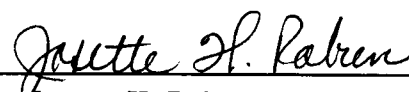


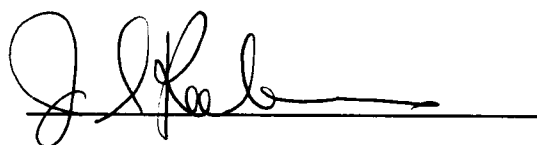
To the Graduate Council:

I am submitting herewith a thesis written by SueAnne B. Lewis entitled "Fire Safety in Homes for the Aged: A Code Perspective." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Interior Design.



Dr. Josette H. Rabun, Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the Council:



Associate Vice Chancellor and
Dean of The Graduate School

**Fire Safety in Homes for the Aged:
A Code Perspective**

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

SueAnne B. Lewis
August 1998

Copyright © SueAnne B. Lewis, 1998

All rights reserved

Dedication

This thesis is dedicated to my husband
Trousdale A. Lewis

who always brings out the best in me.

Acknowledgments

I am deeply grateful to Dr. Josette H. Rabun, Professor of Interior Design, for her keen professional insight, encouragement, and friendship during my studies at the University of Tennessee. I would also like to thank Dr. Debra Wallace, Associate Professor of Nursing, and Dr. Stanley Rabun, Professor of Architecture, for their comments and support while serving as committee members. I greatly appreciate the valuable technical assistance and encouraging support of Laura Davis, Assistant Fire Chief, City of Oak Ridge, Tennessee. Thanks also to my high school friend Jim Brock, who shares my interest in homes for the aged and concern for the safety and comfort of their residents. To Shannon Bays, my editor and friend, thanks for finding the errors I could not see. Beyond moral support and encouragement, my husband, T.A. Lewis, provided expert technical assistance. Finally, I acknowledge the contribution of my late mother-in-law, Myrtle C. Lewis, who first made me aware of the unique problems of older people and the challenges the built environment often presents to them.

Abstract

As the U.S. population ages at an unprecedented rate, the demand for specialized housing will increase, and the issue of fire safety in homes for the aged must be considered. The aging process results in decrements to gait and balance that limit walking abilities. This study examines whether building and life safety codes, which assume normal walking abilities, adequately address the mobility limitations of elderly occupants of homes for the aged in specifying egress requirements. This study uses data from existing geriatric and gerontological research to identify a range of speeds with which older people walk and compares those to the walking speeds needed to evacuate a facility built to current codes. To identify factors that have contributed to fire casualties in homes for the aged, published case histories of fires in elderly housing and residential board and care facilities were analyzed. Finally, a literature review provides information on human behavior patterns in fire situations.

This study reveals that most older people do walk more slowly than the 1.22 m/s considered average and that behavior patterns such as delaying evacuation, failing to isolate fire by closing doors, and use of a customary exit route rather than emergency exits put seniors at greater risk of injury or death in fire. This study concludes that more empirical research is needed in the development of building and life safety codes.

Table of Contents

Chapter	Page
1. Introduction	1
Background and Statement of the Problem	1
Rationale	4
Key Terms and Definitions	5
Relevant Literature	8
Significance of the Research in a Wider Context	10
2. Research Methods	16
3. Results	21
Evacuation Capabilities of the Aged	21
Changes Associated with Normal Aging	22
Changes Associated with Disease	24
Psychological Factors Affecting Walking: Fear of Falling	26
Characteristics of Older People's Walking	28
Walking Speeds of Older Adults	29
Walking Speeds of the Elderly and Building Code Requirements	33
Factors Contributing to Fire Casualties	38
Case Study Analysis of Fires in Housing for Elderly	40
Case Study Analysis of Fires in Board and Care Homes	46
Human Behavior as a Factor in Fire Casualties	51
4. Discussion	61
References	67
Vita	74

List of Acronyms

ADL	Activity of daily living
AHJ	Authority having jurisdiction
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BFRL	Building and Fire Research Laboratory
BOCA	Building Officials Code Administrators International
CCRC	Continuing care retirement community
FEMA	Federal Emergency Management Agency
FIDO	Fire Incident Data Organization of NFPA
HUD	[Department of] Housing and Urban Development
<i>IBC</i>	<i>International Building Code</i>
ICBO	International Conference of Building Officials
<i>NBC</i>	<i>National Building Code</i>
NBS	National Bureau of Standards (see <i>NIST</i>)
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology, formerly National Bureau of Standards
<i>SBC</i>	<i>Standard Building Code</i>
SBCCI	Southern Building Code Congress International
T.C.A.	Tennessee Code Annotated
<i>UBC</i>	<i>Uniform Building Code</i>
USFA	United States Fire Administration

Chapter 1

Introduction

Background and Statement of the Problem

The population of the United States is aging at an unprecedented rate because of increased life expectancy and a higher birth rate. People are living longer today than ever before. A man born in 1900, for example, had a life expectancy of 46 years and a woman of 48 years. The life expectancy of a man born in 1992 is 73.2 years and a woman is 79.8 years (Riekse and Holstege, 1996). The fastest growing segment of the U.S. population today is the age group over 85. In 1950 only about 600,000 Americans were over age 85, but by 1990 that number had climbed to 3 million. Demographers estimate that by 2030, when most of the baby-boomers will have reached old age, more than 8.4 million Americans will be over 85 years old and people over age 65 will constitute over 20 percent of the U.S. population (U.S. Bureau of the Census, 1993, cited in Riekse and Holstege, 1996).

This dramatic increase in the number of older people will create a corresponding demand for more specialized housing for older people. At the same time the country will have to cope with the profound economic impact of a dwindling proportion of younger people in the work force providing for an increasing proportion of older retired persons. Meeting the housing needs of the expanding older population will create a financial burden that

will have to be borne by either the elderly persons and their families or by the citizens at large in the form of public assistance housing. Many new facilities will be constructed, but economics will likely dictate that many existing structures will be converted to housing for older people. Both the new and converted structures must be designed to ensure the safety of their occupants. Fire safety in the older structures is a significant issue, especially considering the limited evacuation capabilities of the elderly occupants. The Federal Emergency Management Agency's (FEMA's) United States Fire Administration (USFA) asserts,

Fire kills thousands of Americans each year, injures hundreds of thousands, destroys billions of dollars in property, and costs tens of billions of dollars overall, but mayors and city managers, school officials, the media, and the general public still are largely unaware of the magnitude of these numbers. Their lack of awareness and failure to realize the seriousness of fire to communities and the country are factors in keeping the U.S. fire problem one of the worst in the world per capita (USFA, 1995, p. 1).

Building and life safety codes are the mechanisms state and local governments use as guidelines for ensuring that buildings meet minimum safety standards. The Southern Building Code Congress International (SBCCI) states the purpose of its *Standard Building Code* is "to serve as a comprehensive regulatory document to guide decisions aimed at protecting the public's life, health and welfare in the built environment (*SBC*, 1997, p. iii)."

Fire safety motivated the first building regulations in the United States, enacted in New Amsterdam in 1625. In the nineteenth century a spate of building fires prompted several large American cities to develop their own building standards for fire prevention. The *National Building Code*, the nation's first model building code, evolved from the National Board of Fire Underwriters, which was formed in 1906 to help insurance companies evaluate fire damage claims (Harmon, 1994).

The three model building codes in the United States are *Standard Building Code (SBC)*, published by SBCCI; *National Building Code (NBC)*, published by Building Officials Code

Administrators International (BOCA); and *Uniform Building Code (UBC)*, published by the International Conference of Building Officials (ICBO). As a rule, a city adopts one of these model codes, writes its own code based on a model code, or is covered by a state code based on a model code. It should be noted, however, that cities sometimes do not adopt the most current edition of code, and many small cities and towns may not enforce the code. This is especially true in rural areas according to architect and engineer J.S. Rabun (personal communication, July 16, 1998). In general the western and upper midwestern states use *UBC*, the northeastern states use *NBC*, and the southern states use *SBC*. A few states use combinations of two or three of the model codes (Harmon, 1994).

In May 1996 an effort began to consolidate the three model codes into a single set of code that would be used throughout the United States. The first drafts of the *International Building Code (IBC)* have been distributed, and public comments are being incorporated. The final draft is expected to go before the membership (made up of representatives from BOCA, ICBO, and SBCCI) for approval in autumn of 1999, and the new unified model code is scheduled to be ready to enact by spring of 2000.

The National Fire Protection Association (NFPA) is another important international codes and standards organization. NFPA evolved from the same need of the insurance industry that led to the *NBC*. Representatives of fire insurance and other industries first came together in 1895 to develop standards for installation of fire-fighting equipment in an effort to improve reliability. The formal NFPA organization was founded the following year, in 1896. The NFPA Bylaws, Article 2, states the organization's purposes:

The purposes of the Association shall be to promote the science and improve the methods of fire protection and prevention, electrical safety and other related safety goals; to obtain and circulate information on these subjects and to secure the cooperation of its members and the public in establishing proper safeguards against loss of life and property (NFPA, 1997, p. 1).

Model building codes reference NFPA codes. Both sets of code are often adopted by states and municipalities, and the provisions that are most restrictive take precedence.

The codes referenced in this thesis research are *SBC*, the draft *IBC*, and NFPA 101, *Life Safety Code*¹. The researcher selected *SBC* for this study because it is the model code used most often in the southeastern United States, where this research was conducted.

Rationale

A basic assumption underlying this research is that building code exists to ensure the safety of building occupants and that violation of building code compromises occupants' safety and may result in casualties. If code is not violated, however, and casualties still occur, then the code may be ineffective. Conversely, if particular code provisions are continually violated and those violations result in casualties, the code writers may need to consider alternate or additional systems to accomplish the intent of the violated provisions.

All types of buildings must necessarily be covered by code, and there is great variety even within an occupancy classification. In specifying the maximum travel distance to an exit or to an area of refuge, the code writers must assume, either intentionally or unintentionally, the speed with which the building occupants are able to traverse the specified distances. If that assumed walking speed is based on an average occupant, then it may be too fast for people who cannot walk well, such as elderly people. This study tests the hypothesis that elderly residents of homes for the aged have decrements in mobility, thus slow walking speeds, that current building and life safety codes do not adequately address.

The study poses the following research questions: Do elderly occupants with limited

¹NFPA 101 and *Life Safety Code* are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA 02269

mobility have adequate time for safe egress with the existing fire codes as they are applied in older multistory buildings adapted to serve as homes for the aged? Furthermore, do current building and life safety codes adequately address the challenge of providing a fire-safe environment for elderly occupants of older structures adapted for use as homes for the aged?

Key Terms and Definitions

Listed below are some of the key terms used in this thesis and their definitions. Some of the terms may have different meanings in other contexts, but the definitions listed here apply in this thesis. Many terms that are specifically defined in *Life Safety Code*, or *SBC* are not included in this list because the code definitions apply.

Accessible. Usable by persons with disabilities.

Adaptive use/reuse. "The process of converting a building to a use other than that for which it was designed. Such a conversion is accomplished with varying alterations to the building (Murtagh, 1993)."

Aged. Refers to persons over 65 years old whose physical or mental conditions are impaired because of age or age-induced illness.

Agonistic muscle. "The muscle directly engaged in contraction as distinguished from muscles that have to relax at the same time; thus, in bending the elbow, the biceps brachii is the agonist and the triceps the antagonist (Thomas, 1993)."

Area of refuge. "An area that is separated from other areas of a building, or an adjacent building, by fire rated walls to provide protection from fire or smoke (Harmon, 1994, p. 269)." See *SBC*, 202, p.12.

Assisted living facility. "Residential care facilities for independent seniors with multiple needs, including slight to moderate physical disabilities and cognitive impairment. Residents receive 24-hour supervision and assistance with the basic activities

of daily living, including meal preparation, housekeeping, transportation, and recreation, ...general health or nursing assistance on an as-needed, intermittent basis (Wasch, 1996, p.49)."

Atrophy. "A wasting; a decrease in size of an organ or tissue (Thomas, 1993, p. 171)."

Automatic closing device. "A door closure that is activated by smoke or heat, causing the door to close in an emergency to prevent the spread of fire and smoke (Harmon, p. 269)."

Baby-boomer. "A term used to describe the largest group of persons ever born in one period of American history, those born between 1946 and 1964 (Riekse & Holstege, 1996, p. 500)."

Board and care homes. "Homes which provide supervision, supportive services, and assistance for persons who cannot live alone because of physical or mental impairments, but who do not require institutional care (Riekse & Holstege, p. 500)."

Community-based care. Use of a network of services, such as home-health care, adult day-care, home delivery of meals, and modern communication technologies, that allow a frail older person to remain in his or her own residence and avoid institutionalization.

Compartmentation. The subdivision of a building into areas (compartments) using fire-resistant barriers to prevent the spread of fire from an area of origin to another area.

Congregate living. "Housing units that have a common dining room in which meals are served on a regular basis along with access to social and recreational services. This type of care is designed to provide services in a residential setting for persons who need some form of assistance with daily living but do not require continuing medical or nursing care (Riekse & Holstege, 1996, p. 501)."

Continuing care retirement community (CCRC). "A living arrangement in which incoming residents enter into a contractual agreement to pay an entrance fee and monthly fees that will provide for their care for the rest of their lives regardless of the status of their mobility and health (Riekse & Holstege, 1996, p. 501)." Such communities often comprise a complex of facilities that provide graduating levels of care from fully independent living to assisted living and finally to nursing care.

Egress. "A way out or exit (Harmon, p. 271)."

Elderly person. See *Aged*.

Geriatrics. The therapeutic treatment of old people.

Gerontology. The study of the process and effects of aging.

Home for the aged. Housing for older people in which supervisory and personal care are provided. The facility generally provides regular meals in a common dining room and some social and recreational services. It might provide assistance with activities of daily living (see *Assisted living facility*) for those who need that level of care but do not need continuing medical or nursing care. Residents must be ambulatory, that is, they must be able to evacuate the building or walk to an area of refuge within 13 minutes with only limited assistance.

Musculoskeletal system. The muscles and bones of the body.

Nursing homes. "Service-based facilities for persons who need more nursing and personal care than can be provided in their own homes, board-and-care homes, or homes for the aged (Riekse & Holstege, 1996, p. 505)."

Older person. See *Aged*.

Personal care. "The care of residents who do not require chronic or convalescent medical or nursing care. Personal care involves responsibility for the safety of the resident while inside the building. Personal care might include daily awareness by the management of the resident's functioning and whereabouts, making and reminding a resident of appointments, the ability and readiness for intervention in the event of a resident experiencing a crisis, supervision in the area of nutrition and medication, and actual provision of transient medical care (NFPA, 1994, *Life Safety Code*, 22-1.3)."

Residential board and care occupancy. "A building or part thereof that is used for lodging and boarding of four or more residents, not related by blood or marriage to the owners or operators, for the purpose of providing personal care services (NFPA, 1994, *Life Safety Code*, 22-1.3)."

Retirement home. A name given to a home for the aged.

Somatosensory. Relating to sensory activity that originates other than from the eyes and ears and provides information on the surrounding environment (Thomas, 1993).

Vestibular. Having to do with the function of the inner ear and sense of balance (Thomas, 1993).

Visual. Having to do with sensory information obtained through the eyes.

