NEARBY OUTDOOR ENVIRONMENTAL SUPPORT OF OLDER ADULTS' YARD ACTIVITIES, NEIGHBORHOOD WALKING AND INDEPENDENT LIVING IN THE COMMUNITY

A Dissertation

by

ZHE WANG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2009

Major Subject: Architecture

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Approved by:

Co-Chairs of Committee,	Mardelle Shepley
	Susan Rodiek
Committee Members,	Chanam Lee
	Michael Duffy
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ABSTRACT

Nearby Outdoor Environmental Support of Older Adults' Yard Activities, Neighborhood Walking and Independent Living in the Community. (December 2009)

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Aging is a global phenomenon. Ways to sustain older adults' aging-in-place in the 'community at-large' (defined as traditional communities where most people live) have been overlooked. Consciously engaging in physical activity helps older adults to remain healthy and gives them the ability to access daily-life services, and thus extend their independent years at home. Nearby outdoor environments on residential sites and in the neighborhoods may influence older adults' independent living through physical activity.

This study surveyed 206 older adults in 11 assisted-living facilities in Texas regarding their past physical activities when they lived in their own homes and perceptions of the residential site and neighborhood environments. Older adults are shown to have long-term recall ability and capable of reliably estimating their physical activities that occurred up to ten years ago. Geographic Information System (GIS) was used to verify the survey responses and further examine the objective measurements of environments on a subset of 117 participants' residences.

Bivariate tests, factor analysis, and multivariate logistic regression modeling were conducted to identify environmental variables correlated to yard activities, neighborhood walking, and years of independent living at home. After controlling for personal and social factors in multivariate logistic modeling, three site features (transitional-areas, connecting-paths, and levels of pleasant indoor sunshine) have been found to influence yard activities; two site features (yard landscaping and corner lot location) and three neighborhood features (walking destinations, safety from crime, and sidewalks) have been found to influence neighborhood walking; one site features (transitional-areas) has been found to influence older adults' years of independent living in the community. Based on the results, guidelines were developed for designing friendly environments for older adults' active and independent living.

Nearby outdoor environments on residential sites and in the neighborhoods appear to be important for older adults. The roles of residential site environments in shaping older adults' behavior and independence need more attention. To better understand environmental influences on older adults and promote aging-in-place, more empirical studies and longitudinal research are needed.

To Jin Weng

my husband and friend

To my parents Loujia Jia and Wenchao Wang

my source of encouragement

ACKNOWLEDGEMENTS

I would like to thank my committee chairs, Dr. Mardelle Shepley and Dr. Susan Rodiek, and my committee members, Dr. Chanam Lee and Dr. Michael Duffy, for their guidance and support throughout the course of this research. Thanks also go to my friends and colleagues, and the faculty and staff for making my time at Texas A&M University a great experience.

The dissertation research was supported in part by a nationwide competitive grant from the American Institute of Architects, and a highly-selective and competitive dissertation grant from the Nurture by Steelcase and the TAMU Center for Health & Systems Design.

I also want to extend my gratitude to all the senior-living facilities and senior citizens who were willing to participate in the research. Several people assisted with the surveys, including Karlen Moore, Ashley Dias, Tiffany DeSalvo, Rachel Randle, Gloria Orsak, Rebecca Duty, Cynthia Neal, and Carrie Draves; their contributions are gratefully appreciated.

Finally, thanks to my parents who have been an ongoing source of inspiration and encouragement, and to my husband for his patience and love.

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CHAPTER I

INTRODUCTION

BACKGROUND

The phenomenon of global aging comes with psychological, physiological, financial, and environmental challenges. By enabling older adults (defined as people aged 65 and older) to age in place at their homes, the demands on society for institutional long-term care can be reduced. Maintaining participation in physical activity for health and daily-life services may help older adults remain independent. Behavior can be presented as the result of interactions between people and their environments (Proshansky et al., 1976; Stokols, 1987). Environments can facilitate physical activity and thereby help older adults remain independent. Investigating correlates of older adults' physical activity is an important prerequisite for designing supportive environments for this fast growing population group.

Independent variables in this study were physical environmental features of residential sites and neighborhoods in which older adults lived in the 'community at-large'. Dependent variables were levels of older adults' yard activities and neighborhood walking (how many times per day and how long per occurrence), and their years of independent living in the community (represented by the age when s/he moved to a senior-living facility). This study focused on relationships among the environmental

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This dissertation follows the style of *Environment & Behavior.*

features, older adults' physical activity, and years of independent living. Personal factors (e.g., gender, health status, income) and social factors (e.g., living arrangements, neighborhood social cohesion) were taken into account in the statistical analysis.

AIMS AND HYPOTHESES

Aim 1: To identify environmental features of residential sites and neighborhoods that are associated with older adults' yard activities, neighborhood walking, or years of independent living in the 'community at-large'.

Aim 2: To develop evidence-based design guidelines and policy recommendations promoting environmental support for older adults.

Hypotheses: Older adults living in attractive, convenient, and safe home environments, engage in yard activities or neighborhood walking more than their counterparts living in other environments; older adults in the former group have more years of independent living in the 'community at-large' than those in the later group.

PROJECT SIGNIFICANCE

PROMOTE HEALTH AND INDEPENDENCE

Eighty-four percent of community-dwelling people aged 50 and older prefer to live in their current residence for as long as possible (AARP, 2005). Whether or not older adults can remain independent at home influences their health and longevity. Community-dwelling older adults have better physical functioning, better clinical outcomes, and higher quality of life, compared to older adults living in institutions

(Avlund et al., 1998; Koltyn, 2001; Marek et al., 2005). After relocating to senior-living facilities, the health of frail, elderly persons typically deteriorates, and the mortality rate significantly rises (Lawton et al., 1970; Marek et al., 2000). The average life expectancy for older adults at the time of moving into senior-living facilities is about 4 years (DeCoster et al., 1995). Lengthening older adults' years of living at home promotes longevity. In addition, the preference for remaining independent at home is related to the psychological links between people and their places (Scheidt et al., 1999). About 70% of older adults in the U.S. own their homes (Lawton, 1999). Living in their own homes allows older adults better opportunities to retain social networks, preferred lifestyles, autonomy, and self-esteem than in senior-living facilities.

The reasons older adults lose their ability to remain independent in their homes are generally associated with age-related health decline and the demanding environments in which they live. Some older adults may prematurely move to senior-living facilities. Lengthening older adult's independent years at home can be pursued by promoting environmental support of healthy and useful behaviors such as recreation and utilitarian physical activities. Generally, elderly people who have sedentary lifestyles are more likely to move to senior-living facilities, compared to their active peers. The extended years of independent living is an ultimate benefit of physical activity for older adults, but has received little attention. Although physical activity has been advocated over a long time for public health, it is estimated that more than 60% of older Americans are physically inactive (DHHS, 1996).

Sedentary living among older adults may be related to the difficulty of adopting and adhering to vigorous or structured activity programs (e.g., gym-based exercises). The process of aging can be used as an intervention strategy to promote health and health behavior needs to be integrated in daily life (Duffy, 1999). Yard activities and neighborhood walking are unstructured and easy to work into one's daily routine. These activities require no special equipment and have generally moderate intensity levels, so the threshold of engaging in them is low. By engaging in utilitarian walking in neighborhoods, older adults can also improve their ability to access services (e.g., convenience/ grocery stores, clinics in the neighborhoods). Promoting these healthy and useful activities helps older adults handle tasks of daily living and pursue more years of independent living.

Neighborhood features were found to influence physical activity, but the subsequent impact on older adults' independent living needs further research. Site features in relation to older adults' physical activity and independence have been largely unexplored. These gaps were addressed in this study by investigating associations among environments, physical activity, and older adults' years of independent living in the 'community at-large'.

HIGHLIGHT SITE-LEVEL ENVIRONMENTS

Site-level environments (defined as nearby outdoor environments on the property, which people can access without crossing vehicular traffic; typically called the yard) play a critical role in older adults' daily life, but have been generally overlooked in the field of active living research which investigates how environments and policies influence physical activity. Neighborhood land-use mix, residential density, street connectivity, perceptions of safety, and the proximity of recreation facilities were found to influence older adults' physical activity at the neighborhood level (King et al., 2003; Lee et al., 2006a; Patterson et al., 2004). However, older adults spend an average of 19.5 hours per day at their homes and in their site-level environments (Brasche et al., 2005; Moss et al., 1982). Site-level environments are the most readily available places for older adults to engage in physical activity. Immediately adjacent to home, the environments are both origins of outdoor trips and destinations on the way back to home.

Few studies focus on the influence of community-dwelling site-level environments on older adults. However, several studies have investigated the influence of site-level environments in senior-living facilities on residents, with emphasis on their walking, outdoor access, and social interactions(Joseph et al., 2007; Rodiek et al., 2005). Based on the results of previous research, this study investigated the unexplored relationships among community-dwelling site-level environments, older adults' physical activity, and their independent living at home.

PROMOTING FINANCIAL SAVINGS

The financial demands on society for institutional long-term care can be reduced by enabling older adults to be independent longer. Older adults generally need more healthcare resources and services than other population groups. The escalating cost of healthcare is considered to be one of the inevitable negative consequences of global aging (Smeeding et al., 2000). Involving policies, social insurance programs, healthcare systems, and financial markets, a variety of emerging economic challenges represent the phenomenon of aging. Significant increases in government expenditures may be needed to address the social entitlements of older adults.

Helping older adults to remain independent longer may slow down the increase of needs for senior services. The number of senior-living facilities (e.g., nursing homes and assisted living facilities) has generally increased in recent years. Living in senior-living facilities in later life becomes common among older adults, but the capacity of existing senior-living facilities in the U.S. might not be large enough to accommodate the aging baby boomer population. Building more senior-living facilities to accommodate the needs of senior services takes time and requires financial support. In addition, the ability of senior-living facilities to provide personal care to meet the needs of older adults with limitations in ADL (Activities of Daily Living) and IADL (Instrumental Activities of Daily Living) can be challenged in the near future, as the group of oldest old rapidly increases. More investment in training senior-living staff and caregivers may be necessary.

Whether or not older adults can remain healthy and independent has economic implications for individuals. Age-related physical and mental chronic diseases and the resulting disabilities are associated with healthcare use. Healthcare costs among older adults have increased in recent years and the costs will grow rapidly as baby boomers retire. Remaining healthy and independent can help older adults reduce healthcare costs. From 1992 to 2001, the average healthcare cost for elderly residents in nursing homes or other long-term care facilities was $46,810, compared with $8,466 for community-dwelling older adults (FIFARS, 2004). Additionally, living in senior-living facilities may not be affordable for low-income elderly people. For instance, from 1992 to 2004, long-term care residents were paying an average of $2740 per month for their housing in the facility (Crum, 2004; NCHS, 2008). Savings are gained by delaying expenses associated with institutional senior living.

CONTRIBUTING TO PRACTICAL PROJECTS

Early in the process of neighborhood and site planning, appropriately dealing with design issues (e.g., land-use mix, sidewalks, building placement and orientation, and ground plan) has significant impacts on the quality of nearby outdoor environments. Guidelines for designing activity-friendly residential sites and neighborhoods should be created and used to promote attractive, convenient, and safe environments for older adults' active and independent living. The guidelines can 1) be applied by designers to build new environments and upgrade existing ones, 2) be adopted by policy makers to guide innovative policy approaches promoting active living, and 3) be used by older adults to find appropriate residences for later life.

For environmental designers and builders, creating activity-friendly residential sites and neighborhoods may require extra time and investment during the periods of design and construction, but having activity-friendly environments can be an important selling point to older adults, who head the majority of households in the U. S. and play a critical role in the housing market (Johnson et al., 2003).

In future studies, design guidelines derived from this study can be used as hypotheses to be tested further. The lists of measures of physical environments at the site and neighborhood levels can be used as a reference to select study features thought to influence older adults.

