The Relationship Between the Design of the Built Environment and the Ability to Egress of Individuals with Disabilities

Keith M Christensen, Shawnee D. Collins, Judith M. Holt, & Curtis N. Phillips
Utah State University

Abstract: Recent catastrophic events have brought into focus the importance of planning for the evacuation needs of all persons, regardless of their diverse physical and mental abilities. While these efforts are primarily concerned with the activities before and after a crisis, there is also a renewed interest in evaluating how effectively the built environment accommodates the needs of all individuals during a crisis. This discussion focuses on the current body of knowledge concerning the relationship between the design of the built environment, the collective egress behavior of complex decentralized groups of individuals, and the ability of individuals with disabilities to effectively egress from the built environment during emergency events.

Key Words: emergency, built environment, egress

Introduction

Recent catastrophic events demonstrated an unacceptable, disproportionate effect of emergency evacuations on individuals with disabilities. These events highlight policies and practices that are less than effective and possibly counterproductive. Research, policy, and practice regarding critical aspects of emergency evacuations focus primarily on the individual with a disability, followed by the evacuation process, and then the built environment (Christensen, Blair, & Holt, under review). This focus results in policy and planning that emphasizes “helping the disabled individual to adjust and accept the existing environment rather than upon altering the environment to accommodate the needs of disabled persons” (Hahn, 1985).

Purpose and Method

Emergency evacuation research, policy, and practice will continue to be ineffective until premised on the understanding that disability is a product of the environment rather than inherent in the individual. Emergency evacuation research, policy, and practice must recognize and respond to the environment first. Christensen, Blair, and Holt (under review) describe four distinct forms of emergency evacuations as they relate to individuals with disabilities: protective, preventive, rescue, and reconstructive. These emergency evacuation forms are defined by classifying the timing (long-term, short-term) and period of evacuation (pre-impact, post-impact). While the built environment is an essential component of each form of emergency evacuation, the emphasis on mitigating the immediate effects of health and safety threats in a rescue evacuation (short-term, post-impact) accentuates the role of the built environment. Under these conditions, when one exits a burning building, for example, there may be insufficient time to adapt to barriers in the environment, requiring that the environment accommodate the behavior of the individual without extraneous supports.

In an effort to facilitate this shift in emphasis to the role of the built environment, an exhaustive review of emergency evacuation research concerning individuals with disabilities was conducted. Initially, a number of databases, such as EBSCOhost and Google Scholar, were searched for publications focused on individuals with disabilities and evacuations, the built environment, emergencies, and other related terms. Roughly one third of the reviewed literature was identified in this way. The remainder was identified by reviewing the citations of previously identified literature, a process which continued until unidentified citations no longer appeared in the literature. During this process, literature was selected for inclusion in this review when there was both a clear focus on an individual(s) with a disability and a focus on the role of the character and design of the built environment. A third criterion was included to identify studies which also focused on evacuations or a closely related aspect of an evacuation. Four studies, concerning navigating the built environment with a visual impairment, dementia, or a cognitive disability, were included as navigating the environment is an important aspect of an evacuation. One study, which may meet the inclusion criteria, was not included in this review as it is only available in Swedish (Hallberg and Nyberg, 1987). Of the three criteria, the role of the character and design of the built environment was the limiting criteria. The identified literature focused on the design of the built environment as it relates to the ability of individuals with disabilities to egress in emergency evacuations is described in this manuscript. From this body of knowledge, future research priorities and general implications are drawn.

Review of the Built Environment Evacuation Literature

The following summary of the literature, focused on the design of the built environment as it relates to the ability of individuals with disabilities to egress in emergency evacuations, is presented by emphasis. The majority of the available literature is a description of the behavior of the individual with a disability in response to the built environment, described almost solely by speed of egress (i.e. how quickly an individual is able to travel along an evacuation route). The majority of the remaining literature is either a description of individuals with disabilities as a constraining factor in the built environment or a description of individuals with disabilities interpreting the built environment.