Relevant Literature

The body of knowledge on aging and on the inevitable physical changes that accompany the aging process is growing as fast as the age group it concerns, and the mobility of older people is the subject of much study. Walking speeds of older people are well documented in the gerontological literature. Many researchers have measured walking speed because it is widely accepted in the gerontology and geriatric medical communities as a reliable measure of functional ability or disability and dependence among older people. Several researchers have measured the walking speed of older people for the purpose of ensuring that traffic signals give adequate time for older pedestrians to cross the street (Coffin, 1993; Hoxie and Rubenstein, 1994).

John L. Bryan (1983), Chairman of the Department of Fire Protection Engineering, University of Maryland, conducted the first major research project in the United States on human behavior in fire emergencies. Bryan consolidated information from two earlier studies in his 1983 publication *Implications for Codes and Behavior Models from the Analysis of Behavior Response Patterns in Fire Situations as Selected from the Project People and Project People II Study Program*. In his initial study, "Smoke as a Determinant of Human Behavior in Fire Situations" published in 1974 as *Project People*, fire department personnel conducted on-the-scene structured interviews with 584 survivors of 335 fire incidents in mainly residential occupancies over a three-year period. In the follow-up study initiated in 1977, *People Project II*, 53 fire department personnel interviewed 150 health care providers and nine patients of health care occupancies (hospitals, nursing homes, and extended care facilities) following fire incidents. This study researched how the fire developed and spread within the buildings as well as "the response of the staff personnel primarily involved in initial investigation of the sensory cues of the fire incident, the initiation of the fire alarm,

the closing of patient room doors, and the rescuing of threatened patients (Bryan, 1983).” The behavior studied in this second project was primarily that of care-givers rather than residents because the care-givers made the life-protection decisions for the non-ambulatory residents. In the 1983 work Bryan compared his research findings to code requirements concerning exit markings, exit lighting, the movement of people through smoke, effectiveness of alarm systems and automatic detection devices, how egress systems (i.e., stairs, doors, corridors, and elevators) were used, and effectiveness of systems for suppressing and controlling the fire. Bryan did not report measuring speed of egress.

Stahl, Crosson, and Margulis (1982) conducted an in-depth literature review to discover the rate at which occupants are able to evacuate a burning building, and they compared their findings to the provisions of the 1976 edition of the NFPA 101, *Life Safety Code*. This study, published by the U.S. Department of Commerce National Bureau of Standards (NBS), identifies several functional criteria where *Life Safety Code* provisions may not be supported by research findings. The authors also point out areas in the technical literature that appear to need further research. Several others have written on human behavior in fires (Bickman, Edelman, and McDaniel, 1983; Black and Cox, 1983; and Canter, 1990). These reports provide excellent information relevant to the proposed research, but little consideration is given to the characteristics of different occupant groups, particularly the mobility limitations of older people or the impact of these limitations on their ability to evacuate a building.

Publications on historic preservation and adaptive reuse of older facilities abound, as well as literature on designing for fire safety. NFPA 914 is a recommended practice for fire protection in historic buildings with specific attention paid to fire safety in rehabilitation and adaptive reuse of old buildings. It does not, however, address reuse in relation to

historic buildings as homes for the aged, nor is it prescriptive as is building code. The NFPA 101 *Life Safety Code* specifically addresses homes for the aged but does not address homes for the aged in adapted older buildings. Lang (1987) discusses the conflict between life safety code and human comfort and environmental behavior in building design, but he does not consider either adaptive reuse or unique needs of older persons.

The literature on mobility of older people, fire safety in adapted older buildings, and fire safety in homes for the aged is extensive. There does not, however, appear to be any publication that addresses the convergence of the three areas.

Significance of the Research in a Wider Context

This study is significant because the growth of the older population segment means that within the next three decades more people will reside in homes for the aged and assisted living facilities than ever before. One may logically assume that to meet the escalating need for specialized housing, some developers will find it cost-effective to convert existing older buildings as has been done in the past rather than design and build new ones.

The strategy of adapting and conserving older structures is widely accepted today and is desirable for three reasons. First, it preserves existing buildings. Thus the architectural styles and construction methods and technologies of the twentieth century become incorporated into the historical fabric of the American culture allowing future generations to better understand their own evolving culture. Just as many 18th- and 19th-century buildings are highly valued today, so the surviving 20th-century buildings will be a valued legacy in the 21st and succeeding centuries.

A second advantage to reuse of existing building stock is that it presents an opportunity for recycling. Pilatowicz (1995) estimates that construction industry waste accounts for

more than 10% of the material in landfills, and most of that waste comes from demolition of old buildings. Recycling older buildings reduces environmental pollution and saves valuable natural resources.

The third and more immediate benefit of an adaptive reuse strategy is that renovation may cost less than new construction. As the ratio of old to young in the general population shifts, fewer wage-earning younger people will be available to care for more and more older people who no longer earn wages. Hence, affordability of specialized housing will become an increasingly important issue. Today, approximately 90% of assisted living facilities in the United States are converted buildings (Bell, 1997).

Such a reuse strategy, however, presents some significant challenges. Simply remodeling an existing building does not necessarily create an appropriate new environment, especially for occupants with special needs like older people. Such spaces must be designed with an understanding of the occupants, their limitations, and the ways they use space. Writing on this issue, Paul Kaassen, chairman and CEO of Sunrise Assisted Living, Inc. of Fairfax, Virginia observed:

Historically, purpose-built buildings have beaten out conversions in almost any industry that requires a carefully designed space, from strip shopping centers to single-family homes. In assisted living, the design of the space is critical to how the community actually operates. . . . For conversions to become more competitive, they need to make a tremendous investment in interior design (Kaassen, 1997, pp. 81, 83).

Poorly designed homes for the aged not only fail to function efficiently; they may be uncomfortable for the occupants, and, worse, they may be unsafe. Designing for fire safety is one of the most difficult aspects of converting an older building. The challenge of protecting both buildings and occupants from fire is a problem much more significant in the United States than is often acknowledged. Carrye Burley Brown, the United States Fire Administrator, states:

America's fire death rate is one of the highest per capita in the industrialized world. Fire kills nearly 5,000 and injures more than 25,000 people each year. Firefighters pay a high price for this terrible fire record as well; approximately 100 firefighters die in the line of duty each year. Direct property losses due to fire exceed \$9 billion a year. Most of these deaths and losses can be prevented (Brown, 1998)!

Protecting people and buildings from fire is an especially critical issue when the occupants are older people with physical or psychological limitations. A case study of the 1989 fire in a Johnson City, Tennessee retirement home illustrates this point.

The fire broke out in a first-floor apartment of the John Sevier Center on Christmas Eve and quickly spread through the open apartment door into the first floor corridor of the 10-story brick building. The flames spread to the second and third floors, and deadly smoke rose to the top of the building through the elevator shaft and unsealed pipechases. The fire killed 16 people and injured 40 others. Firefighters found most of the victims on upper stories in apartments near the elevator. Smoke detectors in apartments and corridors functioned correctly, and emergency personnel arrived on the scene within five minutes of notification. The building, which was constructed in 1927 as a hotel and renovated in 1979 to serve as apartments for older adults, had no sprinkler system because 1979 fire code did not require sprinklers (Fahy, Tremblay, & Barry, 1990).

The John Sevier Center fire was catastrophic but not unique. Three other fatal fires occurred in facilities similar to the John Sevier Center within the same month, killing 23 people. One man died from injuries received in a fire in the John Sevier Center less than three months before the fatal December blaze, and in the same month fire in a nursing home in Norfolk, Virginia, killed 12 elderly patients (Petraglia, 1991). The *NFPA Journal* asserts that older persons are among those most at risk of death from fire in the United States (Hall, 1990). Dr. John R. Hall, Jr., Director of NFPA's Fire Analysis and Research Division, states:

Each year, about 1-fourth of the fatalities in home fires are adults at least 65 years old. That represents a death toll of more than 1,100 people a year. Measured by the number of deaths per million population, the risk of dying in a home fire is twice as high for older adults as it is for the population as a whole and three times as high for older adults as it is for adults 20 to 39. What's more, the risk continues to rise as people get older. The fire risk of those 75 and over is three times the national average. And those 85 and over have a fire risk four times the national average (Hall, 1990).

The physical limitations faced by older persons when they attempt to escape a fire represent one important factor contributing to these statistics. These limitations and their implication in development of fire code applicable to older buildings that serve as homes for the aged become increasingly critical as the older adult segment of the population grows.

A wide variety of specialized housing for older persons exists today, identified by an even wider variety of names, as identified earlier in Key Terms and Definitions. *Life Safety Code* classifies the type of facility with which this study is concerned as "residential board and care occupancy" and defines it as "a building or part thereof that is used for lodging and boarding of four or more residents, not related by blood or marriage to the owner or operators, for the purpose of providing personal care services (NFPA 101, 22-1.3)." The *SBC* (202, p. 23) definition of "residential care/assisted living occupancies" is somewhat more descriptive in its listing of types of facilities included in the subclassification, but it also describes an environment in which "personal care and supportive services" are provided to the residents. The key term is *personal care*, which is defined in *Life Safety Code* as:

The care of residents who do not require chronic or convalescent medical or nursing care. Personal care involves responsibility for the safety of the resident while inside the building. Personal care might include daily awareness of the management of the resident's functioning and whereabouts, making and reminding a resident of appointments, the ability and readiness for intervention in the event of a resident experiencing a crisis, supervision in the areas of nutrition and medication, and actual provision of transient medical care (NFPA 101, 22-1.3).

States differ on the ways they classify and define nursing homes and various types of

residential facilities for elderly people. In Tennessee, where this study is being conducted, the facility of interest is called *home for the aged*, and that is the term that will be used throughout this document. Tennessee defines homes for the aged in the Tennessee Code Annotated (T.C.A.), Rules of the Tennessee Department of Health and Environment, Standards for Home for Aged. One characteristic that T.C.A. uses to differentiate between a nursing home and a home for the aged is the requirement that residents of the latter be *ambulatory*. T.C.A. defines an ambulatory resident as follows:

... a resident who is physically and mentally capable under emergency conditions of finding a way to safety without physical assistance from another person. An ambulatory resident may use a cane, wheelchair or other supportive device and may require verbal prompting (T.C.A., 1200-8-11(2), 1992).

An ambulatory resident, therefore, is a person who is not confined to bed, but whose ability to walk may be severely limited. A person who uses a wheelchair is considered ambulatory if he or she can transfer to and from the wheelchair without assistance from another person. Many older adults who are legally ambulatory have very limited mobility and must use aids to walk. Even those who use no aids often walk with great difficulty. The issues of mobility and slow or unsteady walking make residents of homes for the aged especially vulnerable in an emergency situation such as that posed by a fire. This study focuses specifically on homes for the aged rather than nursing homes because the procedures for evacuation of nursing homes assume that the residents are non-ambulatory, so mobility is not an issue. Furthermore, the research will concentrate on multistory structures because they pose the problem of vertical egress. It is critically important that fire and life safety codes take into consideration these limitations to mobility of the residents of multistory homes for the aged.

The objectives of this research is to establish the effectiveness of building code in providing fire safety for residents of homes for the aged, especially those housed in older structures,

and to identify the physiological and psychological limitations that compromise the abilities of older persons to evacuate a burning building. The ultimate goal of the study is improved fire safety in homes for the aged.

Chapter 2

Methods

This thesis research used existing data to explore fire safety in homes for the aged. The research was qualitative, analyzing and synthesizing the existing data to identify areas where empirical research may or may not support the critical assumptions upon which the building code is based. Data for this study were gathered from government reports, NFPA publications, newspaper accounts of a fire incident, and from scholarly research reports published in respected journals (e.g., *Age and Ageing*, *Journal of Gerontology*, and *Journal of the American Geriatrics Society*). The validity and reliability of the data were assumed to have been established by the original authors. The investigator took three approaches to this research to examine (1) walking speeds of elderly people compared to those required by building and life safety codes, (2) the factors that have contributed to fire casualties in homes for the aged, and (3) human behavior in fires.

The first approach tested the assumption that occupants of homes for the aged are able to evacuate a building or move to a point of safety in sufficient time to escape in a fire emergency. Recognizing that advanced age often results in decrements to walking abilities, this research examined the walking speeds of elderly people and compared those speeds with

the speeds required to traverse the maximum travel distances established in the sections on egress in *SBC*, in the draft *IBC*, and in NFPA 101, *Life Safety Code*. The walking speeds used in this comparison were taken from nine published research reports in journals in the field of gerontology or geriatrics and from one doctoral dissertation. The use of existing data provided a much larger and more diverse sample than it would have been feasible to observe directly for this research project. Use of such data also eliminated any inconvenience or risk to potential participants.

The research journals that served as data sources in this thesis are described in the section titled "Time-Based Evacuation Capabilities of the Aged." Each of the referenced researchers had a different reason for measuring walking speeds of the participants—reasons as diverse as identifying predictors of mortality and determining the appropriate duration of a traffic signal. While all the research on walking speeds cited in this thesis was quantitative, numerous methods were used, and measurements were taken in different units of time (i.e., seconds and minutes), in different units of measure (i.e., feet and meters), and over different distances. For purposes of comparison, all speeds included in this study were converted mathematically to meters per second (m/s). It might be expected that speeds would be faster over a shorter course than over a longer one because of the fatigue factor, but no attempt was made to compensate for differences in the distance measured.

The second approach to the research was a survey and analysis of case histories of fatal fires that have occurred in the United States since 1970 in buildings that housed older people. The case histories surveyed were presented in two documents published by NFPA: *Special Data Information Package, Elderly Housing* (NFPA, 1996) and *Special Analysis, U.S. Fires in "Board and Care" Homes* (Hall, 1993). The report on elderly housing is composed of reprints of articles about 24 fires in homes for the aged published by NFPA

in its journal. The fires occurred between 1972 and 1996, and 12 of the fires resulted in fatalities. To discover a pattern of factors that contribute to casualties, the analysis of these facilities concentrated on the following issues:

- number of fatalities;
- time of day of the fire;
- building height and age;
- whether the building was purpose-built or adapted;
- if the building had functioning smoke detectors, heat detectors, alarm system, or sprinkler system;
- type of alarm system (manual or automatic);
- if there were fire doors and if they worked properly;
- if there were delays in egress or in activating an alarm; and
- whether fire drills were practiced regularly.

The second document presents information about 57 fatal fires in facilities that come under the NFPA Fire Incident Data Organization (FIDO) occupancy classification "residential board and care." Residential properties that do not provide the level of care needed by the residents are given this classification in FIDO. Hence, nearly all of these properties were in violation of some code. Even so, these case studies provided valuable information on the types of design and operational issues that often compromise fire safety in adapted older buildings. Twenty-three of the fires described were in facilities where most of the residents were elderly. The author presents the case studies in a matrix format and focuses on facilities in which most of the occupants were over 65 years old or disabled in some way. The analysis of these case studies concentrated on the following issues:

- number of fatalities;
- height and age of building;

- original and current uses of the building;
- smoke detectors, heat detectors, alarm system, or sprinkler system and whether they functioned;
- whether the building's compartmentation was breached and how;
- whether exit doors were locked or blocked;
- whether stairways were or were not enclosed;
- whether there were delays in egress or activation of alarms;
- whether the appropriate egress route was used; and
- whether fire drills were practiced regularly.

The third approach in the research was to examine human behavior in fires by compiling and reviewing available technical literature on the subject. Most of the research reviewed was qualitative. The researchers identified patterns of behavior by interviewing firefighters and survivors of fires to determine how the people in the fire behaved as well as how the fire developed and spread and how the building and its design influenced the fire and the occupants.

The information gathered from the three research approaches presents a synthesized picture of the psychological and physiological capabilities and behaviors of people facing a fire emergency. A review of the life safety and model building codes in light of the behaviors and limitations may indicate where research supports or does not support the code.