CHAPTER II

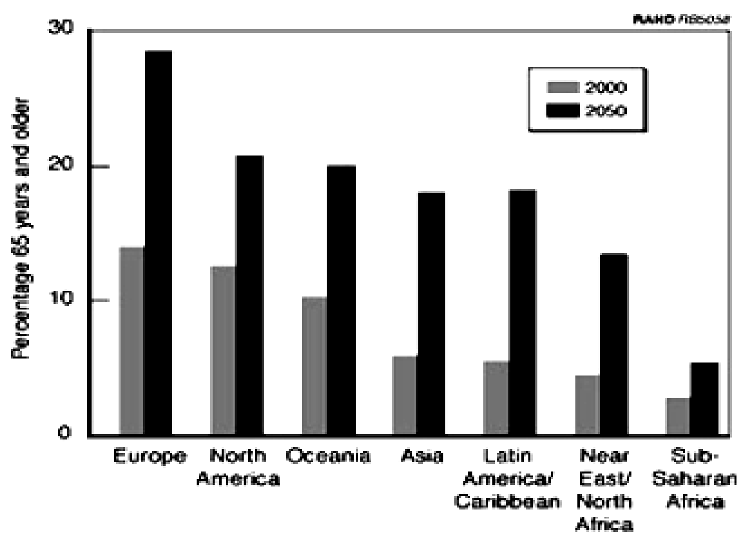
LITERATURE REVIEW

GLOBAL AGING AND CHALLENGES

GLOBAL AGING

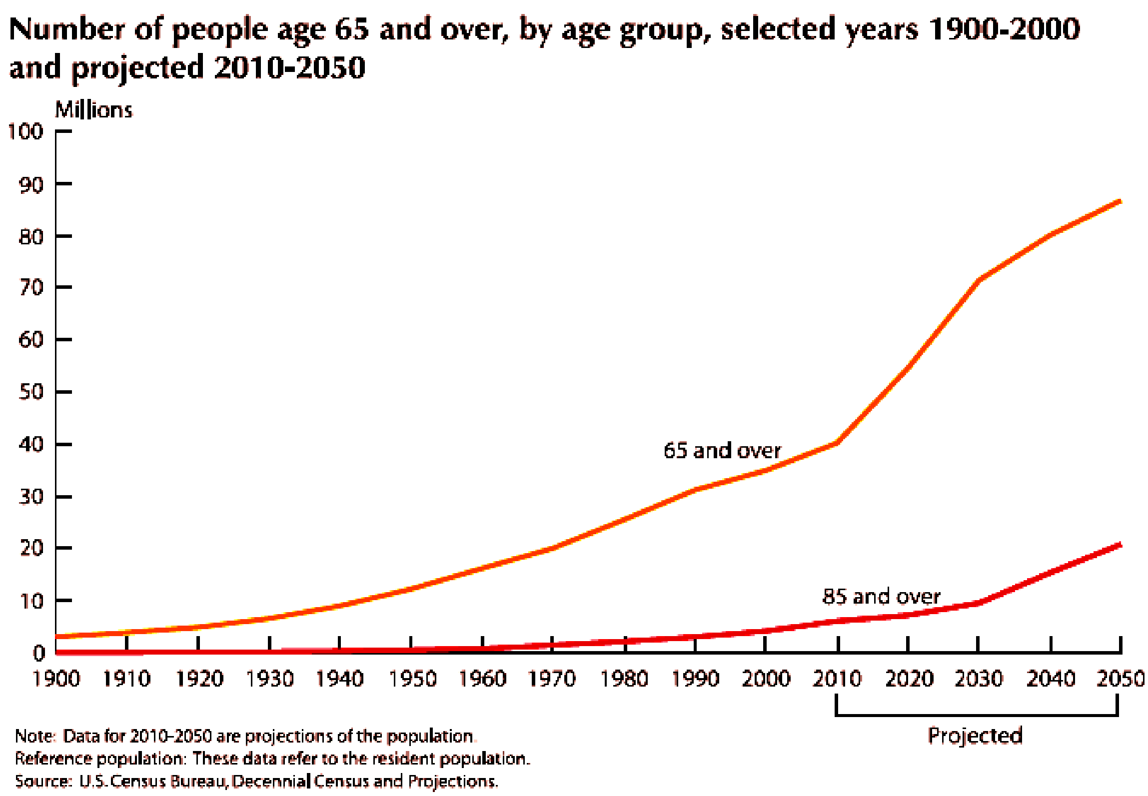
The world's population is aging at an accelerated rate. The population group of older adults globally grew by 795,000 per month in 2000, and the growth rate is expected to be 847,000 per month in 2010 (Kinsella et al., 2001). Between 2000 and 2050, it is predicted that the percentage of older adults will increase from 12% to 28% in Europe, from 13% to 21% in North American, and from 7% to 18% in Asia (Figure 1) (CBASSE, 2001; U.S. Census, 2003). Among older adults, the oldest old (defined as people age 85 and older) is the fastest growing group in many nations (USDS et al., 2007).

Figure 1: Global Aging, 2000 - 2050: Percentage of Elderly by Region



In the U. S., from 2000 to 2030, the population segment of older adults is predicted to increase from 35 to 71.5 million; the population of oldest old could increase from 4.2 million in 2000 to 21 million by 2050 (Figure 2) (FIFARS, 2004).

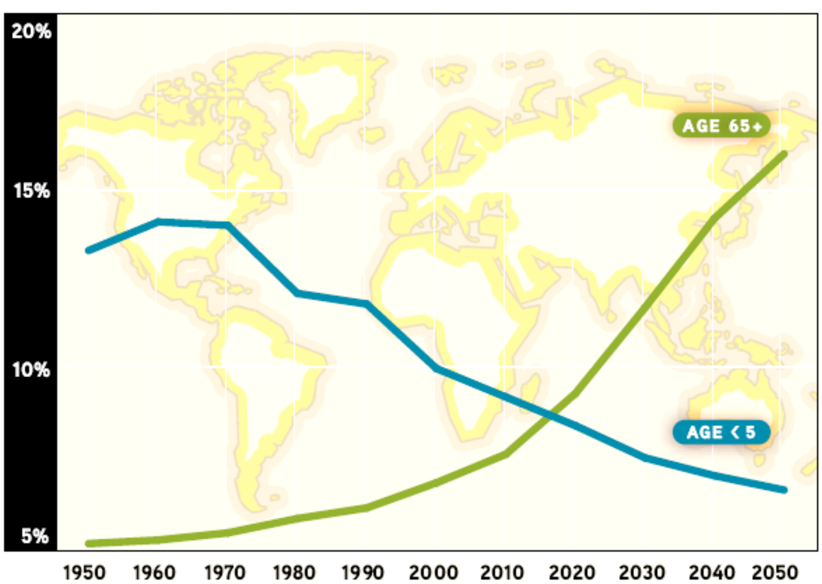
Figure 2: Aging in the U.S., 1900 - 2050: Number of Older Adults by Age Group



Generally, the phenomenon of global aging is associated with improved health and extended longevity in people. In most parts of the world, people are living longer and remaining healthier than before. Progressively, non-communicable and chronic diseases instead of high-mortality diseases such as infectious diseases, childhood diseases, and accidents, have become the main cause for the loss of health and life. During the 20th century, the average life expectancy at birth was doubled in some countries. In the U.S., life expectancy had increased from 47 years in the early 1900's to 77 years in 2001; the current life expectancy for individuals aged 65 years is 18 more years (DHHS, 2001).

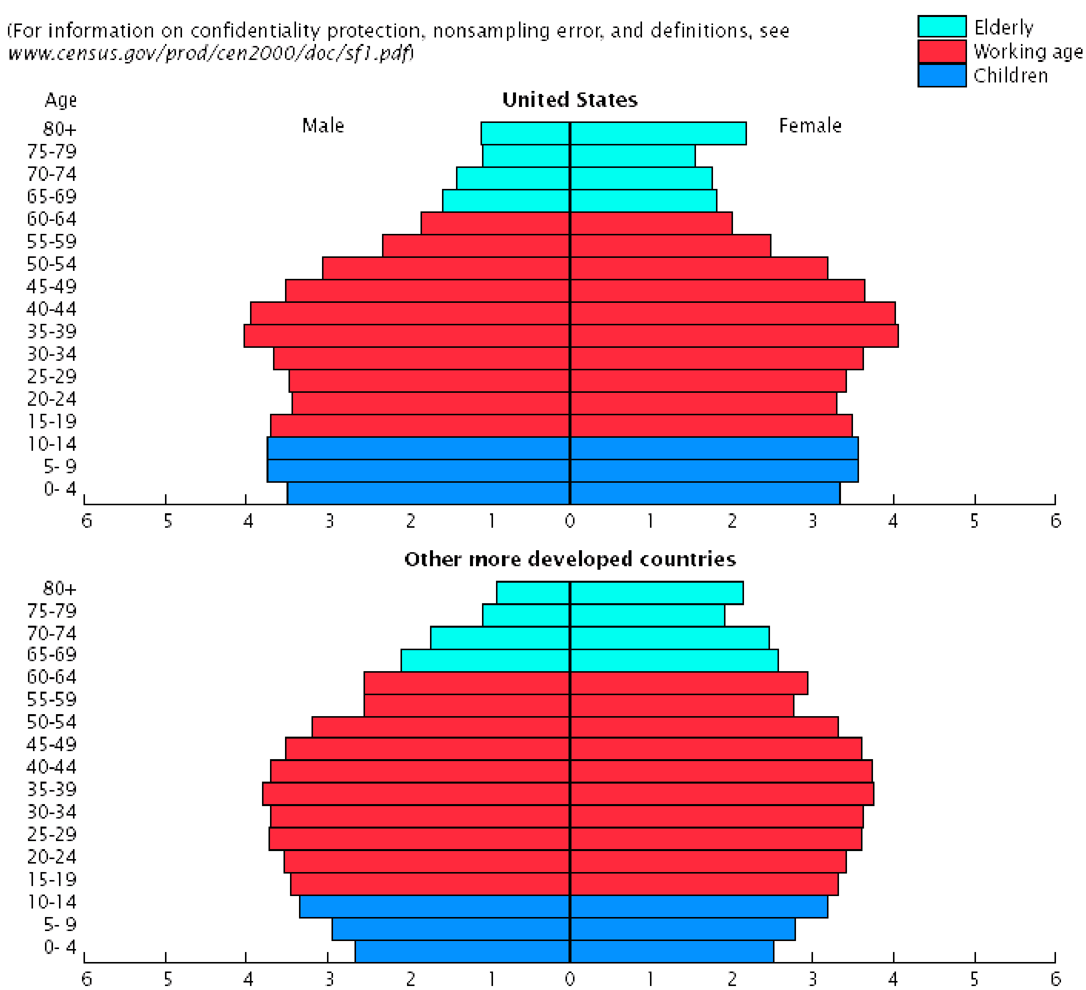
In addition, global aging is related to population decline in many developed countries (e.g., Japan) and less developed countries (e.g., South Africa). In South Africa, the population decline is largely related to the increased mortality caused by HIV/AIDS and medical innovations may help to reverse the decline. In developed countries (e.g., Russia, Japan, and UK), low birth rates will lead to population decline in upcoming decades. For instance, the rate needed to replenish the population in Russian and Japan is much higher than the current fertility rates of 1.4 per woman (USDS et al., 2007). The implications of this demographic shift are clear. The proportion of younger adults of working age will decline, while the cohort of older adults will increase (Figure 3) (UNDESA, 2005).

Figure 3: Older People and Young Children as a Percentage of Global Population



The ratio of men to women also declines in older population groups (Figure 4) (McDevitt et al., 2002). At age 65, women can expect to live an average of 3 to 5 years longer than men (FIFARS, 2004; OECD, 2002). Elderly women are much more likely to be widowed than elderly men. Forty-four percent of women age 65 and older were widowed, while 14% of men of the same age were windowed in 2003 (FIFARS, 2004). Many elderly women live alone at home or move to senior-living facilities soon after the death of their spouse.