Individuals with Disabilities' Speed of Egress in the Built Environment

After reviewing the literature, 44% of the articles included in this review addressed individual with disabilities' speed of egress. In general, the authors measured speed of egress in terms of rate (e.g., meters per second or 70% the rate of an individual without a disability). Moreover, at least one study measured speed of egress in terms of duration (i.e., the duration between the sound of the alarm and the individual exiting the building). Many of the articles identified factors of the built environment possibly influencing an individuals' speed of egress (e.g., stairs); however, with one possible exception, the authors did not experimentally evaluate the effects of the built environment on an individual's speed of egress. The following 11 studies targeted an individual with disabilities' speed of egress.

Sime and Gartshore (1986) investigated the assisted egress speed of an individual in a wheelchair from a six story building. The authors collected data during an unannounced evacuation drill where two men in their 20s, who had no knowledge of the research or special training in assisting in the evacuation of a person in a wheelchair, carried an individual in a wheelchair down the evacuation stairway. The authors determined the average descent speed of the three individuals was .41 meters per second; only slightly slower than the typical .5 meters per second descent speed for a non-wheelchair user. The individual in the wheelchair instructed the men providing assistance as to the proper manner for safe assistance. The authors concluded that the three individuals did not pose a serious obstacle to other evacuees, but note that stairways should be closer to the maximum width of 62 inches instead of the minimum of 47 inches to allow overtaking evacuees to pass. Furthermore, they recommended future research to evaluate different stair widths for evacuation. The authors also suggested that the inclusion of "passing bays," similar to passing lanes on a highway, might be useful in allowing those with faster egress speeds to pass others.

Similarly, while developing a procedure for including mobility-impaired individuals in evacuation models, Rubadiri, Ndumu, and Roberts (1997) measured the speed of six individuals with wheelchairs along a defined evacuation route. The findings were used to develop an evacuation performance index described as the ease of evacuating an individual with a disability relative to the ease of evacuating an individual without a disability. The index is determined by the unassisted speed of the individual through built environments of various types: straight and obstacle-free route, an identified section of an escape route, and the escape route that the individual will use in an emergency. In this way, the effect of the built environment on the egress of the individual with a disability is addressed, but only for the specific route. The factors in the built environment which affect the speed of the individual are not addressed, although various built environments could be compared based on the related evacuation performance index for a specific individual.

Moreover, Pearson and Joost (1983) conducted a series of evacuation studies in a residential setting according to various disabilities including blind occupants, wheelchair users, and the elderly. The authors discussed the mean speed of evacuation for the various groups and concluded that individuals with disabilities had longer, but sufficient, evacuation times. However, the authors did not address the condition of the built environment through which the participants egressed.

In addition to the studies discussed above, three studies evaluated speed of egress for individuals with visual impairments in various built environment. The first study, conducted by Wright, Cook, and Webber (1999), evaluated the effects of different emergency lighting conditions and wayfinding provisions on the mean walking speed of 30 individuals with visual impairments walking through an egress route. Mean walking speeds were also compared with those of individuals without disabilities completing the egress route under the same lighting and wayfinding conditions. The authors found that "visually impaired subjects walk at 43 to 69 percent the rate of a normally sighted person on level parts of the route, and at 70 to 87 percent on the stairs" (p. 39). Individuals with visual impairments achieved the highest walking speeds under both normal lighting conditions and powered emergency lighting systems, such as light emitting floor strips and overhead emergency lighting. Non-powered lighting systems had a negative effect on walking speeds.

The second study, by Soong, Lovie-Kitchin, and Brown (2000), evaluated the differences in preferred walking speed for individuals with visual impairments using a sight guided technique and individuals using a non-sighted guide technique (i.e., walking unassisted along a straight, unobstructed path). The authors found no significant differences in preferred walking speed between the two experimental conditions.

In the third study, Clark-Carter, Heyes, and Howarth (1986) measured the walking speed of people with visual impairments in environments of various complexity. The authors found that the walking speed of individuals with visual impairments is negatively affected by the increasing complexity of the travel environment. In addition, individuals with visual impairments who use guide dogs are not as affected by complex built environments as those who use long canes.

