uniform Building Code (1991 edition), and the Council of American Building Officials (CABO) Board for the Coordination of the Model Codes (BCMC) report on accessibility scoping, means of egress, and mainstreaming.

National concern for life safety of people with disabilities was first marked by a seminar, "Fire Safety for the Handicapped," held in Edinburgh, tland in 1975. A few years later, in the U.S.A., National Task Force on Life Safety and the ndicapped, Inc. was formed. Along with other, re-established organizations it held the first of major conferences in the Washington, D.C. a in 1979 (Levin, 1980). The proceedings of conference provide the best summation of lve key topics (each the focus of preconference rkshops and conference panels):

codes and standards
emergency preparedness planning
building design
education
consumer interests
products
alarm systems
refuge
egress
self-protection
management actions
emergency service actions

Much discussion at this 1979 conference (and a follow-up conference in 1980) centered on the d for special requirements to be incorporated in Life Safety Code, NFPA 101. Attempts were de to introduce such requirements, related ecially to areas of refuge for people with bility impairments, in the 1981 and 1985 tions of the Life Safety Code. Similar but less minent efforts were made at about the same e to introduce new requirements for areas of uge in the three U.S. model building codes. All these attempts were unsuccessful.

During 1982 and 1983, a study funded by the nadian government provided useful information evacuation techniques for people with abilities affecting hearing, vision and mobility hnson, 1983). Also, 1982 marked the beginning a joint U.S.-Canadian study of elevator use for cuation during fires. Numerous publications available on this work by Tamura at the tional Research Council of Canada and Klote at U.S. National Bureau of Standards, now the S. National Institute for Standards and chnology (e.g., Klote and Tamura, 1986).

Among several conferences and satellite econferences held between 1983 and 1989 was a e-day program, "Meeting special needs of the abled in evacuation and sheltering systems," onsored by the U.S. Federal Emergency anagement Agency (FEMA) as part of its nergency Education Network (EENET) satellite leoconference series. Building design features, anagement activities, and one-to-one, egress assistance techniques were addressed in this program.

The 1980s saw much attention to the problem in North American and European standards and codes. The National Building Code of Canada introduced special refuge requirements in its 1985 edition (following the lead of the Province of British Columbia which brought in refuge requirements in 1979 and 1984). In 1987, France issued new fire safety rules including requirements for areas of refuge for people with disabilities. Based on some substantial early effort by the U.K. Home Office, the British Standards Institution, in February 1988, issued a new British Standard, BS 5588:Part 8, "Code of practice for means of escape for disabled persons" (BSI, 1988), which included extensive guidance on use of elevators for egress during fires and built upon BS 5588:Part 5. "Code of practice for firefighting stairways and lifts" (BSI, 1986). Background to these BSI standards was provided in papers by the Home Office (1984) and by Gatfield (1989a, 1989b). These standards cover construction, elevator design and control, power supplies, communication systems and management control.

The U.S. Architectural and Transportation Barriers Compliance Board (ATBCB) sponsored studies, first, on alarms for people with hearing impairments and, later, on egress procedures and technologies for people with disabilities, a study resulting in six reports (e.g., Pauls, 1988a, 1988b) one of which (Pauls, 1988c) was a source document for proposals to the Life Safety Code, NFPA 101, and for the BCMC report on accessibility and egress for people with disabilities (BCMC, 1990). Public Works Canada also sponsored studies by Pauls (1988d, 1988e), paralleling those sponsored by the U.S. ATBCB and influencing a new Canadian Standards Association national standard, "Barrier-Free Design, CAN/CSA-B651-M90" (CSA, 1990).

BCMC's recommendations are usually submitted as proposals to the respective revision processes of BCMC's four constituent organizations: the Building Officials and Code Administrators International (BOCA), International Conference of Building Officials (ICBO), National Fire Protection Association (NFPA), and Southern Building Code Congress International (SBCCI). In September 1990, ICBO anticipated BCMC's proposal, addressing the refuge/egress provisions, with ICBO membership approval of a new Chapter 31 to the Uniform Building Code, 1991 edition, with requirements for "areas for evacuation assistance" (areas of refuge) which included the option of elevator use for egress. In November 1990, NFPA membership approved a "menu item" for the 1991 edition of the Life Safety Code covering areas of refuge and elevator use for egress. During 1991, the memberships of the two other BCMC organizations, BOCA and SBCCI, are expected to process the BCMC recommendations for areas of refuge and elevator use for egress. This would result in revisions to the BOCA National Building Code and the Standard Building Code respectively.