Figure 4: Percentage Distribution of Population by Age and Sex in 2000



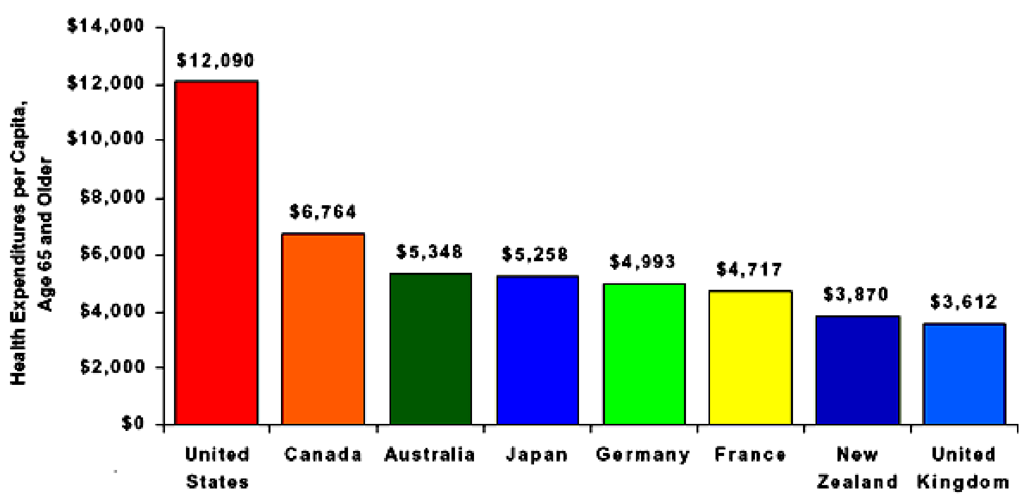
SUBSEQUENT CHALLENGES

Improved life styles and medical advances resulting in longer life span are important achievements of the last century. However, the subsequent phenomenon of global aging will increasingly challenge society financially, socially, and environmentally.

Financial Challenges

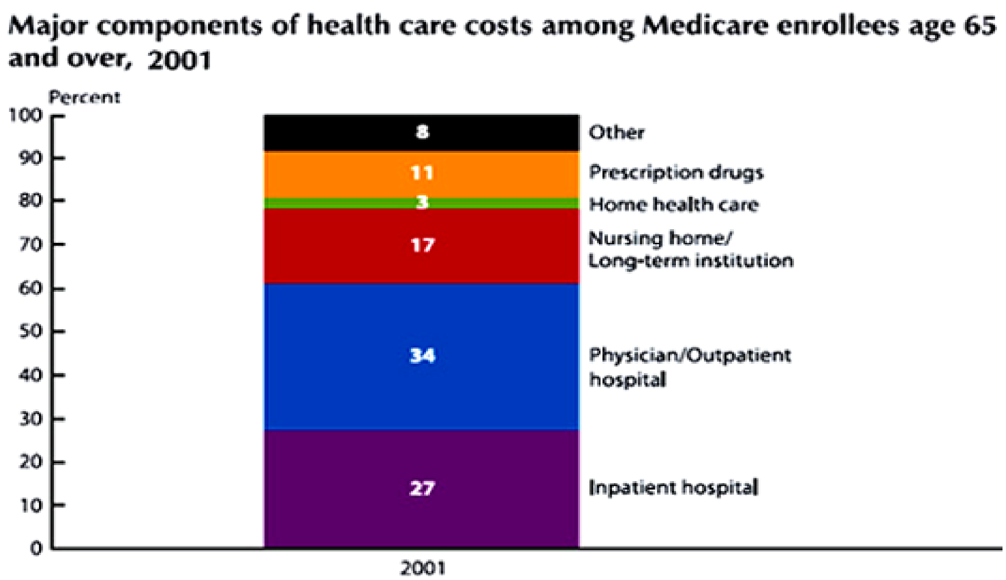
Systems of insurance, pension, healthcare, and long-term care have been challenged, as people generally spend a larger portion of life in retirement. Patterns of work and retirement have been changed. As the percentage of population of working age declines, the mechanisms of society for economic growth and pension systems may not as strong as they were. Labor supply, trade, and patterns of saving around the world require a variety of approaches to accommodate the aging world, as older adults consume social resources disproportionately.

Figure 5: Average Health Expenditures per Capita for People Age 65 and Older in 1997



Among developed countries in 1997, United States had the highest average health expenditures per capita for older adults (OECD, 2002) (Figure 5). In the U. S., long-term care institutions accounted for 17% of total healthcare costs of older adults in 2001, following the costs of inpatient and outpatient hospitals (Figure 6) (FIFARS, 2004).

Figure 6: Major Components of Health Care Costs among Elderly Medicare Enrollee



Social Challenges

In terms of social factors, family living arrangements are also challenged. The percentage of community-dwelling older adults living alone increased from 25 in 1970 to 30 in 2003 (FIFARS, 2004). The majority of households in the U. S. will be a smaller size, and headed by an elderly person without children (Johnson et al., 2003). As the younger generations decrease in size, fewer older adults have the option to live with their grown children or young relatives at home, which has been found to increase longevity.

For instance, the percentage of elderly Japanese living with their grown children or relatives at home is the highest among the world's more developed countries (50% versus 13% in the U.S. in 1997) and the life expectancy of Japanese at age 65 is the longest in the world (an average of 19.2 years versus 17.3 years in the U. S. in 1997) (Anderson et al., 1999; FIFARS, 2004; NIPSSR, 2007; OECD, 2002).

In addition, older adults who lived alone at home were more likely to move to senior-living facilities, than were those living with others (Shapiro et al., 1988). Given that the oldest old among householders will increase from 2.9 million in 2005 to 5.4 million by 2030 (Blake et al., 2005), fewer families will be able to accommodate elderly family members. As soon as older adults lose their ability to remain independent or their families cannot accommodate them at home, they face the challenge of moving to senior-living facilities for the rest of life.

Furthermore, both young and older adults are challenged by the aforementioned change of family living arrangements. In general, young people do not prefer to send their loved ones to senior-living facilities. Most older Americans appear to be reluctant to move from their homes in the community to senior-living facilities (Lawton, 1999). An elderly family member's relocation from home to senior living facilities is a big decision for everyone in the family, and some older adults who are forced to move may suffer psychological problems (e.g., depression). Typically, older adults' health declines and mortality rises after moving to senior-living facilities (Marek et al., 2000).

Environmental Challenges

The quality of environments is also challenged. Given that one in five Americans will be age 65 or older by 2030 (FIFARS, 2004), existing environments should be upgraded and future environments should be built to be more senior-friendly. Since older adults' overall competence declines with age, safe environments for young people may be challenging or even dangerous for the elderly. Residential, work, and entertainment environments should be designed with respect to older adults. Residential environments are the places where many older adults spend the majority of their day; the environmental quality may influence older adults' physical activity and independent living. Furthermore, many older adults may extend their years in the workforce as the proportion of people of working age declines; work environments (e.g., office buildings) should be safe and accessible for elderly employees. In addition, general entertainment environments (e.g., cinemas) also should be barrier-free for older adults. Further research is needed in these fields. This study focused on supportive residential environments for older adults.

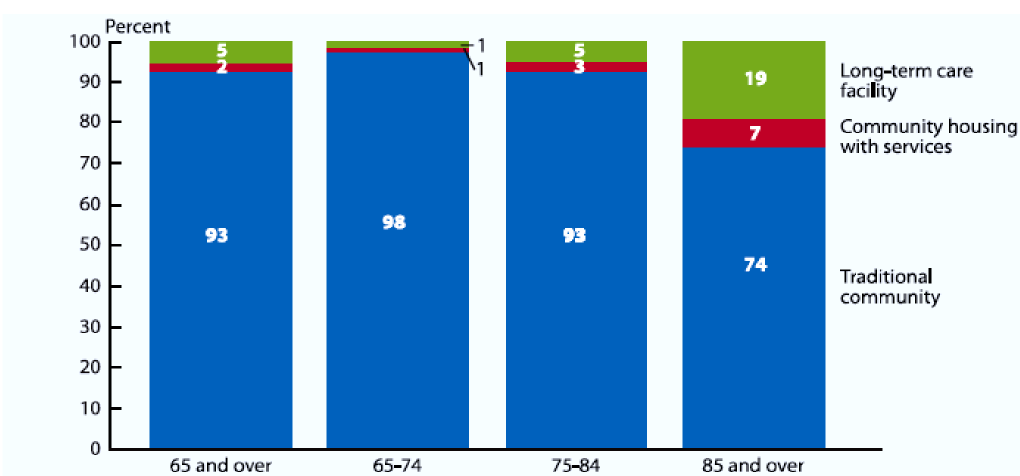
<u>SENIOR-LIVING FACILITIES AND RELOCATION</u>

Responding to the phenomenon of aging, the number of senior-living facilities has increased in recent years. Generally, a senior-living facility is an institutionalized setting providing daily services and/or personal care services for older adults. Older adults who cannot remain independent may relocate from their homes to senior-living facilities.

SENIOR-LIVING FACILITIES

Senior-living facilities can be classified into two groups: long-term care facilities and community housing with services (FIFARS, 2004). Long-term care facilities have been defined as licensed nursing homes and residential facilities providing personal care services or supervision from caregivers 24 hours a day and 7 days a week. Assisted-living facilities and independent living facilities have been included in the group of community housing with services, along with senior housing, Continuing Care Retirement Communities (CCRC), staged living communities, board and care facilities, and other community residences with senior-living services such as meal preparation, housekeeping, laundry, and medication support (FIFARS, 2004). The number of older Americans continues to increase, and the percentage of living in senior-living facilities has consistently remained between 5% to 10% (AARP, 1996; Sherman, 1985). In 2004, 5% of older adults in the U. S. lived in long-term care facilities and another 2% lived in community housing with services for seniors (Figure 7) (FIFARS, 2004).

Figure 7: Percentage of Older Adults Living in Selected Residential Settings, by Age Groups, 2002



To facilitate elderly residents' relocation to higher levels of care as age increases, some senior-living facilities offer senior care at two or more levels. For instance, residents in CCRC's can access senior services of independent living, assisted living, and skilled nursing in one location.

RELOCATION

Moving from home to institutionalized residential settings significantly influences older adults' sense of control, quality of life, and longevity (Blenkner, 1967; Boyd et al., 2005). An older adult may live in his or her own house before the move; after that, he or she may share a bedroom with roommates. Additionally, while living in his or her own home in the familiar neighborhood, the older adult may enjoy his or her social identity and psychological links with the environment, and thereby have a strong sense of control which promotes physical and emotional wellbeing (Cooper Marcus, 1995; Scheidt et al., 1999; Stokols, 1992). After the move, the older adult needs to rebuild his or her social spheres of life (e.g., making friends and getting familiar with the surroundings) and sense of environmental belonging. The reconstruction takes time and energy, but the result cannot be ensured, as it depends on a variety of personal and environmental factors. Furthermore, after moving from home to a senior-living facility, the health of a frail elderly person typically deteriorates, and the mortality rate significantly rises (Blenkner, 1967; Lawton et al., 1970; Marek et al., 2000). An older adult's life expectancy at the time of moving in a senior-living facility is about 4 years (DeCoster et al., 1995).

In Blenkner's study on providing services to older adults, the group receiving maximal care in an institutionalized residential setting had the highest mortality rate at the 6-month follow-up, among the minimal, moderate and maximal care groups. The minimal care group, who lived in a non-institutional setting and only received information about available services, had the lowest mortality rate. One possible explanation for this surprising result is that moving older adults from their own homes to institutionalized residential settings uproots their history of life, reduces their sense of control, and ultimately increases their mortality rate. In addition, older adults living in institutionalized residential settings may not have as much choice as living in their own homes, regarding many issues of daily living, and having the ability to choose has been found to contribute to the well-being of elderly people (Altholz, 1989).

The community at-large is the place where most people live and older adults would prefer to continuously live in later life. As the ability to remain independent at home declines with age, older adults, especially those living alone, move to senior-living facilities and thus are unable to remain living at home. Reviewing and analyzing factors associated with older adults' independent living and aging-in-place is a prerequisite for providing effective support to help older adults sustain their independent years and age in place at home.