Dunlop, Shields, and Silcock (1996) conducted a series of experimental programs to determine the "numbers of disabled people using different types of buildings, the nature of their disabilities and their corresponding capabilities… effecting their escape in the event of an emergency" (p. 154). These studies were commissioned by the Department of the Environment in London and are described in detail in the final report, *Escape of disabled people from fire: a measurement and classification of capability for assessing escape risk* (Shields, Dunlop, & Silcock, 1996). It is important to note that their study methodology is based on disability defined as "the restriction or lack of ability to perform activities in a manner which may be considered normal for a human being" and "could be measured in terms of capability" (p. 3-4), a premise that may have led to the intense scrutiny of individual functional competency rather than the built environment. The authors conclude that "all other things being equal, the presence of a seeing or hearing disability may not be as critical as conventional wisdom suggests in emergency situations" (p. 124). However, the conclusions of this report should be interpreted as referring to comparisons between classifications of individuals with disabilities according to functional competency and not the built environment. The authors describe the findings of these experimental programs in a series of four publications described hereafter.

Boyce, Shields, and Silcock (1999a) determined movement capabilities of 155 individuals living in large day centers on level surfaces, movement on ramps, and movement on stairs. Results are reported in four disability categories: unassisted ambulant, unassisted wheelchair users, assisted ambulant and assisted wheelchair users. One hundred seven of the participants moved through the horizontal route without assistance at a mean speed of 1.0 m/s. Moreover, 14 wheelchair users moved through the horizontal section at mean speeds of .89 m/s and .69 m/s for electric wheelchair users and manual wheelchair users, respectively. Ambulatory individuals requiring assistance walked the horizontal section at various speed (range = .21-1.40 m/s, M = .78 m/s). Assisted wheelchair users went through the horizontal section fastest (M = 1.30 m/s). On ramps, only 54 participants moved upward and downward on ramps without assistance; the mean speeds were .62 m/s (upward) and .60 m/s (downward). Only one individual with a wheelchair used the ramp unassisted at a mean speeds of .7 m/s (upward speed) and 1.05 m/s (downward speed). Eight ambulatory individuals used the ramps with assistance at mean speeds of .53 m/s (upward) and .69 (downward). Seven individuals using manual wheelchairs moved on the ramps with assistance with a mean upward speed of .89 and downward speed of .96 m/s.

A second experiment within the same study evaluated individuals' (N = 136) speed of moving through a 90 degree bend. The authors reported results for all four groups: 95 ambulatory individuals traversed without assistance (M = 3.6 sec.), 11 wheelchair users moved through without assistance (M = 3.5 sec. for electric wheelchair users and 4.2 sec. for manual wheelchair users), 16 ambulatory individuals moved through bend with assistance (M = 4.6 sec.), and 14 wheelchair users moved through with assistance in two to four seconds. Finally, the researchers studied individuals (N = 34) movement on stairs: 30 participants moved on the stairs without assistance (M = .38 m/s), four participants required assistance (M = .29 m/s).

The second study by Boyce, Shields, and Silcock (1999b) evaluated egress capabilities of individuals with disabilities in public-assembly buildings. The authors used 1989 census data from Great Britain and Northern Ireland to report descriptive statistics (e.g., percentages of children and adults with disabilities able to evacuate without assistance).

Boyce, Shields, and Silcock (1999c) evaluated the abilities of 113 individuals with disabilities to negotiate doors with closing forces ranging from 20 N to 70 N. Between 1.5% and 6.9% (1.5% at lowest closing force and 6.9% at highest closing force) of ambulatory individuals failed to negotiate the doors. For those ambulatory individuals who negotiated the doors, mean times increased as a function of closing force (push range = .32 sec. – 4.2 sec. and pull range = 3.5 sec. – 4.6 sec.). Percentage of failures increased for individuals using wheelchairs (N = 7) (push range = 14.3% - 28.6% and pull range = 28.6% - 71.4%).

The final study by Boyce, Shields, and Silcock (1999d) evaluated the effects of exit signs (i.e., non-illuminated, internally illuminated, and light emitting diode (LED) signs) on the locating and reading behavior of individuals with disabilities. One hundred eighteen individuals participated in the study (25 with visual impairments). Overall, participants located and read the LED sign before the illuminated and non-illuminated signs.