As in Britain, the elevator egress requirements evolving in the U.S. do not affect the required capacity of conventional egress routes. Also egress-related elevator use is expected to be restricted to those people who cannot safely use the exit stairs.

Mobility Disability Demographics. It should be recognized that most of the people, who are sometimes included in the group improperly called "the disabled" (reported as including 43 million Americans to help justify passage of the ADA), are quite capable of using stairs. According to U.S. demographic data noted by Pauls and Juillet (1990), only about 0.3 percent of the civilian noninstitutionalized population use wheelchairs. A similar percentage use walkers for getting around. The percentages of noninstitutionalized civilians 65-74 years, using wheelchairs and walkers, are 1.1 and 1.2 respectively. The percentages of those 75 years and over using wheelchairs and walkers are 2.3 and 4.8 respectively. Generally, in the U.S., about 3 percent of noninstitutionalized civilians use one or more mobility aids (i.e. wheelchairs, walkers, crutches, canes, special shoes, braces, artificial limbs). This rate is only 1.8 percent for the 0-64 age group and rises to 8.3 percent for the 65-74 age group and to 22.4 percent for the 75-and-over age group. In buildings used predominantly by people under 65 years of age, we can assume that about 3 percent of building occupants have mobility disabilities but can independently use exit stairs if moving behind others who are able to move faster. We can *conservatively* assume that 0.5 percent, in such buildings, cannot use stairs without assistance. This percentage includes users of wheelchairs, walkers, or crutches. They might need elevators.

Summing up developments: generally the last fourteen years have witnessed many developments on this topic, including many publications on research, standards, and recommended safety programs. Indeed it came as a surprise -- even to researchers active in the area -- that a recent published literature review of the area included some 350 documents (Pauls, 1988e). A more recent, unpublished review included 526 items (Pauls, 1988b). Therefore, this brief paper can do little more than merely introduce a small part of the background to the matter of egress by elevators for people unable to use exit stairs.

LOGISTICS OF EGRESS VIA ELEVATORS

Bazjanac's Simulations of Elevator Use for Egress

Bazjanac and colleagues at the University of California, Berkeley, performed computer simulations of elevator use for evacuating all or portions of tall office buildings (Bazjanac, 1977). Although funded for two years by the National Science Foundation this work had little impact in firesafety and standards organizations. An assumed reliance on *automatic operation* of elevators, with procedures calling for first response *to* the fire floor, might have had something to do with the work's small impact. Indeed some attitudes against such egress methods might have hardened because of Bazjanac's work.

Partial Evacuation. The simplest strategy explored by Bazjanac and his team was to have elevators operate in a "down-peak" mode and respond only to three floors in an evacuation zone. The computer simulation predicted that the last person would be evacuated from any three-floor zone in less than eight minutes. The simulation also suggested that this time could be improved, to less than five minutes, if people were unloaded at an intermediate floor rather than going all the way to the ground floor. Some uncertainty was noted about how short the actual time might be because "it is impossible to predict what percentage of the floor population might escape through means other than elevators in an actual emergency in which elevators *are available*" (Bazjanac, 1977). It was concluded that the "fastest method of evacuation of any individual floor is the simultaneous dispatch of all available elevators to that floor" and "the success of this strategy depends entirely on the ability to get everybody on the floor to the elevator lobby in the short time it takes the elevators to reach the floor and load people."

Complete Evacuation. Bazjanac's simulation suggested that all buildings could be completely evacuated, using elevators, in less than 30 minutes. It was noted that, because of their use of elevator zones and high-speed elevators, some tall buildings could be evacuated in less than half the time of buildings with half as many floors.