AGING-IN-PLACE AT HOME

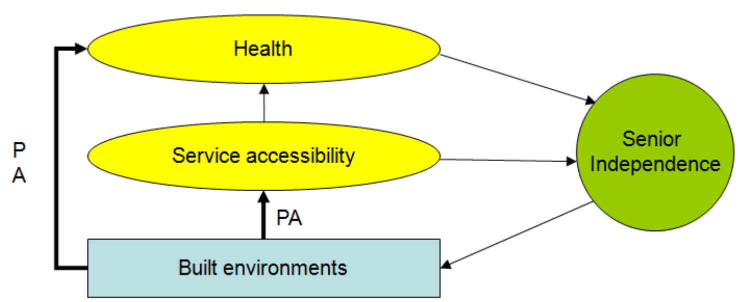
CONCERNS

Older adults' aging-in-place at home is associated with a variety of influences such as personal factors (e.g., health, income), social factors (e.g., neighborhood social cohesion), and environmental factors. As an integral part of successful aging, aging-in-place in one's own home can be pursued by maintaining health and vitality, and access to services necessary for daily life.

Older adults' recreational and utilitarian physical activities enhance health and the ability to access services. By engaging in these physical activities, older adults are expected to have more independent years at home. In light of high long-term care expenditures paid by taxpayers, older adults' efforts to remain independent in their own homes positively impact both individuals and society. As a compensating factor for functional decline in later life, environmental support can help older adults engage in healthy and useful physical activities for aging-in-place at home. Older adults' ability to handle daily living should be defined not only by the number of daily tasks they can or cannot perform, but also by the range of environmental contexts in which tasks can be successfully carried out. Demanding environments may force older adults to prematurely terminate their independent years at home.

Levels of dependence in older adults may continue to increase unless future policy and environmental design can provide increased support for their physical activity. Independent older adults might be living in environments which make them dependent. Positive environment-behavior interactions might slow the rate of decrement with advancing age, and help older adults to remain independent as long as possible. Using environments to promote physical activity for health is advocated by the U. S. Surgeon General, but minimal attention has been devoted to the sequential environment-behavior impact on aging-in-place at home. An adequately supported and methodologically sound research initiative can help improve the understanding of how environment and physical activity influence older adults' aging-in-place at home, so that evidence-based environmental interventions can be developed for older adults. Analyzing correlations among health, services, physical activity, and environments is an important prerequisite for the promotion of aging-in-place at home (Figure 8).

Figure 8: Interdisciplinary Conceptual Framework for Using Environments to Promote Senior Independence through Physical Activities (PA)

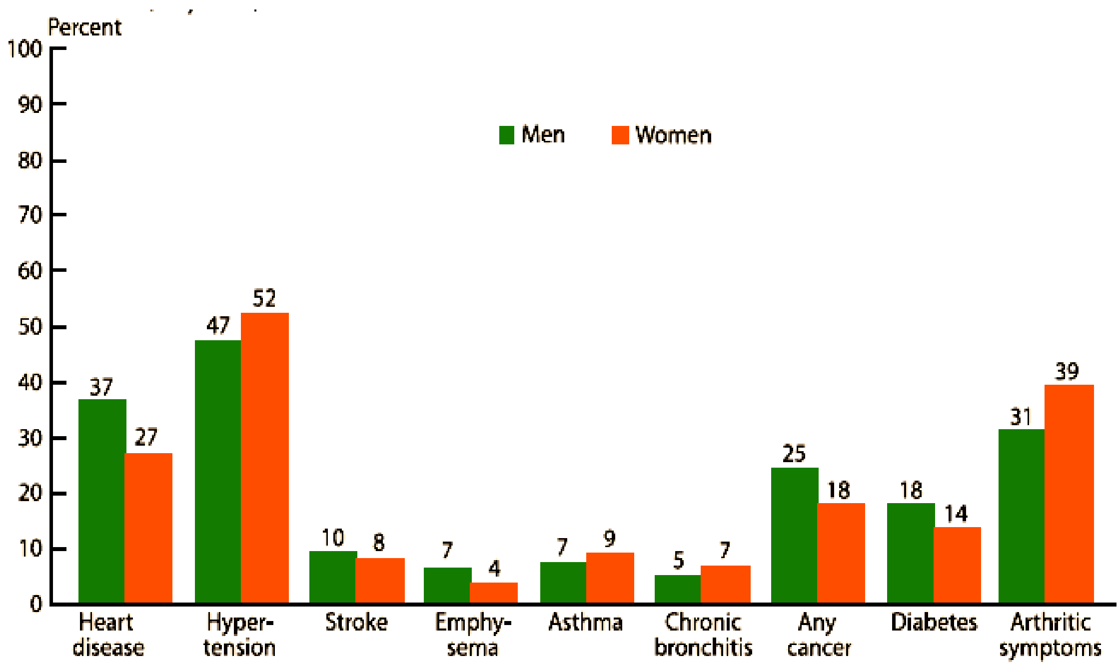


HEALTH AND SERVICES

Health

Age-related physical and/or mental health problems progressively diminish older adults' competence and continuously reduce their independence (FIFARS, 2004; Nagi, 1965). The five most common chronic diseases among older Americans are hypertension, arthritic symptoms, heart diseases, cancers, and diabetes (Figure 9) (FIFARS, 2004). The loss of cognitive functioning in the elderly is indicated by memory impairment. About 11% of older women and 15% of older men in the USA reported moderate or severe memory impairment (FIFARS, 2004). Older adults with memory impairment may also develop symptoms of dementia and/or Alzheimer's. A prevalent mental disorder among older adults is depression (Kritz et al., 2000). Approximately 18% of older women and 11% of older men in the USA were found to have clinically relevant depressive symptoms (FIFARS, 2004). Depressive symptoms sometimes mimic dementia and thereby can be overlooked (APA, 2008).

Figure 9: Chronic Conditions among Older Adults: 2001 – 2002(FIFARS, 2004)



Note: Data are based on a 2-year average from 2001-2002. Data for arthritic symptoms are from 2000-2001.
Reference population: These data refer to the civilian noninstitutionalized population.
Source: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health Interview Survey.

As health declines with age, many older adults have functional limitations and progressively lose the ability to handle daily errands and to age in place at home. The decline generally begins with IADL (Instrumental Activities of Daily Living) limitations, and progresses to ADL (Activities of Daily Living) limitations. Heavy housework (43%), shopping (30%), walking (37%), going outside (27%), and bathing (26.5%) were listed as the most prevalent IADL/ ADL limitations among older Americans by Fredman, Droge, and Rabin (1992).

Services

If older adults have easy access to services necessary for conducting the tasks of daily life, aging in place in their own homes remains a viable option in later life. Direct services- supplant daily tasks. Indirect services, such as public transportation and information about healthcare, provide supplementary assistance to help older adults complete daily tasks. Paradoxically, receiving direct services could reduce community-dwelling older adults' sense of control, cause loss of independence, and ultimately lead to a raise in the mortality rate (Blenkner, 1967; Boyd et al., 2005). Older adults who received indirect services were found to engage in more self-care activities and live longer than their counterpart who received direct services (Blenkner, 1967; Norburn et al., 1995). By supporting rather than supplanting daily activities, supplementary assistance can help older adults remain independent. Helping older adults to help themselves is a feasible way to meet their changing needs for daily living.

PHYSICAL ACTIVITY

HEALTH BENEFITS

Benefits from physical activity

Engaging in appropriate physical activity can help older adults remain healthy, and thereby can prolong their ability to remain independent in their own homes. Older adults' physical activity can be viewed as a preventive behavioral adaptation to age-related decrement.

Physical activity can reduce risk of heart disease, diabetes, colon cancer, and high blood pressure, and can promote the strength of bones, joints, and muscles (CDC, 1996). Walking can improve balance, gait, and mobility in the elderly (Guralnik et al., 1995; Roberts, 1989; Roberts et al., 2005). Engaging in appropriate physical activity was found to slow functional decline in later life (Wang et al., 2002b). Appropriate physical activity also can help older adults who have functional limitations recover and delay the onset of disability (Lee et al., 2006c).

Exercise therapy has been determined to be as effective as various forms of psychotherapy and is widely used in treating depression (Byrne et al., 1993; Lindwall et al., 2007; Martinsen, 1994). Older adults' emotional well-being is positively associated with their exercise engagement (Kritz et al., 2000; Ruuskanen et al., 1995; Strawbridge et al., 2002). Older adults can confirm their social identity and psychological links to their surroundings by being physically active in familiar environments, such as walking in their neighborhoods (Cooper Marcus, 1995; Scheidt et al., 1999; Stokols, 1992). Furthermore, older adults can handle daily errands through utilitarian physical activity;

this promotes a sense of control over one's life and leads to improved self-efficacy and self-esteem. Retired older adults can find psychological substitutes for former employment by engaging in utilitarian physical activity. For instance, by gardening and harvesting fresh fruit or flowers, older adults may feel more productive after retirement.

It is easy for older adults to access nature while engaging in outdoor physical activity. Viewing pleasant nature scenes induces positively-toned feelings and reduces the risk of depression (Ulrich, 1991). A brief outdoor experience can reduce older adults' cortisol levels, which is an indicator of stress (Rodiek, 2002). Access to nature near home is highly valued by older adults and positively related to longevity (Kearney et al., 2005; Takano et al., 2002; Talbot et al., 1991).

Benefits from enhanced social interaction

Older adults' physical activity and social interaction are positively related (Booth et al., 2000; Hovell et al., 1989; Ståhl et al., 2001). Social participation contributes to the prevention of disabilities and the reduction of cognitive decline in later life (Mendes de Leon et al., 2003; Purdie et al., 2002). Socially active older adults have higher levels of hearing, vision, and memory abilities (Avlund et al., 1998). The risk of dementia was found to be reduced by engaging in social interaction (Wang et al., 2002a).

Older adults may feel needed and connected to society while engaging in social interaction. Social interactions can benefit health by meeting people's information needs and making them more reasonable, cooperative, and satisfied (Cohen et al., 1985; Kaplan et al., 2003; Seeman, 2000). After retirement, older adults' social contacts outside home are generally reduced, although they may want to be informed about events. The Reasonable Person Model indicates that unmet information needs may make people feel depressed (Kaplan et al., 2003). Given that 15% of older Americans suffer from depressive symptoms (FIFARS, 2004), promoting social interaction and information access in the elderly is critical. Helping older adults to engage in physical activity can be one way to achieve this goal.

ENHANCED SERVICE ACCESSIBILITY

Safe access to services through physical activity

Many community-dwelling older adults drive vehicles to accomplish the tasks of daily living. There are risks associated with the driving skills of some older adults, as vision and cognition tend to diminish with age (Owsley, 2004). In the U.S. in 1996, 17% of the drivers (7,112 out of 42,065) involved in traffic crashes were older adults, although they represented only about 12% of the total population (FIFARS, 2004; Hakamies, 2004). Safer travel modes need to be investigated for elderly drivers. Utilitarian walking (walking to accomplish tasks) and its integration with sophisticated public transit should be included in the set of choices. As a human-powered mode of transport, walking is a safe and easy alternative of driving, and a moderate and low-threshold physical activity. By walking to or from transit stops and taking public transit, older adults can access multiple destinations along transit routes and accomplish daily tasks.

Older adults' utilitarian walking promotes their access to services and can be viewed as a corrective behavioral adaptation to age-related competence decline. For instance, the ability to shop independently is required for community-dwelling older adults, as most of them live alone or with their spouse only (FIFARS, 2004). However, a decline in the ability to shop is one of the most prevalent IADL limitations among older adults (Fredman et al., 1992). By walking instead of driving to stores, older adults in urban areas can access daily-life services and may sustain their independent years at home longer than they might have in suburban areas. Older urban inhabitants are more than twice as likely as older suburban inhabitants to walk to services; the longevity of aging-in-place among the former group was found to be 11 years longer than that among the latter group (Patterson et al., 2004).

Socially-supported access to services through physical activity

Generally, older adults lose many of their former social networks after retirement, and need to rebuild social resources to help them access services. By meeting and talking with others, older adults can make them aware of their needs for daily living. Older adults have improved opportunities to meet people while engaging in physical activity with others (Cooper Marcus, 1995; Scheidt et al., 1999; Stokols, 1992). Family-centered environments also foster social interaction (Shepley, 1998). For example, doing yard work with family members and friends can enhance the existing social networks of older adults. By walking in their neighborhoods, older adults can learn about local events and be more involved in society. Compared to sedentary peers, active older adults have better opportunities to reconstruct their social resources after retirement, and to access services with support from others.