Individuals with Disabilities as Constraints in the Built Environment

The second most common dependent variable targeted in this literature is the impact of an individual with a disability as a constraint in the built environment. This topic accounted for 24% of the articles included in this review. In general, constraint is defined in terms of how the individual with a disability affects the ability of others to egress during an evacuation. The following six studies targeted individuals with disabilities as constraints in the built environment.

In an early research program, also commissioned by the Department of the Environment, Shields (1993) performed a series of case studies on the evacuation of individuals with disabilities involving a museum, residential home, leisure center, sub-surface station, hospital, and a department store. The author concluded that communication was the critical factor which hindered the evacuation of individuals with disabilities. Additionally, Shields conducted two experiments involving a hotel and a theater to evaluate interactions between individuals with disabilities and those without. Shields found that in the hotel evacuation, individuals who used wheelchairs required 1.9 times longer to evacuate hotel bedrooms than the able-bodied evacuees; were not affected by standard doorway widths (762 mm); did not impede able-bodied evacuees, but did impede other individuals who used wheelchairs. In the theater evacuations, the author concluded that "the orientation of motorized wheelchairs can be just as important in some situations as their location" (p. 63) and that its owner may dominate the evacuation process due to its size and weight.

Moreover, Shields, Smyth, Boyce, and Silcock (1999a, 1999b) conducted a second study evaluating the effects of unannounced fire drills on evacuation of individuals in two residential homes. Only 13 of 22 residents evacuated. The authors discuss the need for evacuation skills during day-time and night-time evacuation, training programs, accommodation strategies, and pre-determined evacuation plans.

In a third study, Boyce, Shields, Silcock, and Dunne (2002) evaluated the effect of an individual using a wheelchair entering the flow of evacuees during an unannounced evacuation. Following the evacuation, researchers viewed video footage of the evacuation and noted that when the wheelchair user entered the stairway, it caused "considerable congestion" and also noted that "at no stage during the evacuation did any evacuee attempt to overtake and pass the wheelchair party, although there was sufficient free width of stair to do so" (p. 144).

Furthermore, Miyazakie, et al. (2004) evaluated the behavior of 30 pedestrians and a wheelchair user. The authors found that the behavior of the pedestrians and wheelchair user influenced the behavior of the other. Moreover, depending on the psychological condition (e.g., competitive, noncompetitive) pedestrian speed changed. The researchers developed a model demonstrating psychological phenomena (e.g., "group psychology") and pedestrian behavior (e.g., speed) in relation to the distance from an individual using a wheelchair.

Additionally, Averill, et al. (2005) described the egress system and evacuation of individuals in the World Trade Center on September 11, 2001. Regarding individuals with disabilities affecting mobility (e.g., physical impairment, wheelchair user, visual impairment), the authors discussed the influence of total distance to an exit on ones ability to exit independently (i.e., as the distance to an exit increases, individuals with disabilities require more assistance). Following their interviews, the authors report that, "51% percent of the occupants in WTC 1 and 33% of the occupants in WTC 2 in 2001, noted that injured and disabled persons in the stairwell were a constraint to evacuation" (p. 159). Following numerous interviews and focus groups, analysts built causal models of the WTC to explore the sources of evacuation initiation delay (i.e., the latency between emergency communication and individuals moving out of the building) and stairwell evacuation time.

Individuals with Disabilities Interpreting the Built Environment

An individual with a disability's ability to interpret the built environment comprised an additional 20% of the articles included in this review. Interpreting the built environment was generally defined as an individual's ability to identify and effectively use certain safety features (e.g., maps, alarms). The following five studies targeted individuals with disabilities interpreting the built environment.

Salmi, Ginthner, and Guerin (2004) compared the effects of environmental features on wayfinding behavior of individuals with mild intellectual disabilities (n = 13) and individuals in the general population (n = 10). The authors found participants with disabilities took longer to exit then individuals in the general population. Information accessible in maps to the general population was inaccessible to individuals with intellectual disabilities.

Moreover, Edelman, Herz and Bickman (1990) explored the behaviors of residents in a nursing home during a fire emergency. The authors determined that the major determinant of the resident's actions was familiarity with the egress routes (85/91 residents used only one of four available stairways due to the familiarity of the used route).