Limitations

In the comparison of the walking speeds of elderly people with code requirements, the study concentrated specifically on the sections of the 1997 edition of *SBC* pertaining to egress requirements, and focused specifically on the occupancy subclassification "R4: Residential

Care/Assisted Living Facilities.” This subclassification appeared for the first time in the 1997 edition, indicating an increased interest in the problem of fire safety in homes for the aged. Specific sections of *SBC* included Chapters 9, 10, 11, 34, and Appendix F102. The classification in the draft *IBC* is the same as in *SBC*, and “Means of Egress” is covered in Section 10. Relevant parts of NFPA 101, *Life Safety Code* (1994 edition) are also analyzed, including Chapters 5, 6, 7, 22, 23, and corresponding chapters of Appendix A. This thesis study was limited to the parts of *SBC*, *IBC*, and *Life Safety Code* cited here.

Numerous other codes and recommended practices have bearing on egress design. *Life Safety Code* is only one of many NFPA codes and recommended practices that must be considered in designing fire-safe environments. Other organizations, such as the American National Standards Institute (ANSI) and American Society for Testing and Materials (ASTM), publish important recommended practices and standards. These other documents were not, however, included in this study.

This research was primarily concerned with building code and building design issues. Related issues that contribute to the problem of fire safety, such as building maintenance and operations, staff training, or procedures and capabilities of emergency response personnel, are outside the purview of interior design. These issues were addressed only as they influenced or were influenced by building design and code issues.

Chapter 3

Results

Evacuation Capabilities of the Aged

The prominence of egress requirements indicates that building code assumes people will evacuate a burning building or move to an area of refuge. Thus, mobility—the capacity of a person to move from place to place—is a significant factor in the ability of an occupant to get to safety in a burning building. In a multi-level environment where accessibility may be limited in an emergency situation, mobility requires more than the ability to walk. Most elevators cease to function when a fire alarm is activated, so a wheelchair, walker, or other device to enhance mobility is rendered useless. Evacuation may require the ability to use stairs as well as to walk.

The normal aging process usually results in decrements to gait and balance that profoundly change the way people walk. Chronic diseases that often accompany the process, such as arthritis or osteoporosis, as well as the fear of falling often exacerbate the decrements of an older person's ability to walk easily from place to place (Guralnik et al., 1989). This study examines the question of whether building and life safety codes address the

issue of limited mobility among older occupants of homes for the aged when it specifies egress requirements. Further, it describes the changes that come with normal aging, the changes associated with common chronic diseases, fear of falling as a factor in decreased mobility, and a description of how older people walk. A discussion of walking speeds and a comparison of walking speeds and code requirements follow the descriptions.

Changes Associated with Normal Aging

Walking has two components: gait and balance. Gait is associated with movement, and balance is associated with stability. Together gait and balance (i.e., stable movement) constitute mobility (Tinetti, Williams, and Mayewski, 1986). A general weakening of the musculoskeletal system associated with normal aging or chronic disease may cause changes in gait and balance.

Both the muscles and the skeletal system deteriorate with age. People generally begin to lose muscle strength at about age 60, and by the age of 80 they have lost up to 40% of their muscular ability. This weakening is due to loss of muscle mass and is more prominent in legs than in arms and hands (Ferrini and Ferrini, 1993).

Bone mass and strength decrease as mineral content is lost; therefore, bones become more porous and less able to withstand shock. This mineral loss may occur because the bones are not able to rebuild as fast as they break down in advancing age. Cartilage and ligaments, especially in the heavily used knee and hand joints, tend to calcify, fray, or crack with repeated use, resulting in stiffness and loss of flexibility. Over time, the joint problems affect posture, gait, and balance (Ferrini and Farrini, 1993).

People who are inactive—a common situation with postmenopausal women, who comprise the majority of those residing in homes for the aged—lose more muscle than those who remain physically active. Ferrini and Ferrini write:

When skeletal muscles contract they pull on the ligaments that are attached to the bones, stimulating the bones to thicken and strengthen. Physical exercise increases bone mass by causing stress on the bones. Without physical activity, bones become weaker and thinner. Similarly, skeletal muscles become strengthened by use. A muscle that is not used decreases significantly in size and strength, or it atrophies (Ferrini and Ferrini, p. 70).

It appears that changes in the central nervous system result in slower reaction times and reduced sensitivity to stimulation. Age-related deterioration of the visual, vestibular, and somatosensory systems affect balance and equilibrium. The ability to walk depends on the body's ability to control balance and to integrate balance into reaching or lifting movements (Woollacott, 1993). When normal balance is interrupted, the body attempts to recover through a series of muscle movements referred to as *postural sway*.

In their study of falls related to postural imbalance in older people, Overstall, Exton-Smith, Imms, and Johnson (1977) found that postural sway increases with age and is more prevalent in women than in men. Moreover, the very old and very young use different muscle groups when swaying than do teens and young adults. When an older person loses his or her balance, it is much more difficult—and sometimes impossible—to correct (Overstall et al., 1977; Woollacott, 1993) because of a general weakening of the musculoskeletal system.

Older people tend to sway from their hips rather than from the ankles. They tend to stiffen joints by tensing appropriate agonistic muscles and their antagonist muscles in adjusting balance to compensate for shifts in the standing surface. The stiffened joints reduce the musculoskeletal freedom that must be controlled to maintain balance (Woollacott, 1993). When young people respond to shifts or movement in the standing surface, they compensate with postural sway that pivots from the ankles. Older people, on the other hand, tend to pivot from the hip more often than the ankle. The hip pivot may occur because diseases of the peripheral nervous system or distal muscle weakness makes it harder to get adequate ankle torque (Woollacott, pp. 56–58). Poor balance and reduced ability to

recover balance due to changes in postural sway may account for the difficulty many older people have in using stairs. This makes evacuation from a multistory building more perilous for older people and may have an adverse effect on their ability to evacuate a building in a fire emergency.

The three types of sensory input—visual, vestibular, and somatosensory—help people in making adjustments in balance. Younger people are able to maintain stability with vestibular information alone. Older people, however, require sensory input from at least two sources to maintain balance (Woollacott, pp. 56–58). It appears that older people rely more on visual input than on other sensory information when they attempt to control postural sway (Staube et al., 1988). Thus, age-induced decrements in vision—impaired visual acuity as well as visual distortions caused by corrective lenses—affect walking and make people more cautious and their gait more tentative. Because vision is vital to maintaining good balance while walking, older people may be at greater risk of falls or decreased walking stability when vision is obscured by smoke that would be found in a fire incident.

Probably the most common cause of deterioration of bone and muscle in old age is inactivity or a sedentary lifestyle. As stated above, when bones and muscles are not used, they weaken and atrophy. In addition, joints become stiff. When the body loses flexibility, its ability to recover balance is greatly impaired, which makes a person much more susceptible to falls. All of the age-induced decrements cited here combine to make an older person slower than normal and less able to escape a fire situation.

Changes Associated with Disease

Chronic diseases may also have profound effects on the ability to walk. Two diseases common to older people are arthritis and osteoporosis. The painful, swollen joints caused by arthritis, an inflammation of the joints, is common in the older population. Osteoarthritis—

the most widespread type, affecting about 24 million Americans—usually affects the joints of the back and legs (Riekse & Holstege, 1996), so it may profoundly influence walking ability. Moreover, the corticosteroid drugs commonly used to treat arthritis can cause muscle weakness and atrophy (Fiatarone, 1993), further limiting walking ability.

Osteoporosis is a disease in which the loss of calcium and other mineral content in bones is exaggerated. The increased porosity makes bones thinner, more brittle, and more susceptible to fracture. The disease affects more women than men and is especially prevalent among postmenopausal women. Osteoporosis also causes the vertebrae to deteriorate, resulting in curvature to the spine. This condition is often referred to as the “dowager’s hump” because the shoulders bend forward. Beyond the minor aches and pains associated with bone loss or joint inflammation, the increased risk of fractures has serious implications.

Other diseases, such as those of the central nervous system and the endocrine system, may impair gait, mobility, and muscle function in elderly persons. Diabetes is a disease of the endocrine system that causes a deficiency of insulin, which prevents the cells from taking glucose from the bloodstream (Ferrini and Ferrini, 1993). Although the source of the disease is in the endocrine system, the nervous system is affected in about 40% of people who have had the disease for 25 years or more. Effects of diabetes on the cardiovascular system is the leading cause of death of persons with the disease, and ischemia and gangrene of the legs may affect the peripheral vascular system causing sufferers to lose the use of their legs or, in serious cases, to require amputation of a foot or leg (Thomas, 1993).

Sometimes the treatment of diseases, even when they have no direct effect on mobility, may be a more subtle cause of losses in balance and impaired gait. Cardiovascular disease and hypertension are often treated with drugs that deplete skeletal muscles of electrolytes, contributing to muscle weakness. Infections—acute or chronic—can adversely affect skeletal

muscle metabolism and result in loss of performance and muscle weakness (Fiatarone, 1993). Many medications, such as those prescribed for the treatment of depression and insomnia as well as self-prescribed drugs, may also affect balance and gait, and over-medication may be a common cause of walking problems that result in falls. These medications also may make it harder for the user to rouse from sleep, so their response to a fire alarm is slowed. Some medications may also impair the user's judgment in a stressful life-threatening situation such as a fire, further increasing the risk of injury or death.

Psychological Factors Affecting Walking: Fear of Falling

The fear of falling causes many older people to reduce the variety and level of their physical activity, thus reducing their independence and self-esteem (Lilley, Arie, and Chilvers, 1995). A worse consequence of reduced physical activity is the loss of muscle and bone mass, which is exacerbated by inactivity. It is not always clear whether a frail elderly person falls because he or she is frail or whether the frailty results from a fear of falling.

Falls have serious consequences for older people, who suffer more disability, have longer recovery and rehabilitation times, and are more likely to die from falls than are younger people (Lilley et al.). Statistics collected in 1976 by the U.S. Department of Health and Human Services show that falls ranked sixth among the leading causes of death for people over 65 (Tinetti et al., 1986). Metropolitan Life Insurance Company data also show that while elderly Americans represent only about 11% of the population, they represent 70% of all fatalities from falls. A person 80 or older is eight times more likely to die from a fall than a person of 60 or younger (Ross, 1991). Tinetti et al. also found that approximately 20% of people who live at home fall each year, and nearly twice as many who are institutionalized fall. The fear of falling is especially problematic when a susceptible individual is confronted by stairs, as is the case in evacuation of a multistory building in an emergency.

Falls in older people are often followed by more falls, and the falls usually result from a combination of several disabilities or decrements rather than a single cause. In this same study Tinetti et al. found nine chronic disabilities that appear to influence the risk of older people falling: mobility, morale, mental status, distant vision, hearing, postural blood pressure, condition of the back, use of medications, and level of ability to perform activities of daily living (ADLs). Mobility and gait have been measured based on the activities listed in Table 1.

Table 1: Balance and Gait Evaluations

Balance Maneuvers	Gait Observations
Sitting balance	Initiation of gait
Rising from a chair	Step length
Immediate standing balance (first 5 seconds)	Step height (does foot clear floor?)
Prolonged standing balance	Step continuity
Withstanding nudge on chest	Step symmetry
Standing balance with eyes closed	Walking stance
Turning balance (360°)	Amount of trunk sway
Sitting down	Path deviation

From "Fall Risk Index for Elderly Patients Based on Number of Chronic Disabilities," by Mary E. Tinetti, T. Franklin Williams, and Raymond Mayewski, 1986, *The American Journal of Medicine*, 80, p. 430.

Mobility relates to such musculoskeletal and neurologic characteristics as strength of lower extremities, extension of back, condition of the neck, and the individual's perception of his or her mobility (Tinetti, et al.). Misperception of the environment and errors in judgment are also factors affecting the mobility of people with dementia or depression (Overstall, 1980). Among institutionalized elderly people who are not chronic fallers (i.e., those who have experienced only one fall), the factors that are most often involved include poor mental status, decreased vision, poor mobility, and limitations in ADLs.

Characteristics of Older People's Walking

Older people generally walk more slowly and carefully than younger people. Their gait is less confident and has less resilience. One of the first indications of changes in the gait of older people is that they do not lift their feet as high as they previously did when walking. This change is often referred to as the "old age shuffle." Overstall (1980) attributes this shuffle to reduced coordination in the legs as well as reduced movement at the pelvis. To allow one leg to swing forward in walking, there must be lateral displacement of the pelvis toward the weight-bearing leg. Reduced joint mobility in elderly walkers results in less lateral displacement; hence, the foot may swing too low (Overstall, 1980). Lower levels of muscle strength and flexibility may affect gait and balance (Rothstein, 1993), whereas alignment of the knee joint affects the cadence of the gait (Wang, 1993). Certainly the reduced muscle strength and joint stiffness contribute to this phenomenon.

As people age often the pads of fat tissue on the bottoms of the feet deteriorate, leaving the feet without the natural cushions that absorb the impact of walking. This condition makes it painful to walk on hard surfaces, especially in shoes that have little or no cushioning in the soles. The pain associated with walking may also contribute to the shuffling gait.

The walk of the older adult, then, may be described as slower, shuffling, and generally less confident and less stable than that of a young person. Some of the changes in gait and balance are the result of deterioration of the musculoskeletal or sensorimotor mechanisms. However, people also tend to change their strategies for negotiating the environment to compensate for fear of falling. This fact probably accounts for some of the loss of spring in the step.

Maki (1997) identified several changes in gait that appear to result from age: strides are shorter and slower, the stance (i.e., lateral distance between the feet) is wider, and more

time is spent with the weight on both legs (double-leg support). In his study of whether these changes were predictors of future falls or rather indicators of fear, Maki writes:

Changes in gait cited previously as risk factors for falling, i.e., decreased stride length and speed and prolonged double support, may in fact be stabilizing adaptations related to fear of falling. Stride-to-stride variability in the control of gait is an independent predictor of falling and may be a useful measure for identifying high-risk individuals and evaluating preventive interventions. Stride width may also be a useful outcome measure. Contrary to common expectation, a wider stride does not necessarily increase stability but instead seems to predict an increased likelihood of experiencing falls (Maki, 1997, p. 313).

The changes that accompany aging and with diseases associated with aging as well as fear of falling result in significant decrements to mobility that make the older person slower and less stable than what is generally considered normal. The design of buildings to house elderly people must, therefore, take these decrements into consideration.

Walking Speeds of Older Adults

As stated previously, this thesis study examines the walking abilities of older people to determine whether building and life safety codes are adequate in establishing minimum standards for fire safety in homes for the aged. Walking speed is a critical issue in this study. Walking speeds of older people are well documented. Many researchers have measured walking speed because it is widely accepted in the gerontology community as a reliable measure of functional ability or disability and dependence among older people. Tinetti et al. (1986) studied risk factors in chronic falling and identified musculoskeletal and neurologic variables that correlate with mobility. Their work is often cited as a standard by other gerontological researchers.

Friedman et al. (1988) assessed physical rehabilitation based on walking speed following stroke and hip fracture and found that it was a good predictor of the level of care needed when a person was discharged from a rehabilitation facility. They measured the walking

speeds of 113 persons over a 2-m course as they were admitted to a geriatric rehabilitation program and weekly thereafter for the duration of their stay. The research team found that participants who were able to return to their homes—either alone or with a care-giver—had mean walking speeds ranging from 0.194 to 0.835 m/s at discharge. Those who were discharged to a rest home² had a mean walking speed of 0.344 ± 0.187 m/s (0.15–0.53 m/s) at discharge. These researchers report that they “found that a discharge walking speed of 0.15 m/s best separate immobile subjects who require long-term hospital care from those sufficiently mobile to be discharged home alone or to a rest home (54% versus 0% below cut-off, respectively) (Friedman, Richmond, and Baskett, 1988, p. 227).” This speed of 0.15 m/s has been accepted by other geriatric researchers as a minimum for considering a person mobile.