ENVIRONMENTAL SUPPORT OF PHYSICAL ACTIVITY

More than 60% of older Americans are considered to have sedentary lifestyles (DHHS, 1996). Older adults are generally more environmentally docile and less environmentally proactive than young adults (Lawton, 1985, 1989; Lawton et al., 1968). Common environmental features,may inhibit older adults' interactions with the environment and thus reduce their mobility (Shumway-Cook et al., 2003). If environments in which older adults live are attractive, convenient, and safe for their physical activities, they are expected to be more active, healthy, and have more independent years.

As age increases, the geographic radius of older adults' environmental involvement diminishes. The most readily available places for older adults to engage in physical activity are outdoor environments near home, including environments at the neighborhood and site levels. Neighborhood walking and physical activities in residential site environments (i.e., gardening, walking, yard work, and other physical activities in the yard or on the property in which people live) are the most popular physical activities among older adults (DHHS, 1996).

AT THE NEIGHBORHOOD LEVEL

Attractiveness

The presence of destinations of interest within walking distance of home can motivate people to walk. The number, size, and attractiveness of neighborhood walking destinations were found to be positively associated with levels of neighborhood walking (Giles-Corti et al., 2005; King et al., 2003). Neighborhood walking destinations for older adults include settings with high visual quality and facilities necessary for daily living. Neighborhood settings with high visual quality can provide recreational walking destinations for older adults, and were found to be positively associated with engagement in physical activity (Hoehner et al., 2005; Owen et al., 2004). For instance, residents who lived close to the sea or hills were found to participate in more physical activity (Bauman et al., 1999; Lee et al., 2006b). Older adults living close to parks, the most common places where people of all ages exercise, were found to have longer park-use duration per occurrence and higher levels of walking and social activity, compared to other older adults (Cohen et al., 2007; Mowen et al., 2007; Zlot et al., 2005). Neighborhood facilities which are necessary for daily living provide utilitarian destinations for older adults. The presence of daily-life facilities near home makes it possible for people to drive less and promotes neighborhood walking (Besser et al., 2005; Handy et al., 2001). Popular walking destinations among older adults are post offices, restaurants, banks, groceries, and convenience stores (Kealey et al., 2005). Older adults living near malls also report high levels of walking (King et al., 2003; Michael et al., 2006).

Pleasant streetscapes can promote neighborhood walking. Refining spatial design and design details of neighborhoods can increase the number of environmental features (such as colors and patterns) noticeable to pedestrians per unit time while walking, and tends to make the environment~~s~~ more attractive for pedestrians (Rapoport, 1987). Further research will be needed to clarify the influence of streetscape on neighborhood walking in older adults.

Convenience

Short distances between home and walking destinations are convenient for elderly pedestrians. Measures of distances between home and walking destinations provide the most effective predictor of neighborhood walkability (Lee et al., 2006b). Generally, the average distance between home and neighborhood destinations is related to the density of destinations in the neighborhood, which depends on many issues including neighborhood location, endemic zoning ordinances, land-use mix, residential density, and neighborhood design orientation. High levels of land-use mix and residential density in pedestrian-oriented neighborhoods (e.g., neighborhoods built before World War II) are considered intrinsic advantages that facilitate neighborhood walking (Frank et al., 2005; Lee et al., 2006b; Schilling et al., 2005). Older adults in pedestrian-oriented neighborhoods were found to be more active than those in auto-oriented neighborhoods (Friedman et al., 1994; King et al., 2005; Patterson et al., 2004; Wister, 2005). In addition, neighborhood street continuity influences the average distance between home and walking destinations (Hoehner et al., 2005; Leslie et al., 2005; Saelens et al., 2003).

Grid street networks provide more street connections and fewer dead-ends than other street networks, and help reduce the average distance to destinations (Frank et al., 2003). High percentages of four-way street intersections in neighborhoods were found to be associated with more walking (Boer et al., 2007).

Walkways can inhibit or facilitate older adults' neighborhood walking. Completed sidewalks, well-developed crosswalks, pedestrian signals, and roadside benches or rest areas were found to be associated with high levels of walking among older adults (Huston et al., 2003; Strach et al., 2007).

Safety

Safety from falls is a critical issue for older adults. Those who experience a fall are more likely to move to long-term care settings than their peers (Valente et al., 1998). Most falls in the elderly occur while walking, carrying objects, reaching, or leaning (Nachreiner et al., 2007). To prevent these falls, sidewalks, curbs, and streets should have regular, even, and slip-resistant surfaces. Adequate lighting on walkways promotes older adults' stepping accuracy and can help prevent falls (Alexander et al., 2005). Outdoor handrails and high levels of environmental maintenance may help reduce risk for falls in older adults (Braun, 1998).

Neighborhood safety from traffic and crime also influences neighborhood walking (Owen et al., 2004). Poorly controlled traffic around buildings can deter older adults from going outside (Strath et al., 2007). Neighborhood traffic calming schemes, such as speed cushion products, were found to contribute to increased physical activity (Morris et al., 2004). Although heavy traffic near home may discourage outdoor usage, having too little nearby traffic may make older adults feel separated from society; the appropriate level of traffic around buildings for older adults needs further research. In terms of perceived neighborhood safety from crime, neighborhood lighting is thought to be an important factor. Sufficient neighborhood lighting was found to improve levels of residents' recreational walking (Huston et al., 2003).

Social environments

Older adults living in a close-knit neighborhood are typically more active than those living in a loose-knit neighborhood, because people who get along, trust, and share the same values are more willing to help each other (Sampson et al., 1997). Older adults with higher levels of neighborhood social cohesion were found to engage in more physical activity (Fisher et al., 2004; King, 2008). Additionally, seeing active people outdoors was found to stimulate the viewer's intention to engage in physical activity (Hoehner et al., 2005; Kowal et al., 2007).

AT THE SITE LEVEL

Attractiveness

In the home, having pleasant indoor sunshine and window views can motivate older adults to go outdoors. Indoor sunshine and window views promote psychological escape from the indoors (Kellert, 1993). Older adults, who reported more pleasant indoor sunshine and window views in their rooms, were found to engage in more physical activity (Wang et al., 2006). Pleasant indoor sunshine can be created by appropriately orienting and placing buildings in site-level environments and strategically configuring building layouts and details such as window shadings. In planning for pleasant indoor sunshine, it is important to integrate principles of sustainability (e.g., designing in a way that conserves energy used in heating and cooling). Inviting window views can be based on the nearby site surroundings (e.g., an active streetscape) and/or created by developing well-landscaped areas on the site itself.

Desired site destinations for pedestrians can be any outdoor setting where people would enjoy lingering, such as a pavilion or landscaped areas. In senior living communities or congregate housing properties where there is a larger shared site, having destinations at the site level can motivate older adults to be more mobile. The presence of desired destinations along walkways was found to promote older adults' walking (Joseph et al., 2007). Physical-activity features at the site level, such as a swimming pool, were found to contribute to more physical activity among elderly residents (Joseph et al., 2005). In addition, the presence of accessible green spaces at the site level was found to enhance social interactions among older adults (Kweon et al., 1998; Sugihara et al., 2000). In the community-at-large, site destinations are under-explored in relation to older adults' physical activity. Landscaping in residential site environments may influence older adults' neighborhood walking.

Appropriate diversity or complexity of environments at the site level may increase the attractiveness of the environments and motivate older adults to engage in physical activity on the site. The presence of transitional areas on residential sites (i.e., indoor-outdoor spaces and outdoor areas relatively independent or semi-enclosed, between the front and back areas) was found to be related to more site-level physical activity among older adults (Wang et al., 2006). Environments at the site level include both the outdoors and the indoors. The incorporation of public or open, semiprivate or half-open, and private or close spaces in buildings was also found to be associated with high levels of physical activity in the elderly (Barnes, 2006).

Convenience

Environmental features may impact patterns of physical activity in older adults. For example, stairs can be used by older adults for vertical transportation and exercise. Older adults living in buildings with stairs were found to engage in more physical activity than those living in buildings with one story or installed with elevators (Van Den Hombergh et al., 1995). However, first-floor elderly residents were found to participate in more outdoor activity than second-floor residents (Verderber, 2006). Indoor-outdoor connection also plays a role in the introductory experience of older adults' outdoor travels. Entrance steps may increase the risk for falls and discourage older adults from going outside. To improve outdoor access, slip-resistant door handles and grab bars, entry ramps, and level entry areas all should be provided to create accessible entrances for older adults.

Paths connecting separated areas in residential site environments were found to promote older adults' physical activity on the site (Joseph et al., 2007; Wang et al., 2006). Having one connecting path can link separated front and back areas; having two connecting paths can create a continuous walking loop on the site. As many older adults spend most of their day at home, having connecting paths at the site level supports low-threshold site-level physical activity. To improve the usability of site-level environments for older adults, well-shaded seating places are needed along walking paths (Cranz et al., 2005; Rodiek et al., 2005).

Safety

Fall prevention at the site level may be even more important than at the neighborhood level, as older adults who perceive risk for falls at home may not go outside at all. To protect older adults from falls at the site level, environmental features such as stairs and flooring need special attention. A recent study analyzed site-level environmental support of fall prevention for the elderly and noted guidelines in relation to building and site design including spatial design and design details (Wang et al., 2008). Site-level safety from traffic is thought to be related to the average setback of buildings from streets and location of site entrances or exits. For instance, if a site is further away and/or well-screened from areas having heavy vehicular traffic, it seems likely that older adults would engage in more physical activity on the site. Site safety from crime is closely associated with neighborhood safety from crime. Perceived safety on a well-lighted site is expected to be high. The provision of property fences may also improve perceived site safety, although this has not been studied in relation to older adults' physical activity.

Social environments

Older adults' living arrangements may also influence their engagement in physical activity. Compared to older adults living alone at home, older adults living with others are expected to have more opportunities to receive instrumental and emotional social support of physical activity, and more years of aging-in-place at home. Researchers found that community-dwelling older adults living with family members or relatives had more independent years at home than those living alone (DeCoster et al., 1995; Shapiro et al., 1988). The influence of living arrangements on older adults' physical activity warrants further research.

SUMMARY

A significant benefit of physical activity for older adults is that it may help them have more years of aging-in-place at home. Taking issues of health and services into account, the idea of using environments to promote aging-in-place at home through physical activity is a conceptual framework that can be used to investigate environment-behavior interactions in relation to aging-in-place at home. The impact of environments on older adults' ability to age in place can be explained by levels of environmental support of their physical activity. Neighborhood and site-level environments influence older adults' physical activity, but their subsequent impact on aging-in-place at home needs more research.

Environmental interventions for older adults should include the broad scope of factors that influence their physical activity. Site-level environments need more attention, as these environments are places where older adults spend most of their day. Additionally, site-level environments are typically easier to modify than neighborhood environments. The conceptual framework of using environments to promote aging-in-place at home through physical activity can be used as a tool to refine practical targets for environmental design and policy aimed at promoting healthy aging.

CHAPTER III

METHODOLOGY

This Chapter has four sections: Research Design, Data Collection, Variables and Measurements, and Data Analysis.

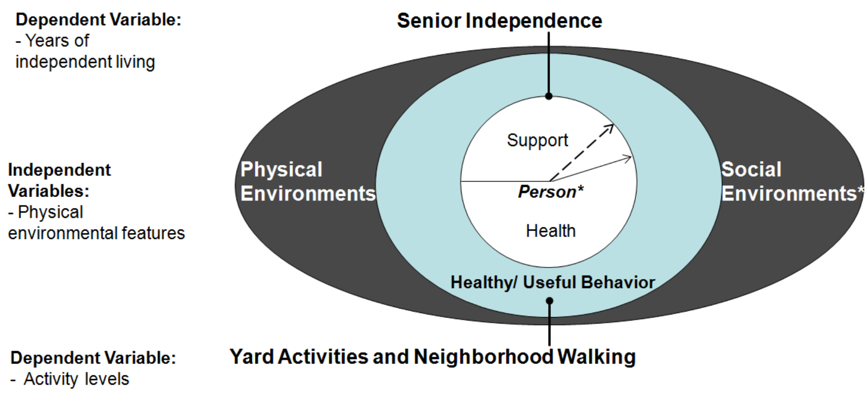
RESEARCH DESIGN

THEORETICAL RATIONALS

This study involved multiple disciplines such as the environment-behavior field, public health, gerontology, and service accessibility. The Ecological Model (EM) and the Social Ecologic Model (SEM) were used as theoretical rationales in this study. The EM describes the nature of behaviors as the interactions between people and their environments along physical, social, and psychological dimensions (Lawton et al., 1973). The SEM describes the structure of relationships among personal factors, social factors, physical environment factors, and physical activities (Zimring et al., 2005).