Furthermore, Vanderkooy (2002) investigated the effect of the acoustic characteristics of residential built environments on the ability of individuals with moderate hearing impairments to hear audible alarms. The study concluded that audible alarm signals are altered by intervening walls or doors causing the signal to fall in the range of sounds associated with hearing loss. The author recommended that either the frequency of audible alarms be changed to make the alarm more detectable by individuals with moderate hearing impairments regardless of obstructions in the built environment or that the alarm is located where the built environment would not obstruct the signal.

Similarly, Robertson and Dunne (1998) discussed wayfinding design and suggest including "elements of buildings or aids that maximize the utility of residual vision" (p. 2) and audible cues. The authors then discussed their findings regarding the accessibility of four buildings to individuals with visual impairments. The authors concluded that purpose-built buildings are most accommodating. Furthermore, the authors made recommendations to improve the environments in each of the buildings (e.g., apply tinted film to lights to reduce glare, replace dado rails with handrails, use non-uniform carpet to increase tactile or sound orientation). The authors also surveyed local authorities (e.g., hospital staff, public transportation buildings) and noted that special provisions for individuals with visual impairment were rarely reported. Generally, provisions were the minimum required for building codes and regulations.

In addition, Passini, et al. (1998) performed an experiment with 14 patients diagnosed with dementia of Alzheimer's type (DAT) and 28 healthy elderly people. They were to find the way from a bus stop to a dental clinic inside a hospital. The authors concluded that organizing space in the simplest manner increases the ability of patients with DAT to find their way. Further, they conclude that graphics identifying locations of interest or characteristics of the building must be done in a consistent and simple manner to maximize functional use by patients with DAT.

Select Related Studies of Individuals with Disabilities in the Built Environment

The final 12% of articles discussed in this literature review were included because they addressed issues of an individual with a disability's ability to egress during an evacuation. However, they do not specifically target speed of egress, constraint, or interpretability in or of the built environment.

Yoshimura (1998) conducted a survey of 220 individuals near Kobe, Japan with lower-extremity disabilities to assess their escape behavior with the intent of using the data to suggest safer fire escape design. Coincidentally, the conclusion of the original survey coincided with the Kobe Earthquake of 1995, after which Yoshimura used the same survey instrument to assess the escape behavior of the participants for comparison pre- and post-earthquake data. The author suggests that the participants confidence in their ability to escape from the built environment during a disaster decreased post-earthquake, and that a barrier-free exit was the most trusted means of egress (although the author did not specify the characteristics of a barrier-free exit) followed by a fireproof elevator, area of rescue assistance, stairwell, exit sign (interpreted as directional assistance), and a rooftop heliport.

Moreover, Proulx (2002) reviewed the literature addressing fire safety planning, building characteristics, procedures to assist those with disabilities, and specific techniques to assess the needs of persons with different types of disabilities in Canada. The author primarily describes various methods to assist individuals with disabilities respond to the emergency and the environment during an evacuation. Consideration of the built environment includes the concept of areas of refuge, safe elevators, sprinkler systems, and ways to effectively communicate the emergency with occupants.

Proulx and Yung (1996) define egressibility and briefly describe two egress strategies: protect-in-place and *everybody-out*. The protect-in-place strategy requires fire and smoke safe compartments for individuals with disabilities to wait for rescue crews. The *everybody-out* strategy requires all individuals evacuate. Both methods have limitations. The authors further discuss protocols to improve both strategies: evacuation procedures and occupant training. Moreover, the authors identify several building characteristics that impact safe evacuation of individuals with disabilities: areas of refuge (particularly if the protect-in-place strategy is used), safe elevators, fire protection systems, communications (e.g., PA system), wayfinding signage (e.g., safe elevator sign), fire wardens (i.e., an on sight employee trained in evacuation procedures), list of occupants requiring assistance, and a buddy system.