Gibbs et al. (1993) used walking speed as a measure of joint impairment. In their study of the influences of impaired joints on walking abilities, they measured the walking speeds of 532 people over age 60 (median age was 76.6 years) as they walked a 50-foot course. The researchers found an average walking speed of 0.914 m/s among the 222 subjects (mean age 83.0 years) who resided in a continuing care retirement community (CCRC) encompassing independent living, sheltered, and intermediate care residents.

Maki (1997) studied whether changes in gait in older people are predictors of falls or if they indicate a fear of falling. He measured the walking speed of 75 healthy older adults (mean age was 82) as they walked 10 meters without using canes, walkers, or other aids. The subjects all lived independently in a self-care apartment complex for the aged. Maki found the mean walking speed to be 0.7 m/s. Those who were confident had walking speeds about 16% faster than those who were afraid of falling. Maki cites other researchers (including

²This research was conducted in Australia, and the term *rest home* was not defined. It may have been equivalent to a nursing home or assisted living center in the United States.

Wolfson et al.; Murray, Kory, & Clarkson; and Elble et al.) who studied walking speeds of healthy older people and found that people in the same age group who lived independently had average walking speeds of about 0.9 to 1.2 m/s, while those who lived in nursing homes had average speeds of about 0.5 m/s (Maki, 1997).

Because walking speed is so widely used as a measure of functional ability, other researchers, such as Bendall, Bassey, and Pearson (1989) have measured it in their studies of factors that affect walking speed of older people. They found that walking speeds of 67 women and 58 men between 65 and 90 years old and living independently measured 1.33 ± 0.17 and 1.17 ± 0.17 m/s, respectively.

In their study of the relationship of leg strength and walking speed, Buchner et al. (1996) measured the usual walking speed of 409 people between 60 and 96 years old whose health status was assumed to be representative of the age group. They excluded people with such debilitating conditions as stroke, dementia, rheumatoid arthritis, chronic corticosteroid use, or terminal illness from the study. They found the usual walking speed to be 1.22 m/s. The measurement was taken over a 50-foot (15.2 m) course with subjects instructed to walk at their normal pace.

In studying the association between maximal isometric strength and mobility, Rantanen, Era, and Heikkinen (1994) measured joint strength, walking speed, and stair-climbing abilities of 287 male and female residents of Jyväskylä, Finland. Each participant was 75 years old and did not have any physical condition that might have contraindicated physical exertion (such as cardiovascular disease or hypertension). The team found mean walking speeds of 1.8 m/s for males and 1.5 m/s for females. Walking speed was measured over a 10-m distance in an interior corridor using a standard stopwatch.

Laukkanen, Heikkinen, and Kauppinen (1995), in research related to that just described,

examined physical capacity as a predictor of survival among 75- and 80-year-old people in the same central Finland city of Jyväskylä. Walking speed was one factor of physical capacity, along with mobility, grip strength, and knee extension strength. The study population of 466 participants included both community-dwelling and institutionalized individuals. Measurements were taken over the same 10-m course, and the mean walking speed was found to be 1.3 m/s. It is possible that cultural differences between the United States and Finland account for the greater walking speeds of Finnish people, but such differences were not included in this research.

Lord, Lloyd, and Li (1996) compared the walking speeds of 96 community-dwelling Australian women over age 65 (mean age was 72.8 years) with 87 women aged 22 to 64 in research on the relationship of sensori-motor function, gait patterns, and falls. Over an 11.2-m course they found a mean walking speed of 1.04 m/s and that walking speed decreases steadily with age (Table 2).

Another group of researchers have investigated the walking speeds of older pedestrians to determine if traffic signals give them adequate time to cross the street. Coffin (1994) measured the walking speed of elderly pedestrians as they crossed the street at signalized crossings and at midblock crosswalks. Her research shows that at signalized crossing the walking speed was 1.2 m/s and in the midblock crosswalk the average speed was 1.0 m/s.

Hoxie and Rubenstein (1994) observed people crossing a busy intersection in a Los Angeles, California neighborhood where many elderly people lived in senior apartments and board and care homes. Over half of the older people who crossed the 15.24-m street with the signals were not able to get across the intersection before the light changed. Noting traffic signals set to allow a person walking 1.22 m/s to cross safely, the actual walking speeds of seniors ranged from 0.86 ± 0.17 to 1.27 ± 0.17 m/s.

Table 2. Average Walking Speed by Age Group

Age Group	Walking Speeds
	(m/s)
20-29	1.38
30-39	1.32
40-49	1.29
50-59	1.24
60-64	1.22
65-69	1.13
70-74	1.07
75-79	1.01
80-99	0.96

Source: Lord, S.R., Lloyd, D.G., and Li, S.K. (1996). Sensori-motor function, gait patterns and falls in community-dwelling women. *Age and Ageing*, 25, 292-299.

Walking Speeds of Older People and Building Code Requirements

Most of the walking speeds observed by the researchers cited above are too slow to allow an older person to evacuate a burning building safely. The published walking speeds range from 0.15 to 1.80 m/s. *Life Safety Code* (NFPA, 1994, 22-3.2.6.1-2) specifies a maximum travel distance of 125 ft (38 m) within a room or living unit and a maximum travel distance of 200 ft (61 m) from the corridor door to the nearest exit of residential board and care facilities that have sleeping accommodations for 16 or more residents, identified as large facilities. (This code does not specify maximum travel distances for small residential board and care facilities, which house less than 16 residents.) Therefore, the maximum distance a person might have to walk from the farthest point in a room or living unit to an exit is specified at 325 ft (99 m).

SBC Table 1004 prescribes the maximum travel distance for Group R occupancies with automatic sprinkler systems as 250 ft (76 m). All Group R4 occupancies must have automatic sprinkler systems (*SBC*, 1997, 903.7.7). Table 3 shows the walking speeds cited in 10 studies and the time required to travel 99 m and 76 m at each of the walking speeds listed. Those times range from 55 s to 10 min 54 s for *Life Safety Code's* 99 m and from 42 s to 6 min 47 s for *SBC's* 76 m.

In *Concepts in Building Firesafety* M.D. Egan (1978) noted that the average person's walking speed is about 1.22 m/s, the same speed cited by Hoxie and Rubenstein as the average speed for timing traffic signals. Egan wrote:

Persons with normal physical ability move forward horizontally at a speed of about 4 feet per second (fps) [about 1.22 m/s] through unobstructed passageways. A 'shuffle,' caused by jamming in exits or overcrowded corridors, can be about $2\frac{1}{2}$ fps or less. For most nonhazardous situations, $1\frac{1}{2}$ to 2 minutes can be sufficient time to move to a safe area after receipt of an alarm warning. For this situation, the travel distance to exits can be estimated by: distance = velocity $\times$ time = $2\frac{1}{2}$ fps $\times$ 90 seconds = 225 ft [distance = 0.762 m/s $\times$ 90 seconds = 68.6 m] (Egan, 1978, p. 180).

One purpose of this thesis research is to show that older people do not have normal physical ability. Rather, their mobility is impaired by the effects of age or age-related disease so they walk more slowly than normal.

T.C.A. defines *evacuation capability* as "...the ability of the occupants, residents and staff to either evacuate the building or move to a point of safety (T.C.A., 1992, 1200-8-11-.01)." Both *Life Safety Code* and T.C.A. establish three levels of evacuation capability: prompt, slow, and impractical. Prompt applies to persons who are able to evacuate the building in three minutes or less, and slow refers to those who evacuate in 3 to 13 minutes. Those who need more than 13 minutes to evacuate are classified as impractical (NFPA, 1994, A-22-1.3 and T.C.A., 1992, 1200-8-11.01[11]). A facility is designated as slow if any

Table 3. Reported Walking Speeds

Source	Living Arrangement	Mean Age	Walking Speed (m/s)	Time to walk 99 m (min:sec)	Time to walk 76 m (min:sec)
Gibbs, 1993	CCRC	83.0	0.914	1:48	1:20
Friedman et al.	Home alone	74.0	0.553±0.282	1:59-6:05	1:31-4:51
	Home care	76.3	0.427±0.233	2:30-8:30	1:55-6:32
	Rest home	83.7	0.344±0.189	3:06-10:30	2:23-8:41
<i>Minimum mobility</i>			0.15	10:54	6:47
Maki	Retirement home	82.0	0.700	2:20	1:47
Buchner et al.	Mixed	60-96	1.220	1:21	1:02
Lord, Lloyd & Li	Community-dwelling	72.8	1.040	1:35	1:13
Laukkanen et al.	Mixed	75 & 80	1.298	1:16	0:59
Rantanen, Era, Heikkinen	Mixed	75 75	M: 1.800 F: 1.500	0:55 1:06	0:42 0:51
Bendall, Bassey & Pearson	Independent	71 72	Male: 1.333 Fem: 1.166	1:14 1:25	0:57 1:05
Coffin	NA	>60	1.200	1:23	1:03
Hoxie & Rubenstein	Mixed	>65	0.410-1.290	1:17-4:01	0:59-3:05
<i>Prompt (0-3 min)</i>			0.550 0.422	3:00	3:00
<i>Slow (3-13 min)</i>			0.126 0.097	13:00	13:00

Table compiled by the author from the following sources: Gibbs, J., et al. (1996). Predictors of change in walking velocity in older adults. *Journal of the American Geriatrics Society (JAGS)*, 44, 126-132. Friedman, P.J., Richmond, D.E., and Baskett, J.J. (1988). A prospective trial of serial gait speed as a measure of rehabilitation in the elderly. *Age and Ageing*, 17, 227-235. Maki, B.E. (1997). Gait changes in older adults: Predictors of falls or indicators of fear? *JAGS*, 45, 313-320. Buchner, D.M., Larson, E.B., Wagner, E.H., Koepsell, T.D., DeLateur, B.J. (1996). Evidence for a non-linear relationship between leg strength and gait speed. *Age and Ageing*, 25, 386-391. Lord, S.R., Lloyd, D.G., and Li, S.K. (1996). Sensori-motor function, gait patterns and falls in community-dwelling women. *Age and Ageing*, 25, 292-299. Laukkanen, P., Heikkinen, E., and Kauppinen, M. (1995). Muscle strength and mobility as predictors of survival in 75-84-year-old people. *Age and Ageing*, 24, 468-473. Rantanen, T., Pertti, E., Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, 23, 132-137. Coffin, Ann M. (1993). The walking speeds of elderly pedestrians (Doctoral dissertation, University of Calgary, Canada) (1993). *Dissertation Abstracts International*, MM83121. Hoxie, R.E., Rubenstein, L.Z., Hoenig, H., and Gallagher, B.R. (1994). The older pedestrian. *JAGS*, 42, 444-450.

resident is classified as slow. Such a facility is required to have staff on duty at all times to assist residents in case of a fire emergency. Facilities that house residents designated as impractical must meet the *Life Safety Code* requirements for limited care facilities (i.e., nursing homes), which assume occupants are "incapable of self-preservation because of age, physical limitations . . . or mental limitations. . . (NFPA, 1994, 12-1.3)." In such facilities the procedures for protecting residents in a fire emergency assume them to be non-ambulatory, and the facilities are staffed accordingly.

This study is concerned with those facilities designated as prompt or slow, where residents must be ambulatory and are expected to move themselves away from danger with minimal assistance. In a prompt facility a person must walk at a rate of 0.55 m/s to traverse the *Life Safety Code* maximum travel distance of 99 m in three minutes, and to walk the *SBC* travel distance of 76 m in three minutes requires a rate of 0.42 m/s. In a facility designated as slow, for a person to walk the two maximum travel distances in less than 13 minutes requires rates faster than 0.126 and 0.097 m/s, respectively, both significantly slower than the 0.15 m/s that Friedman et al. established as the baseline for consideration as ambulatory. Thus using NFPA and T.C.A. designations, a person may be classified as slow and yet be functionally immobile, that is, walk at a rate of less than 0.15 m/s.

If evacuation capability were based solely on walking ability, the fastest walkers would be able to evacuate within one to three minutes. More researchers, however, found speeds below average than above. The chart in Figure 1 shows the average walking speeds or range of speeds that each of the published research reports stated. Rantanen, Era, and Heikkinen (1994) and Laukkanen, Heikkinen, and Kauppinen (1995) found speeds faster than other researchers, and Bendall, Bassey, and Pearson (1989) found men in his study to walk faster than the established average speed of 1.22 m/s. All the other reports cited speeds at or

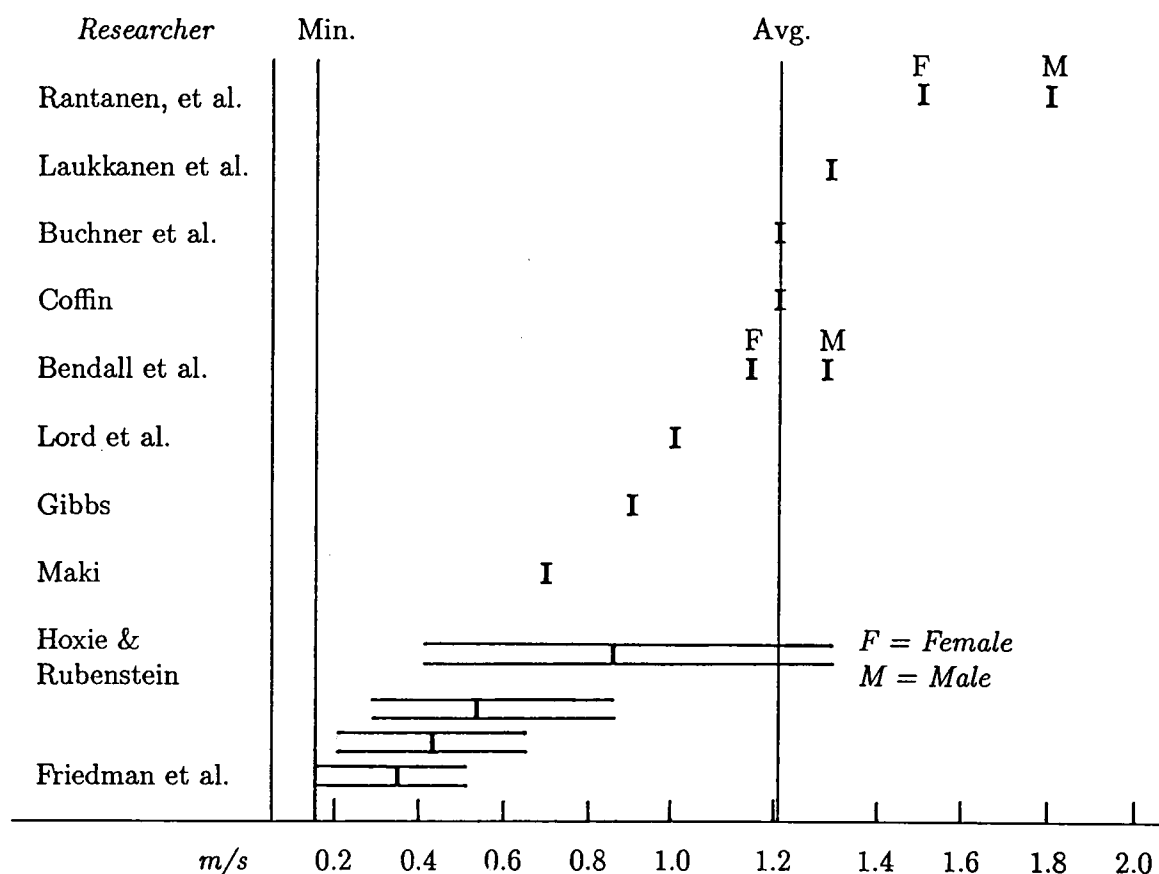


Figure 1. Average Walking Speeds of Older People Measured in Research.