Based on the EM and SEM models, the Interdisciplinary Conceptual Framework for Environmental Support of Older Adults' Healthy/Useful Behavior and Independence was developed for this study (Figure 10). The value of physical environment factors at the site and neighborhood levels in predicting older adults' physical activities and independent years were investigated in this study, along with personal factors (e.g., gender and education) and social factors (i.e., living arrangement and neighborhood social cohesion).

Figure 10: Interdisciplinary Conceptual Framework for Environmental Support of Older Adults' Healthy/ Useful Behavior and Independence



THREE-COMPONENT RESEARCH CORE

This study surveyed older adults residing in assisted-living facilities. Questionnaire surveys and GIS were used to investigate the research aims. The core of this research had the following three components:

1) Questionnaire surveys collected data on participants' demographic information such as age and education, their previous residential addresses before moving to a retirement facility, the physical and social environments of their previous residential sites and neighborhoods, and their yard activities and neighborhood walking in the environments..

2) Based on the availability of data, the presence of environmental features on sample sites and in the neighborhoods was determined in GIS.

3) Quantitative data analyses were performed by using a statistical package SPSS.

FIVE-PHASE RESEARCH PROCEDURE

1) Reviewed the existing literature; interviewed older adults to identify possible environmental factors associated with their yard activities and neighborhood walking, explored relevant confounding variables; developed measurement protocols and a survey questionnaire; and tested GIS instruments and tagged data sources.

2) Performed a pilot study in a local assisted-living facility using the three-component research core; refined confounding variables; revised the questionnaire; updated GIS instruments; and narrowed down data sources.

3) Contacted potential sample facilities for final surveys; visited these facilities; chose 10 facilities with a preference for controlling for confounding variables; recruited older adults; conducted the final study using the three-component research core.

4) Developed guidelines for designing supportive nearby outdoor environments for seniors' yard activities, neighborhood walking, and independent living in the community; collected feedback from local architectural designers and urban planners; revised guidelines and produced policy recommendations; analyzed the effectiveness and feasibility of the aforementioned policy recommendations with local policy makers; revised guidelines and recommendations.

5) Prepared written reports with field notes, collected data, and the results from GIS and statistical analyses; completed the dissertation with a qualitative understanding of quantitative analyses.

DATA COLLECTION

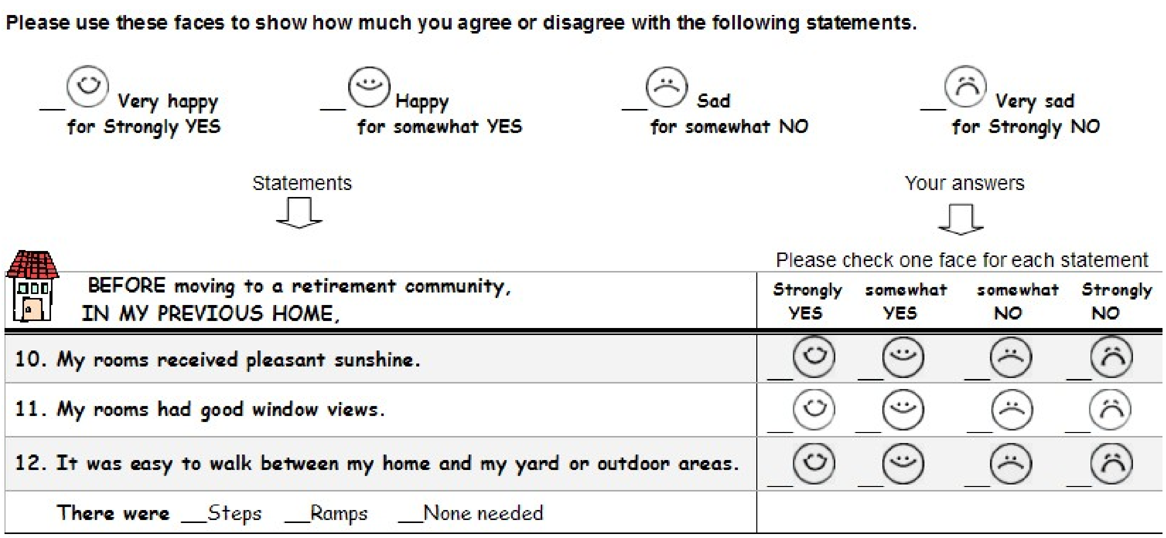
QUESTIONNAIRE SURVEYS

Participants were surveyed about their previous neighborhood walking and environmental perceptions regarding residential sites and neighborhoods, before moving to retirement facilities. Based on previous research, older adults are considered able to give reproducible answers to questions about a wide range of exposures many decades in the past, including physical activity and daily habits (Umming et al., 1994). With a high reliability, people have been able to recall activity patterns through questionnaire assessment and the length of recall interval ranges up to 10 years (Blair et al., 1991; Slattery et al., 1995). Researchers also found that older adults produced equivalent performance to young adults on long-term recall tests (Friedman et al., 1996).

A three-part questionnaire was specifically developed for this study (Appendix B). The 1st part focuses on participants' age, gender, and previous home addresses in the community; the 2nd part collects data on perceived site/ neighborhood environmental features, and previous yard activities and neighborhood walking; the 3rd part addresses previous living arrangement, IADLs, and other personal factors. Icons of smiling faces are used to help participants indicate how much they agree or disagree with given statements (Figure 11).

Questionnaire items focusing on residential site environments were created for this study. Items focusing on neighborhood environments were tailored and transformed from the combination of items used in the Healthy Aging Research Network study (Satariano, 2006) and the Twin Cities Walking study (Forsyth et al., 2004); both studies had acceptable validity. Items of social cohesion were borrowed from the Sampson's study (Sampson et al., 1997). The questionnaire was refined after a pilot study conducted in an assisted-living facility in Bryan, TX in Nov, 2006.

Figure 11: Examples of Questionnaire Items Used in Survey



Please use these faces to show how much you agree or disagree with the following statements.

__ Very happy for Strongly YES   __ Happy for somewhat YES   __ Sad for somewhat NO   __ Very sad for Strongly NO

Statements   Your answers

Please check one face for each statement

BEFORE moving to a retirement community, IN MY PREVIOUS HOME,	Strongly YES	somewhat YES	somewhat NO	Strongly NO
10. My rooms received pleasant sunshine.	__	__	__	__
11. My rooms had good window views.	__	__	__	__
12. It was easy to walk between my home and my yard or outdoor areas.	__	__	__	__
There were __Steps __Ramps __None needed				

GEOGRAPHIC INFORMATION SYSTEMS

GIS data on the environments in Houston, TX were collected from various websites such as Harris County Appraisal District (HCAD) and Geographic Information & Management System (GIMS), and the Department of Forest Science at Texas A&M University (Table 1). Specific data on population density, crime rates, and traffic issues were collected from the U.S. Census Bureau.

GIS data used in this study were downloaded from four websites as follows.

1) The website of Texas Natural Resources Information Systems (TNRIS) at http://www.tnris.state.tx.us/datadownload/
2) The website of HCAD at http://pdata.hcad.org/GIS
3) The website of Harris County Public Infrastructure Department Architecture and Engineering Division (HCPID) at http://www.eng.hctx.net
4) The website of GIMS developed by the City of Houston at http://pwegis.pwe.ci.houston.tx.us

All the data were processed to a common projection and datum as follows:

1) Projected coordinate system NAD_1983_StatePlane_Texas_South_Central_FIPS_4204_Feet
2) Geographic coordinate system GCS_North_American_1983

Table 1: GIS Data and Layers Used in This Research

Layer	Source	Extent	Projection	Datum
Banks Parks Post offices Drugstores Healthcare Facilities Commercial Facilities Utilitarian Facilities (Point/poly-line/polygon files)	HCPID	Left: 2940571.837500 Right: 3283515.176333 Top: 14024450.459667 Bottom: 13699045.328500	NAD_1983_StatePlane_Texas_South_Central_FIPS_4204_Feet	GCS_North_American_1983
Freeways Zip codes	GIMS	Same as above	NAD_1983_StatePlane_Texas_South_Central_FIPS_4204_Feet	GCS_North_American_1983
Harris Roads (A poly-line feature file of roads in Harris county)	Dept of Forest Science, TAMU	After re-projection Left: 2928863.272048 Right: 3265530.153175 Top: 13992550.359229 Bottom: 13748539.241609	GCS_Assumed_Geographic_1	D_North_American_1927
Harris Parcels (A polygon feature file of parcels in Harris county)	HCAD	Left: 2929264.861386 Right: 3269286.273267 Top: 13992542.754455 Bottom: 13748390.427723	NAD_1983_UTM_Zone_14N	GCS_North_American_1983
Aerial photos - NAIP 2004 1-meter quads	TNRIS	As of one selected Quad (the NW Settegast Quad). Left: 270164.000000 Right: 276965.000000 Top: 3307613.000000 Bottom: 3299942.000000	NAD_1983_UTM_Zone_15N	GCS_North_American_1983

SURVEY SETTINGS AND PARTICIPANTS

A total of 206 study participants were recruited from 11 assisted-living facilities in Houston, College Station, Bryan, and Brenham, TX. Based on the mailing addresses of participants' own homes where they lived before moving to facilities, sample sites were identified in Harris County (Houston), Brazos County (College Station and Bryan), and Washington County (Brenham), TX. These counties are in and around a highly diverse metropolitan area: Houston- Sugar land - Baytown area which has high density cities and also covers low density developments (U.S. Census, 2005). Harris County has coastal borders; Brazos County and Washington County are inland counties. The diversity of these areas offered sufficient variations in both environmental and socio-demographic factors for strong statistical data analysis. High quality and longitudinal GIS data of these areas have been developed by the USGS and local cities.

Research programs at Texas A&M University were known to these cities and selected assisted-living facilities, which helped to facilitate data collection and survey access. The principal investigator contacted facility managers and activity coordinators via phone, email, and post mail to introduce this study and collect data. Invitation letters and information sheets were sent to facilities via email and postal mail. Aesthetically pleasing flyers specially designed for this study were mailed to facilities to recruit participants one week before surveys. During the surveys, colorful questionnaires were introduced and distributed to residents. Participants were screened by facility caregivers to verify their cognitive competence for answering survey questions, and were included only if they agreed to join the study. Research assistants helped participants go through the questionnaire. To meet different needs of participants, surveys were addressed in the form of group activities or face-to-face interviews in facilities. The sample size varied from 20 to 30 per facility.

Harris County, TX

Study participants were recruited from residents in five assisted living facilities of a single long-term care management system in Houston, TX; this made it possible to control confounding variables such as different facility policies of entry admission. Participants were residents who agreed to join this study, and their cognitive ability to answer the survey questions was vouched for by their caregivers. Response rates were 25% to 30% in different facilities. The sample size varied from 20 to 30 per facility, with a total of 110 residents. The average age of participants was 84.2 years and 82% of them were female. Seventy-two out of the 110 sample sites were single-family homes; 25 were apartment buildings or condominiums; 13 were townhouses, row-houses, or other types.

Brazos County and Washington County, TX

Study participants were randomly recruited from six assisted living facilities in College Station, Bryan, and Brenham (Table 2). Response rates were 15% to 35% in different facilities. The sample size varied from 10 to 22 per facility, with a total of 96. The average age of participants was 86.5 years, and 79% of them were female. Eightytwo out of the 96 sample sites were single-family homes; 6 were apartment buildings or condominiums; 6 were townhouses or row-houses, and 2 were other types.