Limitations of the Current Body of Knowledge

The preceding review of the literature represents the current body of knowledge focused on the design of the built environment as it relates to the ability of individuals with disabilities to egress in emergency evacuations. Three conclusions can be drawn from this review. First, it is unfortunate that while individuals with disabilities are a significant portion of evacuating populations (Gershon, 2005) they have received very little scholarly attention. The review of the literature focused on individuals with a disability and emergency evacuations identified only 25 published studies indicating a focus on the design of the built environment. There is a significant lack of scholarly study focused on the design of the built environment as it relates to the ability of individuals with disabilities to egress in emergency evacuations.

Second, not only is there a lack of experimental studies in general, there is a significant lack of investigation focused on the design of the built environment. Primarily, the disseminated studies are descriptions of functional competency, predominantly described by travel speed, for individuals with a specific type of disability in a specific environment. Very little investigation is focused on the effect of different environments on the functional competency of an individual with a disability to evacuate. As a result, the majority of empirical data regarding emergency evacuations in the built environment and individuals with disabilities is focused on the ability of the individual with a disability rather than on the design of the built environment.

The effectiveness of using travel speed, or time-to-egress, as a measure of an individual's ability to evacuate in an emergency is secondary to whether or not it is the ability of the individual to negotiate the environment or the ability of the environment to accommodate the function of the individual which affects travel speed, and ultimately successful evacuation. For example, Wright, Cook, and Webber's study (1999) measured the mean walking speed of individuals with visual impairments for various emergency lighting conditions. Interestingly, in preparation for the study a tap board was added along the left-hand side of the stairwell part of the route to facilitate the use of long and short canes by the participants. The authors did not consider this modification to the built environment as part of the study, but assumed it was a necessary accommodation. Future research should evaluate the effect of the tap board in the egress route on the mean walking speed of individuals with visual impairments.

Similarly, while an individual with a disability has been found to be a constraint to evacuation (Averill, et al. 2005; Shields, et al. 2002; Shields, 1993), the question remains as to whether the individual with a disability is a constraint in the built environment or the built environment is a constraint on the individual with a disability? The distinction is critical if the underlying premise of emergency evacuation is that an individual should be able to physically reach safety unassisted.

Third, the majority of the research regarding emergency evacuations in the built environment and individuals with disabilities has been conducted in the United Kingdom (14 of 25) followed by Canada (4), Japan (2), and New Zealand (1). Where the current body of knowledge describes the functional competency of the individual according to a specific environment, generalizing the findings to the United States or other nations may be problematic given the different built environment standards and practices for each. Surprisingly, given the development of the Americans with Disabilities Act Design Requirements for Accessible Egress (DOJ, 2002), there has been no concerted investigation to determine built environment design requirements for accessible egress in the United States.

Future Direction and Priorities

Currently, digital evacuation models are one of the most widely used tools to investigate emergency evacuations in the built environment with upwards of 40 evacuation models currently in use worldwide and many more in development (Galea, 2003). These evacuation models must replicate observable pedestrian phenomena to be considered reliable predictors (Helbing, 2005). As a result, it is problematic to conduct simulations involving individuals with disabilities without an adequate body of empirical data regarding the effect of the built environment on individuals with disabilities. Previously, Shields and Dunlop (1993) note that the common evacuation models did not adequately address the attributes of individuals with disabilities in their simulated occupant populations. The same observation is valid more than a decade later. Indeed, as a result of the emphasis of scholarly study on the functional competency of the individual with a disability, when individuals with disabilities are incorporated into the simulation population, there is the tendency to "standardize" to a singular form of mobility impairment defined by narrow functional characteristics. For example, one model defines individuals with disabilities as those who require assistance and "appliances" in order to move (Kakegawa, et al., 1994). The extent of progress during the past decades is that current models simulate individuals with disabilities by limiting their speed of movement, a narrow approach in keeping with the available empirical data.

Future emergency evacuation research must address the significant lack of scholarly study on the design of the built environment as it relates to the ability of individuals with disabilities to egress. Additionally, future research regarding the built environment must be premised on a model of disability which recognizes that disability is largely a product of environment rather than inherent in the individual (Christensen, Blair, & Holt, under review). This premise is critical if research is to focus on designing the built environment to accommodate the individual, rather than adapting the individual with a disability to the environment.