Chart prepared by the author from the following sources of walking speed data: Gibbs, J., et al. (1996). Predictors of change in walking velocity in older adults. *Journal of the American Geriatrics Society (JAGS)*, 44, 126-132. Friedman, P.J., Richmond, D.E., and Baskett, J.J. (1988). A prospective trial of serial gait speed as a measure of rehabilitation in the elderly. *Age and Ageing*, 17, 227-235. Maki, B.E. (1997). Gait changes in older adults: Predictors of falls or indicators of fear? *JAGS*, 45, 313-320. Buchner, D.M., Larson, E.B., Wagner, E.H., Koepsell, T.D., DeLateur, B.J. (1996). Evidence for a non-linear relationship between leg strength and gait speed. *Age and Ageing*, 25, 386-391. Lord, S.R., Lloyd, D.G., and Li, S.K. (1996). Sensori-motor function, gait patterns and falls in community-dwelling women. *Age and Ageing*, 25, 292-299. Laukkanen, P., Heikkinen, E., and Kauppinen, M. (1995). Muscle strength and mobility as predictors of survival in 75-84-year-old people. *Age and Ageing*, 24, 468-473. Rantanen, T., Pertti, E., Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, 23, 132-137. Coffin, Ann M. (1993). The walking speeds of elderly pedestrians (Doctoral dissertation, University of Calgary, Canada) (1993). *Dissertation Abstracts International*, MM83121. Hoxie, R.E., Rubenstein, L.Z., Hoenig, H., and Gallagher, B.R. (1994). The older pedestrian. *JAGS*, 42, 444-450.

below average. (It should be noted that the studies of Rantanen et al. and Laukkanen et al. were both conducted in Finland, where cultural differences may have influenced walking abilities of older people. Such differences are not, however, confirmed.) These findings give reason to reevaluate building and life safety codes for buildings designed to house elderly occupants.

Factors Contributing to Fire Casualties

Under authorization of the Federal Fire Prevention and Control Act of 1974 (P.L. 93-498), the National Fire Data Center in the United States Fire Administration (USFA) collects and analyzes information about fire incidents in the United States through the National Fire Incident Reporting System (NFIRS). The two stated objectives of NFIRS are "to help State and local governments develop fire reporting and analysis capability for their own use, and to obtain data that can be used to more accurately assess and subsequently combat the fire problem at a national level (USFA, 1998)." NFIRS is the largest national annual collection of fire incident information in the world (USFA, 1998). It is a three-tiered system in which local fire departments use a standardized NFIRS format, either hard copy or electronic, for coding and reporting data on fires. They submit the reports to state fire agencies, who forward the reports to USFA.

Yet, the database comprises only about half of all fires that occur in the United States each year (USFA, 1998). Eight states do not participate in the data reporting, and many local fire departments in participating states do not submit some or all reports. If local fire departments do not report fires, then the fires are not included in the database. The incidents in the NFIRS database are not a random sampling of the fires that occur because the data are weighted more heavily toward those that result in greater loss of life or property

(Ahrens, 1998). It is assumed that many small fires go unreported when there are few serious injuries and property damage does not represent a significant financial loss to the community.

NFPA also collects and publishes information on fires in the United States and shares information with USFA. The organization sends its own investigators to report on fires with high loss of life or property but relies on local sources for information on smaller fires. Sometimes the only source of that information is local newspaper accounts.

Because the United States has no source of complete information on fire incidents, a case study analysis of the factors that contribute to fire casualties must be based on incomplete data. A true statistical analysis is not possible because the fire incidents reported are not a random sample of fires.

The NFIRS database includes information on civilian and fire personnel casualties as well as details on each reported fire incident, including time of day/night, type of occupancy, how and where the fire started, property damage, presence or absence of smoke detectors and sprinklers and whether or not they functioned. The data are presented in *Fires in the United States*, which is updated and published every few years. However, the NFIRS does not have a discrete classification for homes for the aged. Occupancies are classified as residential (including one- and two-family dwellings, multi-family apartments, manufactured homes, hotels and motels, residential hotels, dormitories, and halfway houses) and non-residential (which includes industrial and commercial properties, institutions, educational establishments, mobile properties, and properties that are vacant and under construction). Homes for the aged are counted as non-residential institutional occupancies and are grouped with hospitals, nursing homes, and prisons (USFA, 1997). Therefore, discrete data specifically on fires in homes for the aged are not available from NFIRS.

NFPA does publish articles about fires that the organization deems significant or representative in its bimonthly membership magazine, *NFPA Journal*, and from time to time compiles articles about specific types of buildings or occupancies into reports. One such report is *Special Data Information Package: Elderly Housing*, published in 1996 and comprising articles on 25 fires that occurred between 1972 and 1996. This report may not include every fire that occurred in the United States in housing for the aged during the period, and those that are reported are not a random sample of fires that occurred—that is, they probably represent the worst fires that occurred. Even though an analysis may not be statistically valid, a study of these 24 fires has value because patterns emerge indicating several factors that frequently contribute to fire casualties.

The buildings cited in the NFPA information package are, with the exception of one board and care facility, all referred to as either “apartments for elderly” or a “housing complex for elderly.” All come under *SBC* residential occupancy classification, and all of the fires occurred before the R4 Assisted Living occupancy classification became part of *SBC*. NFPA *Life Safety Code* differentiates between apartment buildings and residential board and care facilities, with the latter providing personal care services. It is not clear whether all of the facilities in this study provide a level of care that would qualify them as residential board and care or if some would be classified as apartment buildings under *Life Safety Code*. All did, however, provide housing specifically for older adults.

Case Study Analysis of Fires in Housing for Elderly People

The NFPA information package describes 24 fires, of which half caused no casualties beyond minor injuries. The 12 other fires took 58 lives, and 26 of those fatalities (44%) resulted from just two fires. The two catastrophic fires occurred in 1972 in Atlanta, Georgia, where 10 people died, and in 1989 in Johnson City, Tennessee, where 16 people died. The most

housing-for-aged fires in a single year occurred in 1975, when five fires took seven lives.

Baptist Towers Home for Senior Citizens was an 11-story apartment building on the southwest side of Atlanta completed only eight months before the fatal fire occurred. Designed with the intent of meeting local and federal codes, the \$4.5 million facility was built by a nonprofit corporation composed of seven local Baptist churches and was financed through the U.S. Department of Housing and Urban Development (HUD) 236 Program. It contained 200 one-bedroom and efficiency apartments and was constructed of fire-resistive materials. A sprinkler system protected only the maintenance shop and a first-floor room where trash from the refuse chute accumulated.

The fire began in the seventh-floor living room of a 61-year-old woman who was disabled by Parkinson's disease. When she discovered the fire at about 2:00 a.m., she left her apartment to tell others, leaving the apartment door open. She returned, however, to get her medicine and died in the corridor about 10 feet from her door. Eight other people on the seventh floor died. Seven of the nine fatalities were from carbon monoxide poisoning and two were from thermal burns. Another man, who was on the 10th floor, died in a hospital six days later from smoke inhalation. Thirty people were injured.

NFPA cited several factors that contributed to the seriousness of the fire. Delay in activating the manual local-only fire alarm upon discovery allowed the fire to reach flashover stage before the fire department was notified by telephone calls. When the occupant of the apartment of origin left her apartment door open, the smoke and fire spread into the corridor and up the elevator shaft to the higher floors of the building. This defeated the compartmentation features of the building (i.e., one-hour rated partitions and solid-core composite doors). Two other significant factors were the design of the ventilation system and the choice of carpeting in the corridor.

The ventilation system consisted of exhaust fans on the roof designed to remove approximately 100 cfm of air from each apartment through exhaust vents in the bathrooms and kitchens and a 20,725-cfm fan located on the first floor in a ventilation shaft adjacent to the elevator shaft. Make-up air for individual apartments flowed from the corridors under the entry doors, which were undercut by as much as $1\frac{1}{2}$ inches to allow the air flow. A highly flammable loop-pile polypropylene carpet with polypropylene fiber backing bonded to a secondary backing of foam rubber was cemented to the concrete floor in the corridor (Willey, 1973, p. 16). The NFPA report states,

Smoke and toxic products of combustion were drawn into other apartments by exhaust vents in kitchen and toilet areas. The exhaust system fans and the air supply fan continued to operate during the fire. . . . The exhaust systems were designed to exhaust up to 100 cfm of air from each unit. This design violates the intent of certain codes, such as NFPA No. 90A, the *Standard for the Installation of Air-Conditioning and Ventilating Systems*, which does not contemplate such a high continuous air flow between the corridor and the apartments and the undercutting of apartment entry doors (Willey, p. 21).

The combination of forced air circulation and toxic fumes from the burning carpet, which also failed to meet code, proved deadly.

The 1989 Christmas Eve fire in the John Sevier Home in Johnson City, Tennessee was briefly described in the first section of this study. In contrast to the new Baptist Towers Home, the John Sevier Home was an adapted older building. The 10-story brick John Sevier Hotel was originally constructed in 1924 and an addition was added in 1929. It was operated as a hotel until 1977. In 1980 the building was renovated and converted to apartments for elderly adults. A 1977 renovation had added two fire stairs, emergency lighting, a standpipe system, a system to detect false fire alarms, and an intercom system for firefighters. When the building was converted to housing for elderly people, it was approved for HUD use.

The fire began about 5:00 p.m. in a first-floor apartment in an area that had originally been the ballroom. When the elderly female resident evacuated her apartment, she left

the door open. This allowed smoke to spread into the corridor. It then moved through the elevator shaft and unsealed pipechases to the upper floors. Firefighters found victims on the second, fourth, fifth, seventh, eighth, and tenth floors. Most were clustered around elevators (Kirkland, 1989, p. 12).

In hearings before a Tennessee Senate-House committee studying building safety issues, "faulty construction, inadequate enforcement of building codes, lack of sprinklers and slow response to smoke alarms (Wozniak, 1990, April 17, p. 1)" were cited as the leading causes of the fatalities in the John Sevier Home fire. Faulty construction refers to installation of a false ceiling in what had been the ground-floor ballroom of the hotel. In the 1980 renovations the ballroom was subdivided and converted to apartment units. The wood-fiber tiles on the original ceiling were apparently not removed during the renovation and were hidden by the new suspended ceiling. In the confined space between the two ceilings, the wood fiber burned and produced large quantities of lethal carbon monoxide gas. Howard Boyd, retired Nashville, Tennessee fire marshal, also cited wood wall studs used in the partitions of the ballroom apartments as poor construction and code violation. He was quoted in the Johnson City newspaper as saying, "... partitions were built of two by fours. You can't put wood in a type one building, but somebody didn't enforce the building code (Travis, 1990, p. 5)."

As in the Baptist Towers fire, smoke spread contributed to the high death toll. Fire investigators in the John Sevier Home incident found that unsealed pipechases allowed smoke to rise to the upper floors. When the fire started, the emergency systems caused the elevators to go to the ground floor and stop. The doors of the elevators, however, stayed open. This not only provided a source of oxygen to fuel the fire, but it provided another path for smoke to spread upward. Most of the fatalities occurred on upper floors.

The lack of sprinklers at the John Sevier Home was not a code violation. Code requires that when a building is altered and the occupancy classification changes, the building must be brought up to the code requirements for the new occupancy. When this building was renovated in 1979-80, the code that was in force did not require sprinklers for the new occupancy. It was not until several years later that sprinklers became a requirement for this occupancy. Functioning sprinklers in this building may have controlled the fire.

These two fires had much in common. Both the John Sevier Home and the Baptist Towers fires are believed to have started from careless cigarette smoking, the leading cause of fatal fires in the United States (USFA, 1995). Neither building was equipped with sprinklers in the area of fire origin. In both of the catastrophic fires the person who first discovered the fire was incapacitated in some way—one by Parkinson's disease and the other by documented psychological problems—and did not take immediate action to activate a fire alarm. The critical factor in both fires was smoke spread. The occupants of both of the rooms of fire origin left a door open when they evacuated the burning room. This is a common occurrence. Of the 12 fatal fires described in the NFPA report on fires in housing for elderly people, doors to the room of origin were left open in five of them, accounting for 39 fatalities and many more injuries. A comparison of the research findings of researchers Peter Wood (1972) in England and John Bryan (1983) in the United States indicates that people in England are better trained in the practice of confining a fire to the room of origin by closing doors than people in the United States.

Early warning is a significant factor in saving lives in fires. Three types of warning systems are widely used: smoke detectors, heat detectors, and alarm systems that are either manually activated or automatically activated by one of the other sensors. Of the fires studied, seven of the buildings where fatal fires occurred had smoke detectors, but in

two of those fires the devices did not function (Table 4). In one case the batteries had been removed, and in the other the smoke detectors were located only in front of elevators and were used to send the elevator to the first floor.

While smoke detectors are widely used, heat detectors are less prevalent. Five buildings in this study had heat detectors (Table 4), but among those that had fatal fires the devices were present in only two buildings. In both cases the heat detectors were located only in the corridors and did not sense the heat generated from a fire inside an apartment until a door was opened allowing smoke to fill the corridors. One of these was the same fire in which the smoke detector was installed only in front of the elevators, and it indicates the importance of appropriate placement of alarm devices.

**Table 4. Fire Warning and Control Device Usage
in Housing for Elderly People**

	Fatal Fires n=12	Non-Fatal Fires n=12
Smoke Detector	7	7
Functioned	5	6
Heat Detectors	2	3
Functioned	2	3
Sprinklers	2	4
Functioned	0	4
Fire Alarms	9	9
Manual	8	3
Automatic	2	6
Local	6	1
Fire Dept.	3	8

Source: National Fire Protection Association (1996). *Special Data Information Package: Elderly Housing*. Quincy, MA: NFPA.

Eighteen of the facilities studied had fire alarms of some type (Table 4). Among the non-fatal fires most alarms were automatic (6 of 9) and were wired to notify the fire department or an alarm company that notified the fire department (8 of 9). In the buildings where fatal fires occurred, more of the alarms were manual (8 of 9) and the alarm sounded only locally (6 of 9) rather than notifying the fire department immediately. In eight of the fatal fires delay in activating an alarm was a factor, and 47 people died in those eight fires. Even in fires with no casualties, delayed warnings resulted in more damage and property loss.

Four of the non-fatal fires were in buildings equipped with sprinkler systems, and in each case the sprinkler either extinguished the fire or controlled it until firefighters arrived and put it out. All four of those fires occurred between 1986 and 1996, after sprinklers became a code requirement in some facilities. Only one of the properties in which fatalities occurred had sprinklers in the area of the fire, and that system did not function correctly because of an insufficient water supply. The installation had not been inspected by city building officials and did not meet code. The 1997 edition of *SBC* is the first edition to establish an occupancy classification specifically for housing for elderly people and require sprinkler systems in all of them. As late as 1994 sprinklers were required only in facilities that were three or more stories high.