Table 2: Samples in Harris, Brazos, and Washington County, TX

Facilities surveyed	Response rates	Sample size	Average age	Female	Building Type
5 facilities in Harris County	25% to 35%	110 (20 to 30 per facility)	84.2 years	82%	72 single-family h. 25 apartments 13 townhouses 0 others
5 facilities in Brazos County 1 facility in Washington County	15% to 25%	96 (10 to 22 per facility)	86.5 years	79%	82 single-family h. 6 apartments 6 townhouses 2 others

<u>VARIABLES AND MEASUREMENTS</u>

DEPENDENT VARIABLES AND MEASUREMENTS

The main dependent variable in this study is “Years of Independent Living in the Community At-large”. It was measured in years, by subtracting participants’ facility stay from their current age.

Sub-dependent variables in this study are activity levels. Levels of physical activities (i.e., yard activities and neighborhood walking) were measured by how often per day and how long per occurrence in minutes.

INDEPENDENT VARIABLES AND MEASUREMENTS

At the neighborhood level

Based on the results from previous research, neighborhood environment features were pre-classified into three factors (Table 3). This classification would be refined after conducting factor analysis of neighborhood features in SPSS.

1) Attractiveness: Environmental amenities encouraging older adults to go outdoors, such as desired walking destinations in the neighborhood.
2) Convenience: Environmental features which make neighborhood walking convenient, such as feasible walkways, shaded seating areas along walking routes, and short distance between home and destinations.
3) Safety: Environmental features thought to be related to neighborhood safety perceived by older adults, such as the presence of sidewalks and lighting systems.

It was noted that 1300 feet or 400 meters was the distance that average American adults would rather walk than drive (Atash, 1994). Radiuses of 100, 500, and 1000 meters were used to study neighborhood walking (Berke et al., 2007; Moudon et al., 2003). The distance which older adults generally travel in their neighborhoods needs further research. To address this gap, this study investigated neighborhood environments at four levels: 1) within a 1300-feet or quarter of a mile radius of home; 2) within a 2600-feet or half mile radius of home; 3) within a 1-mile radius of home; 4) within a 2-mile radius of home.

Length and size of neighborhood environmental features were measured in feet and square feet. Levels of perceived environmental features were scored in quartile, with 4^{th}

and 1st used to represent the highest and lowest level respectively; perceived features included walking route choices, sidewalks, crosswalks and traffic signals for pedestrians, benches/ rest areas and restrooms along walking routes, levels of environmental safety from traffic and crime, and lighting systems in the neighborhood.

Table 3: Environmental Features at the Neighborhood Level

Category	Variables	Measurements	Data collection
Attractiveness	1. Retail/ Food /Healthcare Facilities (CFH)	number	GIS
	2. Walking destinations	number	Survey
	3. Interesting things to see while walking	4-level rate	Survey
Convenience	4. Distance bt. home and nearest CFH facilities	in 100-feet	GIS
	5. Size of areas occupied by roads	in 30x30 sq feet	GIS, Survey
	6. Walking route choices	4-level rate	Survey
	7. Sidewalks	4-level rate	Survey
	8. Crosswalk/ traffic signals for pedestrians	4-level rate	Survey
Category	Variables	Measurements	Data collection
Convenience	9. Benches/ rest areas/ restrooms	4-level rate	Survey
Safety	10. Traffic	4-level rate	Survey
	11. Crime	4-level rate	Survey
	12. Lighting systems	4-level rate	Survey

At the site level

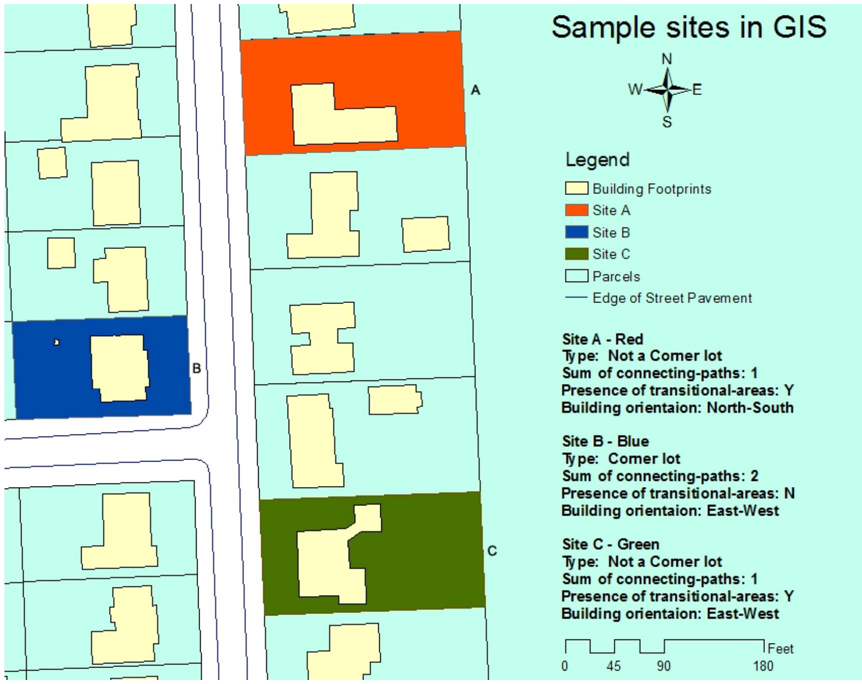
Based on the results from previous research, physical environment features of residential sites were classified into four factors as follows.

1) Typology: The building type, size, height in number of stories, orientation toward sun, orientation toward the frontage street, setback from street, site type, size, and lot coverage.
2) Attractiveness: Environmental amenities encouraging older adults to go outdoors, including pleasant indoor sunshine and good window-views at the building level, and yard landscaping and interesting transitional-areas at the site level.
3) Convenience: Environmental features convenient to older adults' yard activities, including feasible indoor-outdoor connections, connecting-paths, side-areas, site walkability, paving and shading. Outdoor seating was not feasible to identify in aerial photos and thus not included.
4) Safety: An environmental feature thought to be related to the safety perceived by older adults in the yard or on the property: the distance between site entrance and the nearest street intersection. Older adults may hesitate to go outdoors if the site is close to vehicular traffic.

Site-level environments focus on the physical environments adjacent to residential buildings on the property, which older adults can access without crossing vehicular traffic. These environments may be more attractive to older adults if they site-level destinations and could pass through multiple spaces while traversing the site, and be more convenient to their yard activities if there are convenient paths connecting separated areas around the building.

Similar to neighborhood environments, residential site environments need destinations to motivate older adults to go outdoors. Site destinations could consist of both inviting and functional outdoor spaces such as landscape settings and gardening areas . In addition to the front and back areas around the building, some spaces could be described as *transitional-areas*. Transitional-areas could be side-yards and other areas relatively independent or semi-enclosed, between the front and back areas; these could be created by building ground plans in multi-edge shapes (Figure 12- A and C), proper spatial relationships between the main building and accessory buildings. Having transitional-areas at the site-level is considered to increase the complexity and/or diversity of the environment and thus to enhance the environmental attractiveness. If a *side-area* between one side of building and the nearby edge of parcel, or a *mid-area* between buildings or building parts, is comfortable to walk through (defined as >= ten feet), a *connecting-path* could be developed to link separated areas around the building (Figure 12 - A and C). As connecting-paths facilitate yard walking and provide flexible choices of environments for yard activities, they are convenient for physical activity at the site level.

Figure 12: Sample Sites in GIS



If a site has at least two streets on different directions along its edges, it could be classified as a *corner lot* (Figure 12 - B). Building type was classified as 1 for single-family houses, 2 for townhouses or row-houses, and 3 for apartment buildings or condominiums. Site type was classified as 1 for corner lots and 0 for others. The height of building was counted in the total number of stories. At the site level, features were categorized into two groups: building and site (Table 4).

Table 4: Environmental Features at the Site Level

Category	Building		Site	
	Variables	Data collection	Variables	Data collection
Typology	1. Building Type	GIS, Surv.	1. Site Type	GIS
	2. Building Size	GIS	2. Parcel Size	GIS
	3. Height of building (# of stories)	GIS, Surv.	3. Lot coverage	GIS
	4. Building orientation toward Sun	GIS		
	5. Building orientation toward the frontage street (parallel or not)	GIS		
Attractiveness	6. Pleasant indoor sunshine	Survey	4. Yard landscaping	Survey
	7. Good window-views	Survey	5. Transitional-areas	GIS
Convenience	8. Indoor-outdoor connections	Survey	6. Perceived site walkability	Survey
			7. Sum of connecting-paths	GIS
			8. Average width of side-areas	GIS
			9. Presence of paving	Survey
			10. Shading of tree canopy	GIS, Survey
Safety			11. Building setback	GIS
			12. Distance between the site entrance and the nearest street intersection	GIS
			13. Safety from surrounding traffic	Survey

Length and size of relevant environmental features were measured in feet and square feet. Levels of perceived environmental features were scored in quartile, with 4th and 1st used to represent the highest and lowest level respectively; perceived features included levels of pleasant indoor sunshine, good window-views, yard landscaping, indoor-outdoor connections, and site walkability. Levels of building orientation toward sun were also classified in quartiles, with 4th and 1st used to represent the highest and lowest level of building facing North-South, and with a preference of somewhat East-facing to somewhat West-facing as shown in the figure on page 93. Levels of building orientation toward the frontage street were rated as "1" if the long axis of building was parallel to the frontage street and otherwise as "0." The presence of environmental features was measured as "1" if the feature existed and otherwise as "0." Based on the analyses of satellite photos of sample sites, levels of shading were rated as "1" if the percentage of site areas shaded by tree canopy was below 25%, as "2" if the percentage was 25% to 50%, as "3" if 50% to 75%, and as "4" if more than 75%.

OTHER VARIABLES AND MEASUREMENTS

Personal factors included issues of age, gender, race, education, marriage, self-efficiency, previous income, health, IADLs, and building ownership before moving to a long-term care facility (Table 4). In this study, age was measured in years. Self-efficiency was measured by using two reported items on walking: self-estimation of ability to walk one-half mile and one mile; these items were rated in quartile, with 4^{th} and 1^{st} used to represent the highest and lowest level of ability. Previous IADLs also was rated in quartiles, with 4^{th} and 1^{st} used to represent the highest and lowest level of functional independence. Education levels of graduate school or higher, college, high school, and grade school or less were classified as "4" to "1" sequentially. Building ownership was rated as "1" if a participant owned his or her previous residence and otherwise as "0."

Social factors studied in this research were issues of living arrangement and neighborhood social cohesion (Table 5). The variable of neighborhood social cohesion was derived from five reported items on neighbor relationships, which were rated in quartiles with 4th and 1st used to represent the highest and lowest level. The five items were borrowed from the Sampson's study and their validity was approved to be acceptable (Sampson et al., 1997). Living arrangement was classified as "1" if a participant was not living alone in the residence and as "0" if living alone. Neighborhood social cohesion was rated in quartiles, with 4th and 1st used to represent the highest and lowest level of cohesion.

Table 5: Personal and Social Factors Studied

Personal		**Social**	
Variables	Measurements	Variables	Measurements
1. Age	# in years	1. Living arrangement (alone or not)	Y/N
2. Gender	F/M	2. Neighborhood social cohesion	4-level rate
3. Race	Non-Hispanic White/ Black/ Asian/ Hispanic/ others	3. Longevity-in-place in previous community-dwellings	Number in years
4. Education	4-level rate	4. Facility stay	Number in years
5. Income	4-level rate		
6. Previous health	4-level rate		
7. IADLs*	4-level rate		
8. Self-estimated ability to walk one-half mile	4-level rate		
9. Self-estimated ability to walk one mile	4-level rate		
10. Building ownership	Y/N		

*: IADLs: Instrumental Activities of Daily Living – a measure of functional competence.

DATA ANALYSIS

ENVIRONMENTAL ANALYSIS USING GIS INSTRUMENTS

Based on the availability and quality of data, environmental analysis using GIS instruments focused on sample sites in Houston, Harris County, TX. Sixty-one out of the 206 addresses reported by survey participants were located on the street map of Houston by using geo-coding tools in GIS. The 61 sites were normally distributed (Appendix A: Location of Sample Sites in Houston, TX).