Keith M. Christensen, MLA, is a Landscape Architect with the Center for Persons with Disabilities at Utah State University. Christensen's research emphasizes the planning and design of socially inclusive environments, including current research activities focused on the built environment and the egress behaviors of individuals with disabilities.

Shawnee D. Collins, is a doctoral candidate in the Department of Special Education at Utah State University.

Judith M. Holt, Ph.D., is the Director of the Interdisciplinary Training Division of the Center for Persons with Disabilities at Utah State University. Dr. Holt's research and exemplary service emphasizes the social system issues of disability, and includes numerous multi-site interdisciplinary research, education, and technical assistance programs.

Curtis N. Phillips is a doctoral candidate in the Department of Special Education at Utah State University.

References

Averill, J. D., et al. (2005). Occupant behavior, egress, and emergency communications (Draft). *National Institute of Standards and Technology, World Trade Center Investigation*: U.S. Department of Commerce.

Boyce, K. E., Shields, T. J., & Silcock, G. W. H. (1999a). Toward the characterization of building occupancies for fire safety engineering: Prevalence, type, and mobility of disabled people. *Fire Technology, 35*(1), 35-50.

Boyce, K. E., Shields, T. J., & Silcock, G. W. H. (1999b). Toward the characterization of building occupancies for fire safety engineering: Capabilities of disabled people moving horizontally and on an incline. *Fire Technology, 35*(1), 51-67.

Boyce, K. E., Shields, T. J., & Silcock, G. W. H. (1999c). Toward the characterization of building occupancies for fire safety engineering: Capability of disabled people to negotiate doors. *Fire Technology, 35*(1), 68-78.

Boyce, K. E., Shields, T. J., & Silcock, G. W. H. (1999d). Toward the characterization of building occupancies for fire safety engineering: Capability of people with disabilities to read and locate exit signs. *Fire Technology, 35*(1), 79-86.

Christensen, K. M., Blair, M. E, & Holt, J. M. (submitted). *The built environment, evacuations, and individuals with disabilities: A guiding framework for disaster preparation and emergency response*. Manuscript submitted for publication.

Clark-Carter, D. D., Heyes, A. D., & Howarth, C. I. (1986). The efficiency and walking speed of visually impaired people. *Ergonomics, 29*(6), 779-789.

Department of Justice-DOJ (2002). *ADA accessibility guidelines for buildings and facilities (ADAAG).* Washington, DC: U.S. Government Printing Office.

Dunlop, K. E., Shields, T. J., & Silcock, G. W. H. (1996). Towards the quantification of emergency egress capabilities for disabled people. *Fire Engineering and Emergency Planning,* 154-161.

Edelman, P., Herz, E., & Bickman, L. (1990). A model of behaviour in fires applied to a nursing home fire. In E. Canter (Ed.), *Fires and Human Behavior* (pp. 181-203). London: David Fulton Publishers.

Galea, E. R. (Ed.). (2003). *Proceedings of the 2nd International Conference on Pedestrian and Evacuation Dynamics*. Greenwich, UK. 20-22 August 2003.

Gershon, R. (2005, January 26). Personal Communication / Center for Disease Control moderated conference call.

Hahn, H. (1985). Disability policy and the problem of discrimination. *American Behavioral Scientist, 28*(3): 293-318.

Hallberg, G., & Nyberg, M. (1987). *Utrymningssakerheten i servicehus.* Byggnadsfunktionslara KTH (Rapport R3: 1987). Stockholm, Sweden.

Helbing, D., Buzna, L., Johansson, A., & Werner, T. (2005). Self-organized pedestrian crowd dynamics: Experiments, simulations, and design solutions. *Transportation Science, 39*(1), 1-24.

Kakegawa, S., Yashiro, Y., Ebihara, M., & Ohtsuki, A. (1994). Evaluation of fire safety measures in care facilities for the elderly by simulating evacuation behavior. In L. Rubadiri (Ed.), *Fire Safety Science—Proceedings of the Fourth International Symposium* (pp. 645-656).

Miyazaki, K., Matsukura, H., Katuhara, M., Yoshida, K., Ota, S., Kiriya, N., & Miyata, O. (2004). Behaviors of pedestrian group overtaking wheelchair user. *National Maritime Research Institute (NMRI)* (Report 181-0004). Shinkawa Mitakashi, Tokyo, Japan.