Case Study Analysis of Fires in Board and Care Homes

In addition to the information package on elderly housing, NFPA has published a special analysis, *U.S. Fires in "Board and Care" Homes* (Hall, 1993). Presented in matrix format, the document presents analyses of 57 fatal fires that occurred between 1971 and 1992. The data come from NFPA's Fire Incident Data Organization (FIDO) and represent all the reported fires classified as board and care homes in the FIDO database. Only the fires with high numbers of fatalities were investigated by NFPA directly. Many of the fires with

fewer fatalities are poorly documented, with much of the information gathered from news accounts.

Author John Hall notes that FIDO "...records a property as 'board and care' home if there is a pronounced mismatch between the level of care the property is designed to provide and the level of care required by some or all of its residents.... All or nearly all the incidents coded as 'board and care homes' in FIDO, therefore, are to some degree inadequate to the needs of their occupants (Hall, 1993, p. i)." It is not surprising, then, that investigations of the fires uncovered many code violations. Still, as with the NFPA information package on elderly housing, the descriptions in this document have value because patterns emerge that indicate several factors contributing to fire casualties. Many of these patterns appear primarily in structures that have been adapted from other uses.

Of the 57 fires reported, 23 of the facilities were reported to house primarily elderly people. Some of these properties housed both elderly people and others who were disabled in some way, either mentally or developmentally retarded, mentally ill, or physically handicapped. This study is generally confined to the 23 fire incidents involving elderly people, which occurred between 1973 and 1991. The fires accounted for 162 fatalities.

Seventeen of the facilities are known to have been housed in older buildings that had been converted from another use. (Others may have been in older buildings, but the information was not reported.) Fifteen of these buildings were originally designed to be one- or two-family dwellings and were of unprotected wood frame construction. Some of the converted buildings were as much as 75 years old and over the years had had numerous alterations. Most of the buildings were two to three stories high.

The most deadly fire, in which 31 people died, occurred in 1981 in a New Jersey building that had been designed as a four-story beach hotel but was converted to a two-story lounge

after a fire damaged the upper two floors sometime before 1969. In that year the original building was converted to a sheltered board and care facility, and a one-story addition was added and used as an intermediate-care facility. The fatal January 1981 fire started in the living/dining room on the ground floor of the two-story section of the building.

The use of hollow-core or wood-paneled doors and wood paneling on walls and especially around stairways were cited as significant factors in the development and spread of the fire. The extensive use of these materials as well as carpeting that was not fire resistant were factors that contributed to the intensity of many of the fires described in the document. Several other factors appeared again and again in the various fires described.

In his research on human behavior in fires, Bryan (1988) found that previous experience, education, and personality, as well as the behavior of those sharing the experience are significant factors in how a person will react in a fire emergency. As Bryan's research indicated, training is a key to fire safety. Yet only five of the 57 facilities included in the total document reported conducting regular fire drills, and in only two of those were the drills conducted in such a manner that they were valuable in teaching either the residents or the staff what to do in a real emergency. In some facilities where drills were held, residents participated only when they chose to do so, and in one facility drills were held at times when most residents were already located near the exits. Because they were not adequately trained, staff often failed to take appropriate action, which led to confusion among residents and frequently to delays in evacuation. These delays were sometimes fatal. In the 1981 New Jersey fire described above, it was noted that "...residents often reinforced bad habits in these drills, using normal routes out instead of nearest exits, refusing to evacuate at all, or delaying evacuation to take belongings with them (Hall, 1993, p. 31)." Three cases were cited in the case histories in which residents in their efforts to escape the fire and smoke

made their way past fire exits to the exit route they customarily used, which was often an unenclosed stairway. Further, the lack of training is one reason why people in the United States often fail to close the door to the room of origin, allowing smoke to endanger many more lives.

Not only were staff poorly trained to handle emergencies, but in most of the facilities staffing levels were inadequate to deal with the emergency. Although the staffing levels of most facilities met regulatory requirements, when an emergency occurred, there were not enough people to take care of the residents. It is important to note that most of the fires occurred at night, when staffing was lowest. Time of day was recorded on 21 of the 23 fires. Seventeen of them occurred between 8:00 p.m. and 6:00 a.m., accounting for 113 fatalities. Only four fires occurred between 6:00 a.m. and 8:00 p.m., resulting in 19 fatalities. The New Jersey facility where 31 people died housed 37 residents, and only one attendant was on duty when the fire was discovered at 3:45 a.m. In another facility where 16 residents lived, the two on-duty staff were both asleep when the fire was discovered at 12:30 a.m., and in another where 25 people resided, there were two attendants present and one was asleep. A total of 51 persons died in these five night-time fires.

Unenclosed stairways were significant factors in at least eight of the 23 fires studied. This particular problem appears to be more prevalent among converted older buildings than among purpose-built properties. Another problem was the lack or disabling of fire doors. Only two of the facilities studied were equipped with fire doors that closed automatically, and in one of those the doors had been blocked open. Breaches in compartmentation like these contributed to nearly all of the fatalities.

The inadequacy of fire warning and control devices in the residential board and care facilities was another significant factor contributing to casualties. Most of the properties (at

least 78%) had smoke detectors located somewhere in the facility, but in many cases they were located where they were too remote from the fire origin to be effective. For example, when a fire started in an apartment or bedroom and the smoke detector was located in the corridor, the door to the living unit prevented the smoke from activating the detector. This was also true of the heat detectors, which were reported in six of the facilities but functioned in only four. In two facilities smoke detectors were installed, but the batteries had been removed. Two facilities had neither smoke nor heat detectors.

Only six of the facilities (26%) reported having fire alarm systems. Three had manual pulls and three were automatic, activated by smoke or heat detectors. However, only one was connected directly to the fire department. All others alarmed locally, and in at least five cases the delay in notifying firefighters contributed to the fatalities. These delays were another effect of the inadequate training of staff and residents in the use of the fire alarms. The value of sprinkler systems to suppress fires is widely recognized. NFPA's John Hall states that, "the number of deaths per 1,000 fires drops more than 50 percent when sprinklers are present and this measure of impact emerges even without specifying that the sprinklers are operational or part of a well-designed complete system (Hall, 1990, p. 40)." Even so, only one of the facilities studied had a functioning sprinkler system. It was installed in the kitchen and basement area, but the fire began in the attic so it was not useful.

This analysis shows that among converted older buildings some of the most significant building features that contributed to casualties were unenclosed stairways, lack of compartmentation due to inadequate or nonexistent fire doors and rated partitions, smoke and heat detectors that were poorly located and badly maintained, and the need for sprinkler systems. In the operation of the facilities, the lack of emergency training (i.e., fire drills) and inadequate staffing were contributing factors.

Human Behavior as a Factor in Fire Casualties

Any study of the factors that contribute to casualties in fires would be incomplete without consideration of the behavior of occupants. Empiric research on human behavior in fires is scant. Fortunately, opportunities for direct observation are few, and when they occur are usually unplanned and unexpected. When such an observation opportunity does present itself, serious ethical and moral issues arise if observation takes priority over rescue and protection of subjects. Similar ethical issues surround attempts to simulate observation opportunities, especially with elderly subjects. Hence, the best information available is based primarily upon ex post facto research, relying on the memories of those who escaped a fire or those who participated in rescue efforts.

Moreover, it appears that the depth of analysis and reporting on fires is often in direct proportion to the number of lives lost. NFPA sends professional fire analysts to study and report on catastrophic fires, but reporting on smaller fires is left to the local authorities, whose reports are generally less informative, or to news accounts, which often exaggerate for dramatic impact. As a result, little is known of behavior in fires where there were few occupants or those where most people survived. Because most of the fires studied in depth involved large groups of people, some of the literature on human behavior amounts to the behavior of crowds rather than individuals actions.

Serious research on human behavior in fires generally began in 1972 when Peter G. Wood published the ground-breaking Fire Research Notes 953, *The Behaviour of People in Fires* in Great Britain. In the United States the publication of *America Burning* in 1973 prompted similar research on this continent. This landmark report called attention to the severity of the fire problem in the United States compared to the rest of the world and prompted the fire research community to examine why this nation has such a poor record.

Even though research on behaviors in fires is recent, a significant body of knowledge has accumulated over the past two decades. Many researchers have discovered the same behaviors in fire incidents, so the behavior patterns should be considered when designing for fire safety. Several researchers have noted that model building and life safety codes do not adequately address these behavior patterns (Schwalm 1981; Stahl, Crosson, & Margulis, 1982; Levin, 1984; Bendinelli, 1993; Pedersen, 1994). Keating (1985) wrote,

While the hardware innovations in both detection and suppression of fire in built environments has been impressive, it is essential for the proper utilization of such equipment, that the natural tendencies of human responses during an emergency be understood. Until relatively recently little attention has been paid to psychological factors that are critical in directing a persons [sic] behavior during fire emergencies (cited in Pedersen, 1994, p. 2-3).

Some behaviors that have been assumed to be unusual, such as delaying evacuation, appear to be common. Other behaviors that were once believed to be typical of people in fire emergencies, such as panic or an every-man-for-himself attitude, appear to be atypical and indeed seem to be very rare. Research does not support the long held belief that people panic in a fire situation. In fact, the opposite appears to be true, that people become altruistic more often than they panic. This is not to say that people are not afraid, but the word *panic* implies that fear is unreasoned, irrational, and anti-social and that people are not able to adapt to a changing environment, thereby reducing the probability of escape for the individual and the group (Schultz, 1968, cited in Bryan, 1986, p. 1-26). "Behavior in fires can be understood as a logical attempt to deal with a complex, rapidly changing situation in which minimal information for action is available (Bryan, 1986, p. 1-30)." The decisions made under the stressful circumstances of a fire may appear to be irrational when viewed in retrospect, but research has shown that they are, for the most part, quite logical given the information available at the time they are made. Sime, who researched panic behavior extensively, wrote that

... behaviour in a fire can only be properly judged against the individual's awareness of the options available at different stages of the fire, his familiarity with the building and general constraints of the fire situation. Unfortunately, the primary criterion adopted for panic or irrationality is the inappropriateness of behaviour as judged from [sic] someone else's perspective (Sime, 1990, p. 77).

Interviews with survivors of the 1993 terrorist attack on the New York World Trade Center illustrate these findings about panic:

'Clearly there was distress; some were crying,' Hurlbut [division operations manager, Kemper National Insurance Companies] said. 'Interestingly, I have never seen so much peer group support for one another. People consoled and comforted people who needed to be comforted. So much happened spontaneously. It was heavily skewed to the positive....'

'We had all the ingredients for panic and chaos, but it just didn't happen,' he [Nelson Chanfrau, general manager of risk management, Port Authority at the World Trade Center] said. 'The sense of order in an atmosphere of darkness and smoke was exceptional. No one was trampled, nor were there any incidents of that sort (Hershfield, 1995, pp. 65, 66).'

Time is a critical factor in safe evacuation in a fire emergency, and the decisions made and first actions taken are the most critical. Research on fire behavior shows that

... the period between detection of the fire and the arrival of the fire department is the most *crucial lifesaving period* in terms of the first compartment (the area in direct contact with the room of origin and the fire). Thus, lifesaving efforts in this crucial period must be performed by human and technological devices without the benefit of the fire department. (Lerup, Cronrath, and Liu, 1990, p. 163).

Bryan (1991) identified five stages in the decision-making process that people use in fire situations: recognition, validation, decision, evaluation, commitment, and reassessment. Recognition occurs when a person first senses that a fire may be present, but the first signals of fire are often ambiguous, causing people to investigate to discover their source. For example, the first indication of a fire may be the smell of smoke, or it might be unusual noises. It is not uncommon for people to misinterpret the initial signals or to trivialize them, not believing that a serious threat exists until they confirm it. People have to

validate their initial suspicions in some way before they make a decision to take action. Many underestimate the speed at which a fire develops.

Three factors influence the first actions a person will take in a fire emergency: previous experience with fire, training for fire emergencies, and gender. Those who had experienced a fire emergency before and those who had training in what to do in an emergency generally took the most appropriate first actions. Men and women behave differently in fire. As a first action men are more likely to try to fight the fire or rescue others, whereas women are more likely to call the fire department, to warn others, or to leave the building (Bryan, 1983). Men are also more likely to reenter a burning building than are women, but women are more apt to take time to get dressed. These differences are important because the overwhelming majority of residents of homes for the aged are female.

Latane and Darley (1968) studied how the presence or absence of other people influence escape behavior. Working with college students in an experimental situation they found that when a person was alone in a room with a task and smoke was introduced to the room through a vent, the person would leave the room to report a fire immediately upon recognizing the smoke. However, when other people were in the room and smoke was introduced, no one reported the fire immediately. The presence of other people seems to be an inhibiting factor. It appears that people look to each other to confirm that there is a problem to avoid embarrassment. This same behavior pattern is apparent among older people. In the case studies of fires in homes for the aged cited above, occupants, unless directly confronted by the fire, often sought out other people for validation of their suspicions before they took any action to escape a fire. Moreover, the position of the person in the social structure influenced the level of confidence the occupant had in the confirmation. For example, in one fire residents sought out a member of the staff to confirm the presence

of an emergency rather than taking the word of another resident. It was also found that people tend to assume the same roles during a fire incident that they have under normal conditions. Case studies of the Beverly Hills Supper Club fire in Kentucky revealed that the individuals seated at tables to which a particular waiter was assigned looked to that specific waiter for help in getting to safety, and waiters did not help the patrons seated at tables assigned to another waiter (Swartz, 1979). In an emergency people have a tendency to look for a leader for guidance. Following the World Trade Center bombing one survivor is quoted as saying, "It was quite frightening at first because no one seemed to be in charge and everyone was looking for a leader. I took the initiative and began to look for evacuation routes (Fahy and Proulx, 1995, p. 65)."

Other behavior patterns of people in fire situations that are of particular importance in designing facilities for elderly people include delayed evacuation and a tendency to follow the customary path of egress. Several factors play a part in delaying egress. One was the tendency to ignore or trivialize early warning signs discussed above. A 1997 NFPA survey of 500 American adults revealed that most Americans were unaware of the speed with which a fire develops and how little time they have to escape safely (Figure 2) (Wolf, 1998). Their limited mobility plus their inclination to delay egress place older people at great risk in a fire. Many times people have even disregarded fire alarms all together. One reason for ignoring alarms is the frequency of false alarms.