The Need for Management Control. Bazjanac compared results of an actual complete evacuation of a 22-story office building in San Francisco with results of a computer simulation. In the actual evacuation, which occurred because of smoke spread from a fire, "using both elevators and stairwells it took over half an hour to evacuate the building. The evacuation caused a lot of confusion and was far from efficient." The evacuation was simulated with the elevators in normal "down-peak" mode. "The simulated evacuation of the entire building (with no use of stairwells) was accomplished in 8 minutes and 20 seconds." The difference was attributed to "the extent of control exercised in the evacuation exercise." Bazjanac noted that "all experimental results are based on the assumptions of a steady flow of people to be evacuated to the elevators and the smooth loading of elevators without any delay. . . . In fact, the ability to provide such controlled loading of elevators is by far the most critical factor for accomplishment of fast evacuation."

By way of conclusion, Bazjanac contended that "the decision to pull elevators out of service should be made according to the spread of danger in each individual case by an authorized person on location—not a priori through legislation."

Simulations by Pauls

While Pauls' simulation efforts were contemporary with those by Bazjanac, they (and their funding) were far less extensive than Bazjanac's. Pauls presented a graphical simulation of a few procedures in which elevators were used — in *non*-automatic mode and with fire service supervision — in conjunction with stairs to evacuate tall office buildings (Pauls, 1977). Like Bazjanac, Pauls considered treating sky lobbies (the floors where elevator zones overlap) as "refuge areas" but the usage was quite different; Bazjanac treated these floors as ones to which the elevators would take people; Pauls used these floors as points of departure for the majority of people who would first utilize exit stairs to move downward to the closest sky lobby. From this level the building occupants could then utilize elevators serving a zone other than one in which a fire was occurring. This should be safer and would also leave the fire-zone elevators — if safe — free for possible use by firefighters.

Graphical Simulation. First published by Pauls (1977), Figure 1 is a graphical simulation showing the complete evacuation of 4500 persons, in 35 minutes, from a 41-story office building. Of the total time, fully 15 minutes are assumed to be needed for fire department response, elevator capture (Phase I in ASME/ANSI A17.1), elevator system checking, and dedicated (Phase II) use to remove people, unable to walk down stairs, from all of the 40 above-grade, office floors. The other 20 minutes are used for express trips from three refuge floors or sky lobbies to which ambulatory, stair-capable persons descend by means of the exit stairs before boarding elevators in an organized fashion. The simulation assumes that there are four 3500-pound (1600 kg), 19-passenger elevator cars per elevator zone with vertical speeds in the range of 800 to 1200 feet per minute (4.1 to 6.1 m/s). Due to fire conditions and fire fighting, one zone of elevators is assumed to be unusable for the egress from these transfer floors. If stair use were increased — with one-third of those above the 12th floor using stairs for their entire egress, the evacuation time could be reduced to under 30 minutes. A superimposed simulation of 4500 persons able to use stairs, utilizing only the exit stairs, predicts a total evacuation time of nearly 40 minutes, including 27 minutes of queuing by the uppermost occupants before they can descend. For this simulation, each of the two exit stairs is assumed to be 44 inches (1120 mm) in nominal width and each is assumed to be optimally used.

General Prediction. Figure 2, also from Pauls (1977), can be used to predict evacuation times for various building heights, evacuation procedures, and populations utilizing stairs alone or elevators with stairs. As with Figure 1, it is assumed that there are four 3500 pound, 19 passenger elevator cars per elevator zone with vertical speeds in the range of 800 to 1200 feet per minute (4.1 to 6.1 m/s). Although evacuation time increases linearly with total building population when only stairs are used, the combined use of elevators and stairs — with a conservative 15 minute period allowed before mass use of elevators begins — is shown as requiring approximately 30 to 35 minutes, starting from the first alarm. A less conservative 5 minute delay in beginning elevator egress is also shown. However, it is felt that such a short delay does not permit sufficient time for the supervisory personnel (firefighters or specially trained building staff) to assess the situation and decide on the best course of action for the particular situation encountered.

Finally, as discussed more completely elsewhere (Pauls 1980, 1988f), the population figures assumed in Pauls' simulations are actual occupants, not building-code occupant loads based on one occupant per 100 square feet (9.3 sq. m) of gross floor area. The latter are generally too high by a factor of two or more for office buildings.