Passini, R., Rainville, C., Marchand, N., & Joanette, Y. (1998). Wayfinding and dementia: some research findings and a new look at design. *Journal of Architectural and Planning Research 15*(2), 133-151.

Pearson, R. G., & Joost, M. G. (1983). *Egress behavior response times of handicapped and elderly subjects to simulated residential fire situations.* National Bureau of Standards, Department of Commerce (Report No. PB83-222695). Washington, DC,

Proulx, G. (2002). *Evacuation planning for occupants with disability*. Internal Report No. 843, Fire Risk Management Program, Institute for Research in Construction, National Research Council Canada.

Proulx, G., & Yung, D. (1996). Evacuation procedures for occupants with disabilities in high-rise buildings. *3rd International Symposium, Applications of Performance Concept in Building.* Symposium held at Tel-Aviv, Israel.

Robertson, B .S., & Dunne, C. H. (1998). Wayfinding for visually impaired users of public buildings. *Journal of Visual Impairment & Blindness, 92*(5), 349-355.

Rubadiri, L., Ndumu, D. T., & Roberts, J. P. (1997). Predicting the evacuation capability of mobility-impaired occupants. *Fire Technology First Quarter,* 32-53.

Salmi, P., Ginthner, D., & Guerin, D. (2004). Critical factors for accessibility and wayfinding for adults with intellectual disabilities. *Designing for the 21st Century.* Symposium held at Rio de Janeiro, Brazil.

Shields, T. J. (1993). Fire and disabled people in buildings. *Building Research Establishment* (Report No. BR 231). Borehamwood, England.

Shields, T. J., Boyce, K. E., Silcock, G. W. H., & Dunne, B. (2002). The impact of a wheelchair bound evacuee on the speed and flow of evacuees in a stairway during an uncontrolled unannounced evacuation. *Evacuation from fires. Volume II.* (139-149). Amityville, NY.

Alternate Source – Boyce, K. E., Shields, T. J., Silcock, G. W. H., & Dunne, B. (1998). The impact of a wheelchair bound evacuee on the speed and flow of evacuees in a stairway during an uncontrolled unannounced evacuation. *Journal of Applied Fire Science, 7*(1), 277-289.

Shields, T. J., Dunlop, K. E., & Silcock, G. W. H. (1996). Escape of disabled people from fire: A measurement and classification of capability for assessing escape risk. *Building Research Establishment Laboratory Report*, Watford, England.

Shields, T. J., Smyth, B., Boyce, K. E., & Silcock, G. W. H. (1999a). Evacuation behaviors of occupants with learning difficulties in residential homes. *Disability and Rehabilitation, 21*(1), 39-48.

Shields, T. J., Smyth, B., Boyce, K. E., & Silcock, G. W. H. (1999b). Towards the prediction of evacuation behaviors for people with learning difficulties. *Facilities, 17*(9/10), 336-344.

Sime, J. D., & Gartshore, P. J. (1987). Evacuating a wheelchair user down a stairway: A case study of an 'assisted escape'. In J. Harvey and D. Henning (Eds.), *Environmental design research association conference* (pp. 128-133). Symposium held in Ottawa, Canada.

Soong, G. P., Lovie-Kitchin, J. E., & Brown, B. (2000). Preferred walking speed for assessment of mobility performance: sighted guide versus non-sighted guide techniques. *Clinical and Experimental Optometry,* 83.5, 279-282.

Vanderkooy, J. (2002). Audible alarms for the hearing impaired. *Journal of Audio Engineering Society, 50*(1/2), 73-79.

Wright, M. S., Cook, G. K., & Webber, G. M. B. (1999). Emergency lighting and wayfinding provision systems for visually impaired people: Phase I of a study. *Lighting Research Technology, 31*(2), 35-42.

Yoshimura, H. (1998). Sounding out the disabled in the lower-extremities on their escape behavior in building fire for safer fire escape design. *Human Behavior in Fire-Proceedings of the First International Symposium*. Belfast, UK: 353-359.