NFPA estimates that 1,646,500 false alarms occurred in 1993. Malfunctions of automatic alarm systems accounted for 41% of them, 25% were caused by malicious or mischief calls or bomb scares, and 35% were unintentional false alarms (Hershfield, 1995). False fire alarms are more than a nuisance; they are a problem for everyone concerned. They are a financial burden on the agency providing emergency service and ultimately expensive for taxpayers,

America's Perception vs. Actual Rate of Fire's Growth and Speed

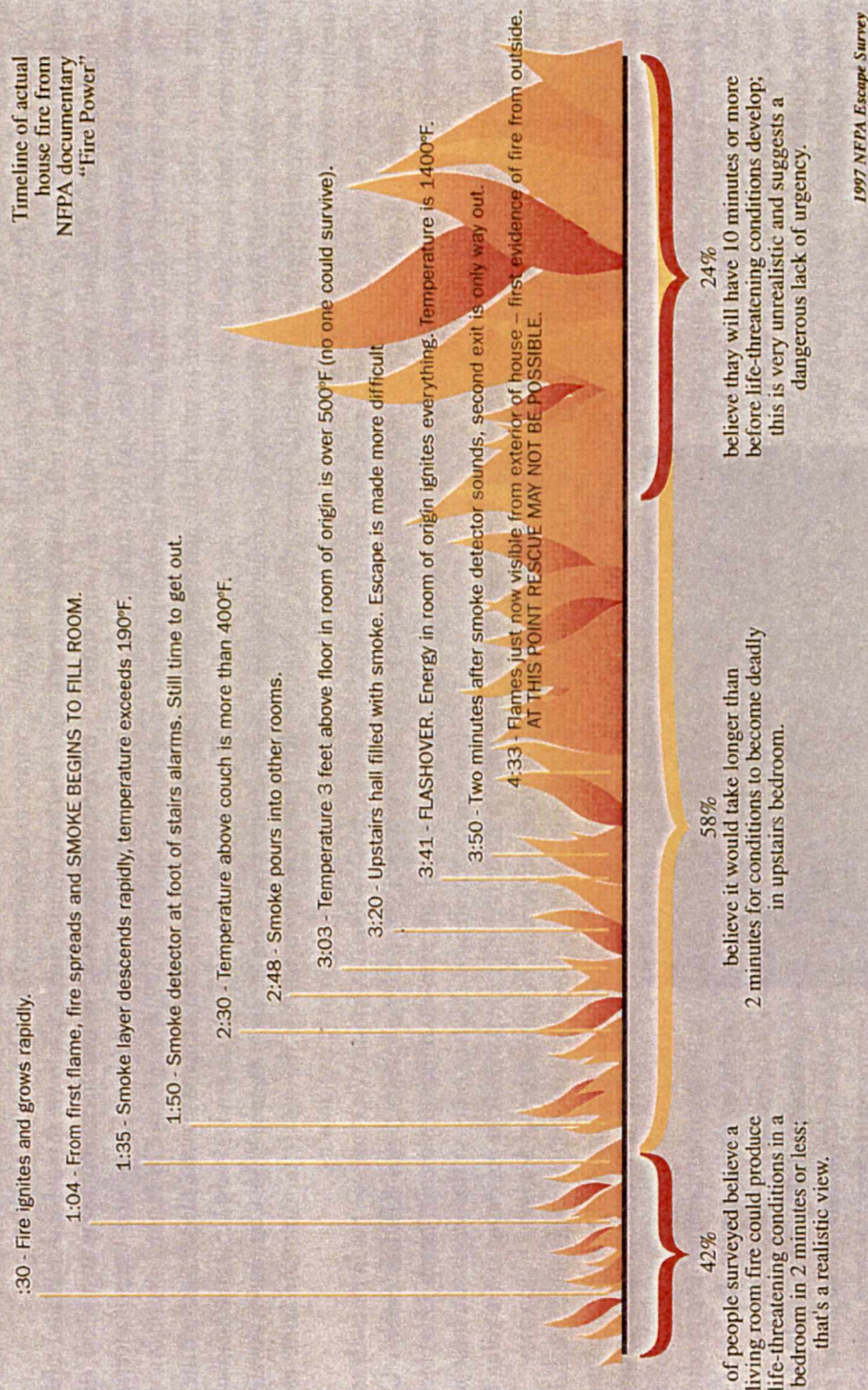


Figure 2. America's Perception vs. Actual Rate of Fire's Growth and Speed.

Source: Wolf, A. (1998, May/June). The great escape. *NFPA Journal*, p. 78. Chart by C. J. McCusker. Reprinted with permission.

and they put firefighters at needless risk. Between 1984 and 1993, 26 firefighters were killed while responding to false alarms (Hershfield). Worse yet is their effect on occupants of facilities where they occur.

Clinton Towers is a seven-story apartment complex for elderly people located in Clinton, Tennessee. Smoke detectors, installed over the kitchenette in each efficiency apartment, were hardwired to a central alarm connected directly to the fire department. The detectors were so sensitive that boiling water or burnt toast would activate them, and there were numerous false alarms, sometimes more than one a day. When the alarm was activated, the elevators went to the first floor and stopped. The frequent false alarms made residents of the complex, many of them with poor walking abilities, afraid to leave their floor because the elevators were undependable, and many of the residents could not climb stairs. The frequency of false alarms also caused people to ignore fire drills, and many would probably have ignored the alarms in a true emergency. Newspaper accounts of the fire in the John Sevier Center cited earlier state that the building had a history of false alarms (Coutant, 1989), and interviews with several residents indicates that they either did not hear the alarm announcing the fatal fire or ignored it (Roberts, 1989).

Another factor in delayed egress may involve arousal from sleep. The majority of fatal fires occur at night, when sleep delays discovery of the fire. People are less likely to smell smoke early in the fire development when they are sleeping. One experiment to discover how fast people were awakened by smoke odor and radiant heat revealed that only three out of 12 subjects were awakened within the first 20 minutes of exposure. It may take less than five minutes for fire to become deadly in the room of origin. Sleep may also slow response to an alarm, especially if the alarm is a continuous tone or if the alarm sound is less than 20 dBA louder than background noise. Occupants who have taken medications

that influence sleep or who have used alcohol are likely to respond even more slowly (Levin, 1984). Because hearing decrements affect so many older people, it must be assumed that alarms in homes for the aged need to be even louder than in other occupancies to rouse a sleeping resident, and *Life Safety Code* now allows the use of visual alarms such as strobe lights in areas with people who have impaired hearing. Even in cases where people are awake, fire alarms in homes for the aged may need to be louder than in other facilities. Several residents of the John Sevier Center reported after the fatal 1989 fire there that they did not hear the fire alarm. One resident, Texie Hamric, is quoted as saying, "Everybody that I talked to didn't hear a fire alarm. I heard mine [local smoke detector] but I never heard one outside (Roberts, 1989, pp. 1, 6)."

Once the decision has been made to evacuate, other factors influence the movement of people to a place of safety. Unless people have been very well trained in what to do in a fire emergency, they are likely to follow the same routes to exit the building that they used to enter. Often the customary path of travel is not the safest one in a fire. Fire investigations have revealed many cases in which people made their way through smoke past a safe fire exit in their attempt to follow the route with which they were familiar, and many have died in the process. In a dangerous situation, people will tend to opt for the familiar route rather than consider a safer unfamiliar one. In many buildings like homes for the aged, where many people live in the same building and staff are generally present to supervise the residents, there may be rules against using the fire exits except for an emergency. Sometimes these exits have alarms that sound if doors are opened, and people may even have been chastised for using them in nonemergencies. Hence, people are hesitant to use them at all. Exits that are "off limits" under normal conditions are often avoided in the emergencies for which they were designed.

Another factor that may cause people to pass safe exit routes in their efforts to evacuate a burning building is that smoke may obscure the signs directing them to the fire exit. Because smoke rises, and illuminated exit signs must be a minimum of 60 inches (152 cm) above the floor (*Life Safety Code*, 5-10.1.3), the sign may not be visible through smoke. One of the NFPA case studies used in the analysis of board and care facilities cited earlier revealed that a firefighter carried an elderly resident past a fire exit because smoke obscured his view of the exit sign.

Finally, one other behavior somewhat unique to older people is the avoidance of using stairs, especially walking up stairs. People with arthritis or osteoporosis often experience pain in their knees and hips when they climb stairs. Further, people who use walkers find it virtually impossible to use stairs. In the fire at the John Sevier Center, not one resident used stairs to go to safety on the roof, even those on the 10th floor, where two died near the elevator doors. Newspaper accounts noted that although a helicopter and construction crane were ready to rescue people from the roof, "no rooftop rescues were made because no residents went up to the roof. 'People that age do not think of walking down all those flights of stairs, much less up,' [Fire Captain Roger] Teinert said. 'We found them clustered around the elevators, just waiting there and pressing the button until they were overcome (Brooks, 1989, 'This was the fire...' p. 12).'"

As stated earlier, research on human behavior in fires is still a relatively recent endeavor, and much is still to be learned. Yet, enough information is currently available that the psychological as well as physiological aspects of people should be considered and incorporated into codes. J.L. Pauls and B.K. Jones of the Division of Building Research, National Research Council of Canada, writing for NFPA stated: "Exit design [i.e., egress] will increasingly become an insensitive, expensive, and meaningless exercise if it continues

to be considered largely in quantitative terms, instead of in terms of qualitative factors that include normal occupancy conditions and actual behavior of people in emergencies (Pauls and Jones, 1980, p. 39)."

Chapter 4

Discussion

This study found that the average walking speeds of elderly people generally range from 0.145 to 1.8 m/s. Accordingly, the speeds required to walk the 99 m maximum travel distances specified by *Life Safety Code* or the 76 m required by *SBC* in three minutes (i.e., the time specified by code as prompt evacuation capability) were found to be 0.55 and 0.42 m/s, respectively. As stated earlier, Egan (1978) and others established that a person with average physical ability is able to walk on a horizontal surface at a rate of 1.22 m/s. Based on this normal rate, most of the average walking speeds of older people reported in the research cited were slower than normal. These average speeds are compared in Figure 1, which shows that most of the older people whose walking speeds were measured walked more slowly than 1.22 m/s. These figures indicate that many older occupants of homes for the aged walk so slowly that they do not have time to evacuate a burning building that meets minimum code requirements safely. Thus, current building and life safety codes appear not to address the challenge of providing a fire-safe environment adequately, especially in older facilities.

Walking speed, however, is not the only factor that affects the speed of evacuation.

Numerous other issues must be considered, both physiological and psychological. First, it must be noted that most of the speeds cited in this study were measured over somewhat short courses—all except one were under 22 m. Thus, the fatigue factor does not generally influence these speeds. In a real fire situation over the longer distances needed to escape a fire, fatigue must be considered as a factor that would decrease the average speed because the rate would be slower at the end of the course than at the beginning. For example, a person who can walk 10 m in 5.5 seconds (i.e., at a rate of 0.55 m/s) may not be able to walk 99 m in 3 minutes.

As noted earlier, time is a critical factor in safe evacuation, yet the research has shown that much valuable time is lost before people begin to evacuate. The firefighting community has given much attention to the issue of false alarms, and newer, smarter detection and alarm devices are being developed. Research on human response to fire alarms seems to indicate that alarms with verbal messages are more effective than those that sound a continuous tone. This is especially true in homes for the aged, where the need to confirm the validity of the alarm seems to be especially strong.

While training in what to do when a fire alarm sounds is not a design issue, many excellent design features have been circumvented because people took inappropriate actions. One of the most disturbing behavior patterns identified in case studies as well as the literature was the tendency to use a customary or familiar path of travel when attempting to evacuate a burning building, sometimes even passing up a safer route. If people are taught not to use a fire exit any time except during a fire, they will probably forget to use the fire exit when a fire emergency occurs. Allowing people to use fire stairs and other parts of the egress way as usual routes might help eliminate this problem. Yet, training is still a key to safer evacuations as well as control of the fire. In many of the fatal fires the fact that a door

to the room of origin was left open contributed to the spread of smoke. Both residents and staff in homes for the aged need training in how to contain a fire.

The behavior of smoke is also an issue that must be addressed. Since heat and smoke rise, the safest place to be in a smoke-filled environment is on the floor. However, elderly people cannot crawl along the floor as young people can. If they get down on the floor, they would have to have help getting back up. Hence, they are at greater risk from smoke.

All of the speeds shown in Table 3 were measured on level courses. In multistory buildings, people are apt to encounter stairs in the route they must take to evacuate the building, and many who are able to walk with relative ease on level surfaces are not able to ascend or descend steps with the same ease. The issues of how well older people are able to use steps and their speed of ascent and descent are issues that need additional research.

In an effort to avoid having to evacuate older residents of homes for the aged, the code provides for areas of refuge or safety. By separating a building into compartments with 1- to 2-hour rated walls, floors, and ceilings, people may theoretically move from a compartment where there is fire to one that is safe on the same level of the building. This is an excellent concept, and many newer buildings make good use of the principle. However, only a small breach allows smoke to move from compartment to compartment. When people open the door to move from one compartment to another, smoke moves with them, compromising the environment in the area of refuge. Thus, compartmentation alone is not an adequate safety strategy, especially in older buildings where fire rated divisions may have been retrofitted.

Firefighting professionals place a great deal of confidence in sprinkler systems and detection and notification devices to control fires and protect people and buildings. Sensor technology has advanced greatly in the past two decades, and it continues to improve heat and smoke detectors as well as sprinkler systems. Yet it may not be appropriate for *SBC* to

allow greater maximum travel distances in homes for the aged because they have sprinklers, which may be activated by heat detectors. A situation in which there is much smoke but little heat—as produced by a smoldering cigarette in bedding—might not be detected in time to prevent injury from smoke. Additionally, when the sprinkler system does not provide coverage of all areas of the facility, including residents' rooms (as was found in some of the case histories included in this study), they are of limited value.

It is important to note that code is created through a consensus process. An NFPA booklet on its codes- and standards-making system describes this consensus process. The booklet states:

Anyone can submit a request for a new fire safety project. NFPA then publishes an announcement in its membership newsletter, *Codes and Standards News*. The announcement acknowledges that the NFPA has received a request for a new project and requests comments on the need for the project, information on organizations that may be active in the subject matter of the proposed project, a listing of resource material that is available, and in indication of who would be willing to participate in the project if it is approved by the Standards Council. The proposed project and the public comments that it generates are then reviewed by the Standards Council (NFPA, 1997, p. 2).

If a project is deemed appropriate, it is assigned to a technical committee that writes a proposal for the new code or amendment to existing code. Technical committees are made up of volunteer experts who represent educational institutions, government, business insurance companies, consumers, and industry. Thus experts from all aspects of fire safety are involved, and any NFPA member may comment or make recommendations concerning proposals. The codes are based on consensus among volunteer experts, including the manufacturers of fire safety devices, and empirical research may not be considered. This leads one to wonder if the *Life Safety Code* is influenced by equipment manufacturers to rely too heavily on these devices.

An issue not so far discussed in this study but that must be considered is the role of

the authority having jurisdiction (AHJ). The AHJ approves or disapproves fire protection plans for any facility but has great latitude in use of his or her judgment in assessing the suitability of these plans for a given facility. He or she has the authority to allow trade-offs in fire protection systems that, in his or her opinion, would meet the intent of the code. Furthermore, the AHJ may allow a facility that is not in full compliance to continue operation, only giving warning to the operator to correct problems, as was the case in the John Sevier Center fire. There the operator had been notified of unsealed pipechases but had not corrected them. An AHJ also has the authority to shut down a noncomplying facility. The guidance provided to the AHJ for assessing the fire safety of a facility, however, does not generally address the special needs of older people.

The issue of building economy must also be addressed. If code is so restrictive that the risk of injury from fire is reduced to its lowest possibility, then the building may become so expensive that no one could afford to build or operate it profitably. It is difficult to find the middle ground where safety and economy are balanced.

Much research has been done on fire safety, the factors that contribute to casualties, and even how people behave in fire emergencies. However, very little research has been done specifically concerning elderly people's behavior in fires. Some important questions that need to be answered through further research are:

- How much does fatigue influence walking speed over the maximum travel distances specified by code? Does fear influence the speed?
- What is the attitude of older people toward fire and fire safety? Do they believe it won't happen to them, or that it is a trivial issue that does not deserve attention?
- Do the behavior patterns of people in general hold true for older people, or are they exaggerated in this age group? For example, are older people more apt to use the most familiar route rather than the safest one? Are older people more likely than younger people to block open a fire door or to leave the door to the room of fire origin open?

- Are older people more likely to delay evacuation than younger people? Do they delay for the same reasons? Does their evacuation actually take longer than younger people's?
- Are older people more likely than younger people to ignore a fire alarm? Are false alarms more apt to influence older people to ignore fire alarms than they are to influence other age groups?
- If older people need louder alarms, how much louder do they need to be? How much more effective are verbal alarms than sirens or wails? How do medications affect an older person's arousal from sleep when a fire alarm sounds?

When a particular population segment with special needs is small relative to the total population, it may not be appropriate to require that all buildings meet those special needs. However, when a population segment with special needs becomes a much larger portion of the total population, as older citizens are becoming today, then their special needs take on greater importance. Much additional research is needed to provide fire safe environments for older people.

References

- Ahrens, M. (1998). All fired up. *NFPA Journal*, 92 (3).
- Ballast, D.K. (1988). *Egress from buildings in emergencies*. Monticello, IL: Vance Bibliographies.
- Bell, C.S. (1997, September). Eye on the future. *Contemporary Long Term Care*, 81, 83-84, 87.
- Bendall, M.J., Bassey, E.J., and Pearson, M.B. (1989). Factors affecting walking speed of elderly people. *Age and Ageing*, 18, 327-332.
- Bendinelli, J. (1993). *A look at the feasibility of reaction studies and human response to fire emergencies*. An applied research project submitted to the National Fire Academy as part of the Executive Fire Officer Program. Washington, DC: United States Fire Administration, Federal Emergency Management Agency.
- Bickman, L., Edelman, P., and McDaniel, M.A. (1983). A model of human behavior in a fire emergency. In C. Rapkin (Ed.), *The social and economic consequences of residential fires* (pp. 101-117). Lexington, MA: LexingtonBooks, D.C. Heath and Company.
- Black, C.M., and Cox, R. (1983). Human behavior in fires: A proposed direction for research. In C. Rapkin (Ed.), *The social and economic consequences of residential fires* (pp. 119-136). Lexington, MA: LexingtonBooks, D.C. Heath and Company.
- Boyce, P.R. (1991). *The emergency egress roundtable: 1991*. Roundtable conducted at Rensselaer Polytechnic Institute on June 10, 1991. Troy, NY: Rensselaer Polytechnic Institute.
- Brooks, J. (1989, December 26). Holiday visit turns tragic for area man. *Johnson City Press*, p. 1.
- Brooks, J. (1989, December 26). 'This was the fire we had been dreading all along.' *Johnson City Press*, pp. 1, 12.
- Brown, C.B. (1998). A message from the Fire Administrator [On-line]. Available at: <http://www.usfa.fema.gov>.
- Bryan, J.L. (1983). *Implications for codes and behavior models from the analysis of behavior response patterns in fire situations as selected from the Project People and Project People II study programs*. College Park, MD: University of Maryland.
- Bryan, J.L. (1988). Behavioral response to fire and smoke. In *Handbook of fire protection engineering*. Quincy, MA: NFPA Press.
- Buchner, D.M., Larson, E.B., Wagner, E.H., Koepsell, T.D., DeLateur, B.J. (1996). Evidence for a non-linear relationship between leg strength and gait speed. *Age and Ageing*, 25, 386-391.

- Canter, D. (1985). *Studies of human behaviour in fire: empirical results and their implications for education and design*. Borehamwood, England: Department of the Environment, Building Research Establishment, Fire Research Station.
- Canter, D., Ed. (1990). *Fires and human behaviour*, 2nd ed. London: David Fulton Publishers.
- Coffin, A.M. (1993). The walking speeds of elderly pedestrians (Doctoral dissertation, University of Calgary, Canada, 1993). *Dissertation Abstracts International*, MM83121.
- Coutant, L. (1989, December 28). Performance pleased officials. *Johnson City Press*, pp. 1, 6.
- Egan, M.D. (1978). *Concepts in Building Firesafety*. New York: John Wiley & Sons.
- Fahy, R.F., and Proulx, G. (1995, March/April). A study of human behavior during the World Trade Center evacuation. *NFPA Journal*, 59-67.
- Fahy, R.F., Tremblay, K.J., and Barry, J.J., III (1990, July/August). The catastrophic fires of 1989. *Fire Journal*, 60-79.
- Ferrini, A.F., and Ferrini, R.L. (1993). *Health in the later years*, 2nd ed. Madison, Wisconsin: WCB Brown & Benchmark Publishers.
- Fiatarone, M.A., and Evans, W.J. (1993). The etiology and reversibility of muscle dysfunction in the aged. *Journal of Gerontology*, 48, 77-83.
- Friedman, P.J., Richmond, D.E., and Baskett, J.J. (1988). A prospective trial of serial gait speed as a measure of rehabilitation in the elderly. *Age and Ageing*, 17, 227-235.
- Guralnik, J.M., Branch, L.G., Cummings, S.R., and Curb, J.D. (1989). Physical performance measures in aging research. *The Journal of Gerontology*, 44, M141-146.
- Gibbs, J., et al. (1996). Predictors of change in walking velocity in older adults. *Journal of the American Geriatrics Society*, 44, 126-132.
- Gibbs, J., et al. (1993). Joint impairment and ambulation in the elderly. *Journal of the American Geriatrics Society*, 41, 1205-1211.
- Hall, J.R., Jr. (1990, July/August). The elderly, the sick, and health care facilities. *Fire Journal*, 32-42.
- Hall, J.R., Jr. (1993). *U.S. fires in "board and care" homes: Matrix display of selected fatal fires*. Quincy, MA: National Fire Protection Association.
- Harmon, Sharon K. (1994). *The codes guidebook for interiors*. New York: John Wiley & Sons, Inc.
- Hershfield, V. (1995, March/April). The worst part was the fear of the unknown. *NFPA Journal*, 64-67.

- Hoxie, R.E., Rubenstein, L.Z., Hoenig, H., and Gallagher, B.R. (1994). The older pedestrian. *Journal of the American Geriatric Society*, 42, 444-450.
- International Building Code*, 1st Draft (1997, November). Birmingham, AL: International Code Council.
- Investigators sift fire ashes. (1990, January 11). *Johnson City Press*, pp. 1-2.
- Kirkland, T. (1989, December 26). Fifteen admitted to area hospitals. *Johnson City Press*, p. 1, 12.
- Klaassen, P. (1997, September). Eye on the future: Purpose-built beats conversions. *Contemporary long term care*, 20, 81, 83.
- Lang, Jon (1987). *Creating architectural theory: The role of the behavioral sciences in environmental design*. Current sociophysical issues in environmental design—a normative stance. New York: Van Nostrand Reinhold Company, 233-241.
- Latane, B., and Darley, J.M. (1968, November). Group inhibition of bystander intervention in emergencies. *Journal of Personal and Social Psychology*, 10, 215-221.
- Laukkanen, P., Heikkinen, E., and Kauppinen, M. (1995). Muscle strength and mobility as predictors of survival in 75-84-year-old people. *Age and Ageing*, 24, 468-473.
- Lerup, L., Cronrath, D., and Liu, J.K.C. (1990). Fires in nursing facilities. In Canter, D. (Ed.). *Fires & Human Behaviour*. 2nd ed. (pp. 155-180). London: David Fulton Publishers..
- Levin, B.M. (1984). *Human behavior in fire: What we know now*. Paper presented at the 1984 SFPE Fire Protection Engineering Seminars, New Orleans, Louisiana, May 21-24, 1984. Gaithersburg, MD: Center for Fire Research, National Bureau of Standards.
- Lilley, J.M., Arie, T., and Chilvers, C.E.D. (1995). Accidents involving older people: A review of the literature. *Age and Ageing*, 24, 346-365.
- Lord, S.R., Lloyd, D.G., and Li, S.K. (1996). Sensori-motor function, gait patterns and falls in community-dwelling women. *Age and Ageing*, 25, 292-299.
- Maki, B.E. (1997). Gait changes in older adults: Predictors of falls or indicators of fear? *Journal of the American Geriatrics Society*, 45, 313-320.
- Murtagh, W.J. (1993). *Keeping time: The history and theory of preservation in America*. New York: Sterling Publishing Co., Inc.
- National Fire Prevention and Control Administration (NFPCA) (1973). *America Burning*. Washington: NFPCA (U.S. Fire Administration).
- National Fire Protection Association (1985). NFPA 101, *Life safety code*. Quincy, MA: National Fire Protection Association.

- National Fire Protection Association (1994). NFPA 101, *Life safety code*. Quincy, MA: National Fire Protection Association.
- National Fire Protection Association (1994). NFPA 914, *Recommended practice for fire protection in historic structures*. Quincy, MA: National Fire Protection Association.
- National Fire Protection Association (1996). *Special Data Information Package: Elderly Housing*. Quincy, MA: National Fire Protection Association.
- National Fire Protection Association (NFPA), (1997). *NFPA Codes- and Standards-Making System* [Booklet]. Quincy, MA: National Fire Protection Association.
- Neef, N.A., et. al. (1995). Exercise participation with videotaped modeling: Effects on balance and gait in elderly residents of care facilities. *Behavior Therapy*, 26, 235-151.
- Overstall, P.W., Exton-Smith, A.N., Imms, F.J., and Johnson, A.L. (1977). Falls in the elderly related to postural imbalance. *British Medical Journal*, 1, 261-264.
- Overstall, P.W. (1980). Prevention of falls in the elderly. *Journal of the American Geriatrics Society*, XXVIII(11), 481-484.
- Pauls, J.L., and Jones, B.K. (1980, May). Research in human behavior. *Fire Journal*, 35-41.
- Pedersen, R.P., Jr. (1994). *Human behavior in fire emergencies: Strategic analysis of fire prevention programs*. An applied research project submitted to the National Fire Academy as part of the Executive Fire Officer Program. Washington, DC: United States Fire Administration, Federal Emergency Management Agency.
- Petraglia, John S. (1991). Fire and the aging of America. *NFPA Journal*, 85(2), 36-46.
- Pilatowicz, Grazyna (1995). *Eco-Interiors: A guide to environmentally conscious interior design*. New York: John Wiley & Sons, Inc.
- Rantanen, T., Pertti, E., Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, 23, 132-137.
- Rieskse, Robert J., and Holstege, Henry (1996). *Growing older in America*. New York: The McGraw-Hill Companies, Inc.
- Roberts, K. (1989, December 27). Survivors find fault in center. *Johnson City Press*, pp. 1, 6.
- Ross, J.E.R. (1991). Iatrogenesis in the elderly. *Journal of Gerontological Nursing*, 17, 19-23.
- Rothstein, D.E. (1993). The interrelationships among physical activity status, musculoskeletal variables, and gait in the elderly. (Doctoral dissertation, Arizona State University, 1993). *Dissertation Abstracts International*.
- Schwalm, N.S. (1980, May). Behavior of special populations in fires. *Fire Journal*, 41-42.

- Schwalm, N.D. (1981, July). The effect of attitudes and experience on human behavior in fires. *Fire Journal*, 118-122.
- Sime, J. (1990). The concept of panic. In Canter, D., Ed. (1990). *Fires and human behaviour*, 2nd ed., (pp. 63-81). London: David Fulton Publishers.
- Solon, Thomas E. (1992). Protecting buildings for life: A fire safety equivalency system. *CMR*, 15(6), 30-32.
- Standard Building Code* (1997). Birmingham, AL: Southern Building Code Congress International, Inc.
- Stahl, Fred I., Crosson, James J., and Margulis, Stephen J. (1982). *Time-based capabilities of occupants to escape fires in public buildings: A review of code provisions and technical literature*. Washington, DC: U.S. Department of Commerce, National Bureau of Standards [Springfield, VA: National Technical Information Service].
- Staube, A., Botzel, K., Hawken, M., Palus, W., and Brandt, T. (1988). Postural control in the elderly: Differential effects of visual, vestibular and somatosensory input. In Amblard, B., Berthoz, A., and Clarac, F. (eds.) *Posture and Gait: Development, Adaptation and Modulation*, 105-114. Cited in Woollacott.
- Swartz, J.A. (1979, May). Human behavior in the Beverly Hills fire. *Fire Journal*, 73.
- Tennessee Code Annotated of 1992, Rules of Tennessee Department of Health and Environment, Chapter 1200-8-11, Standards for Home for Aged.
- Thomas, C.L. (Ed.) (1993). *Taber's Cyclopedic Medical Dictionary*, 17th ed. Philadelphia: F.A. Davis Company.
- Tinetti, M.D., Williams, T.F., and Mayewski, R. (1986). Fall risk index for elderly patients based on number of chronic disabilities. *The American Journal of Medicine*, 80, 429-434.
- Travis, F. (1990, August 28). Hearing examines fire prevention. *Johnson City Press*, 5.
- U.S. Fire Administration (1995). *Fire in the United States*, 9th ed. Emmitsburg, MD [On-line]. Available: <http://www.usfa.fema.gov>.
- U.S. Fire Administration Homepage (1998). National fire programs [On-line]. Available: <http://www.usfa.fema.gov>.
- Wang, H. (1993). Relationships of biomechanical performance of the knee in level walking to alignment, strength and function in asymptomatic elderly subjects. (Doctoral dissertation, Queen's University at Kingston, Canada, 1993). *Dissertation Abstracts International*.
- Wasch, W.K. (1996). *Home planning for your later years*. Beverly Cracom Publications.

- Welford, A.T. (1978). Motor performance. In Birren, J.E., and Schaie, K.W. (Eds.). *Handbook of the Psychology of Aging*(pp. 450-496). New York: Van Nostrand Reinhold Company.
- Willey, A.E. (May, 1973). Baptist Towers Housing for the Elderly, *Fire Journal*, 15-21, 105. In NFPA (1996). *Special Data Information Package: Elderly Housing*. Quincy, MA: NFPA Fire Analysis and Research Division.
- Wolf, A. (1998). The great escape. *NFPA Journal*, 92 (3).
- Wood, P.G. (1972). *The behaviour of people in fires*. Fire Research Notes 953. Fire Research Station, Borehamwood, England.
- Wood, P.G. (1990). A survey of behaviour in fires. In Canter, D. (Ed.). *Fires & human behaviour*, 2nd ed., (pp. 83-95). London: David Fulton Publishers.
- Woollacott, Marjorie H. (1993). Age-related changes in posture and movement. *The Journals of Gerontology*, 48 (Special Issue), 56-60.
- Wozniak, J. (1990, January 11). Sevier inspection report in. *Johnson City Press*, pp. 1, 2.

Vita

SueAnne Blair Lewis was born in Rockwood, Tennessee on January 23, 1944. She attended the public schools in Oak Ridge, Tennessee, where she graduated from Oak Ridge High School in 1962. She entered Maryville College, Maryville, Tennessee in August of 1962 and received the Bachelor of Arts in English with teaching certification in secondary education in January of 1967. She taught English in Oak Ridge High School for three years. From September 1975 to August 1976 she studied at Roane State Community College, Harriman, Tennessee and received the Associate of Arts in Fine Art, summa cum laude. She then pursued a successful career in advertising, marketing, public relations, and technical communications until January 1992 when she entered The University of Tennessee, Knoxville to study interior design. After completing undergraduate interior design and architecture courses, she entered the graduate program in May 1997. Her focus has been historic preservation with emphasis on adaptive use and design for older people. She was awarded the Master's degree in Interior Design with a minor in Gerontology in August 1998. While at The University of Tennessee Ms. Lewis was a graduate teaching associate, a member of the UTK chapter of Kappa Omicron Nu, and a member of the Student Chapters of the American Society of Interior Designers. She is a student member of American Society on Aging, The Gerontological Society of America, and Southern Gerontological Society, the National Fire Protection Association, and Southern Building Code Congress International.