At the neighborhood level

Objective measures of neighborhood environmental features were collected by using GIS instruments. These measures were two groups: 1) straight-line distances between home and the nearest destinations of interest and 2) the amount of roads and selected utilitarian facilities in neighborhood areas, which included in this study were post offices, banks, drugstores, malls, retails, shopping centers, supermarkets, convenience food markets, food stands, and restaurants.

Destinations of interest in this study were: 1) healthcare facilities such as hospitals, medical centers and clinics, 2) supermarkets and convenience food markets, 3) post offices, 4) banks, 5) drugstores, and 6) parks and trails. Selected *daily-life facilities* were: 1) healthcare facilities which included medical centers and hospitals, 2) supermarkets and convenience food markets, 3) a group of facilities necessary for conducting daily errands, including shopping centers, malls, retails, restaurants, food stand, drugstores, banks, post offices, supermarkets, and convenience food markets. Based the definitions of neighborhood in this study, neighborhood areas were studied at four levels: Within a

1300/2600/5280/10560-foot radius of home.

Procedures used in this study to collect and analyze data in GIS were as follows.

Locate mailing addresses

1) Create an address locator

Address locator style: US Street; Reference data: the layer of Harris Roads

2) Geo-code mailing addresses and review/ rematch

Input table: the table of mailing addresses; Address locator: product of step 1

Result: A point file of 61 addresses located on Harris Roads

Find specific sample parcels

1) Select by location

Select parcel features from the layer of Harris Parcels, within a 500-foot radius of the address points located in step 2; Result: A total of 596 parcels.

2) Identify the 61 parcels which match mailing addresses reported in surveys

Manually select the 61 sample parcels out of the 596 parcels, by confirming the parcel address with survey reports

Export the selected 61 parcels as a new layer

Record the HCAD_NUM which is the parcel ID used in GIS, and Survey ID for each of the sample parcel; join this table to the survey table.

3) Make 1300-, 2600-, 5280-, 10560-foot buffers of the 61 sample points

Convert the feature file of 61 parcels into a raster file in which parcel cells have the value of “1” and all other cells have the value of “0.” The cell size: 30x30 feet. Results: A raster of 61 sample parcels: [S61ras30re].

Analyze the distance between home and the nearest healthcare facility

1) Merge the feature layers of hospitals, medical centers and clinics, which were downloaded from GIMS or HCPID websites or developed after analyzing the downloaded data. Result: A point layer of healthcare facilities.
2) Use spatial analysis tools to create a straight-line distance raster for the location of healthcare facilities. The cell size: 30x30 feet; the extent: the layer of Zip codes.
3) Reclassify the distance raster with a remap table in 100-foot unit. Results: The reclassified distance raster [HHdistre15].
4) Assign the value of distances of home to the nearest health facility to parcel cells by using the Raster Calculator: S61HealthFt = [S61ras30re] x [HHdistre15].
5) Use the Zonal Statistics tool and create a table “S61HealthFtzo” which records the distances of sample sites to the nearest health facility.
Zone: the 1300-foot buffer layer [Site61Buf13].
Field: Survey ID, Value layer: [S61HealthFt], Function: Max

By using the similar procedures to those previously mentioned, tables recoding the distances between home and destinations of interest were created and exported from GIS. These tables were then inserted in EXCEL and merged into the survey table, by using the Survey ID as the reference key.

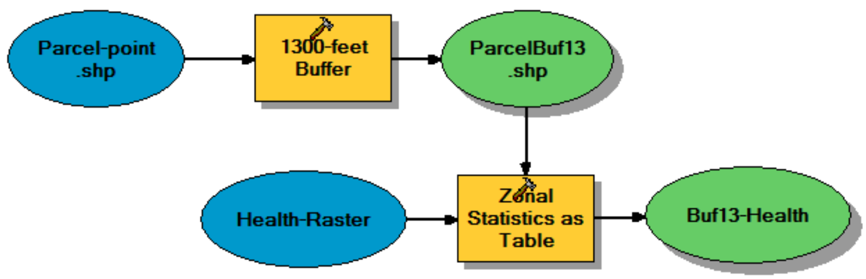
Analyze the amount of selected daily-life destinations in neighborhood areas

1) Open the feature file of selected daily-life destinations

2) Use GIS Models (e.g., Figure 13) to generate tables recording the sum of destinations within a 1300/2600/5280/10560-foot radius of each sample site.

3) Manually record the results in EXCEL.

Figure 13: A Sample of GIS Models Used in This Study



Analyze the amount of areas occupied by roads in the neighborhood

1) Convert the poly-line file of Harris Roads into a raster file [HarrisRdras10]

Use 10x10 feet as the size of raster cells to ensure the accuracy of GIS calculation.

2) Use GIS Models developed for this study (e.g., Figure 3) to generate tables recording the sum of road cells within a 1300-, 2600-, 5280-, 10560-foot radius of each sample site.

3) Manually record the results in EXCEL.

One-meter Digital Orthophoto Quads (DOQs - a digital mapping product with aerial photographs acquired in 2004), were collected of sample sites from TNRIS. High-resolution satellite photos from Google-Map online were used to detail the TNRIS DOQs after identifying sample sites in GIS. Layers used in the GIS study included

Destinations, Daily-life facilities, Parcels, Building footprints, Street outlines, Freeway, Zip-code, DOQs, and Satellite photos.

At the site level

Objective measures of site-level environmental features were collected by using GIS instruments. Issues of building type, size, orientation, setback from streets, site type, parcel size, lot coverage, shading, transitional-areas, connecting-paths, and the distance between site entrance and the nearest street intersection were studied in GIS.

GIS data were collected from various data sources online, including websites of the Geographic Information & Management System of Houston, the Harris County Appraisal District, the Houston- Galveston Area Council, the Texas Natural Resource Information System (TNRIS), the U.S. Geological Survey, the U.S. Census Bureau, and the Environmental Systems Research Institute. One-meter Digital Orthophoto Quads (DOQs - a digital mapping product with aerial photographs acquired in 2004), were collected of sample sites from TNRIS. High-resolution satellite photos from Google-Map online were used to detail the TNRIS DOQs after identifying sample sites in GIS. Layers used in the GIS study included Parcel, Parcel measure, Building footprint, Street outline, Freeway, Zip-code, DOQ, Satellite photo, and others.

Measures were collected in GIS following these procedures:

1) Identify individual sample sites in GIS by geo-coding addresses or selecting address attributes in parcel data;
2) Find measures of environmental features of interest in attribute tables of GIS layers;

3) Measure distances of interest in GIS by using GIS measure tools;
4) Analyze DOQs and satellite photos of sample sites to reconfirm measures;
5) Record measures in EXCEL and generate study maps in GIS.

For example, if one side-area measured in GIS was more than ten feet wide, a connecting-path was counted after checking the side-area in the satellite photo of site to make sure there was a noticeable path or an area supporting a connecting-path.

Based on the availability of data, GIS data on different years were used to match the physical environments in which older adults lived. Layers used in GIS include Building footprints, Parcels, Streets, Sidewalks, Traffic, Crime, Population, Land-use, and Aerial photos.

STATISTICAL ANALYSIS

Analysis of Neighborhood Walking in Relation to Environments

The Statistical Package for the Social Sciences (SPSS version 13.0) was used for the quantitative data analysis. Based on the results of a previous environment-behavior research project (Wang et al., 2006), physical environmental features were expected to explain at least 30% of the variance of the frequency and duration of older adults' neighborhood walking.

Normality and Correlation Analysis

The distributive normality of data was tested by interactive bars and normality plots. Some variables were re-coded to meet the requirement of normality for statistical analysis. For instance, the frequency of older adults' neighborhood walking was recoded as dichotomous, whether or not a participant walked at least once per day. The duration of older adults' neighborhood walking was also recoded as dichotomous whether or not a participant walked at least ten minutes per occurrence. Bivariate correlations among variables were analyzed by fishers' exact test. Test variables were filtered from all variables of interest by the above correlation tests and organized in blocks.

Factor Analysis

Factor analyses were conducted to analyze the relationships among variables. Ten neighborhood environmental items reported by older adults were walking destinations in the neighborhood, levels of environmental interesting, walking route choices, the presence of sidewalks, traffic safety, the presence of traffic signals for pedestrians, safety from crime, lighting systems, and the presence of benches/ rest areas and restrooms along walking routes. Statistical methods used in the factor analysis were as follows.

1) The Kaiser-Meyer-Olkin Measures of Sampling Adequacy and the Bartlett's Tests of Sphericity value were used to test the significance of factor analysis.

2) Principal components of studied variables were extracted by factor analysis.

3) The Eigen One Rule and the Scree plot were used to determine the number of factors. The method of promax rotation was used, as factors were assumed correlated.

4) Thurstone's Simple Structure rules were used to interpret the rotated factor matrices which contained the relationship between each item and each factor. Based on the Simple Structure rules, selected items were those related strongly to one proposed factor

and the factor loadings were 0.40 or above. Items with factor loadings of 0.40 or above on more than one factor were double-loaded items and dropped from the analysis. Items that loaded high on a factor that was not the proposed factor also were deleted.

5) The pattern and structure matrices were appeared in the output.

Binary Logistic Modeling

Binary logistic models were used to investigate the value of environments in predicting older adults' neighborhood walking, with personal and social variables in the modeling. Only significant variables identified by the aforementioned bivariate tests were included in the multivariate logistic analysis. In the first part of the analysis, environmental variables at the site and neighborhood levels were investigated separately. In the second part of the analysis, both site and neighborhood variables were sequentially added in the modeling process. In the analysis, personal and social variables were entered as the 1st block in the modeling and their sequences of entering were decided by theoretical concerns; environmental variables at the site and neighborhood levels were added as the 2nd and/or 3rd blocks, and the stepwise function of SPSS was used to select predictor variables and their sequences of entering. Missing values were excluded list-wise.

Analysis of Yard Activities in Relation to Environments

The statistics package SPSS was used for quantitative data analyses in the study. The distributive normality of data was tested by normality plots and histogram curves.

Bivariate correlations among variables were analyzed by t-test and Chi-square test. Only one of the variables which were significantly correlated with another ($p<0.05$, two tailed) was selected for multivariate analyses. Factor analyses were also conducted to analyze the relationships among variables.

The study participants were divided into two groups in SPSS, based on whether or not they had engaged in yard activities at least one time per day; and another two groups, based on whether or not the yard activities had lasted at least ten minutes per occurrence. Significant differences ($p < 0.05$) in environmental features between sites of the two groups were identified by independent sample t-tests.

Multinomial logistic models were also applied to examine the value of physical environments on residential sites in predicting levels of older adults' yard activities, with personal factors and social factors in the models, and physical environmental factors entered as the last block in modeling process. In full models, variables entered and their sequences of entering were decided by theoretical concerns. In nested models, the procedure itself selected predictor variables to enter the modeling by using the stepwise function of SPSS. Both full models and nested models were used to investigate environmental features associated significantly with yard activities of older adults. Test variables were filtered from all variables of interest by correlation tests and organized in three blocks: personal & social, site, and building.

Analysis of Independent Living in Relation to Environments

The dependent variable in this analysis was the number of older adults' years of living in their own homes. It was measured in years, by subtracting the length of senior-living facility stay from current age. Independent variables were ordinal or categorical variables, including personal and social factors, and environmental factors at the residential site and neighborhood levels.

Data were analyzed by using the Statistical Package for the Social Sciences (SPSS 13). The distributive normality of data was tested by normality plots and histograms. To meet the requirement of normality, continuous GIS variables were recorded into 6-level ordinal variables and survey variables in quartiles were recorded into 2-level or 3-level variables.

Bivariate correlations between the years and the personal, social, and environmental variables were analyzed by one-way ANOVA. A factorial ANOVA was then conducted to further investigate the effect of interactions among the significant variables identified by one-way ANOVA, on the years of living at home.

CHAPTER IV

RESULTS

This Chapter has three sections: 1) Results from the Environment & Neighborhood Walking Analysis; 2) Results from the Environment & Yard Activity Analysis; 3) Results from the Environment & Independent Living Analysis.

THE ENVIRONMENT AND NEIGHBORHOOD WALKING ANALYSIS

Data used in the environment and neighborhood walking analysis were collected in Houston, TX, by using survey and GIS instruments. A total of 114 assisted-living older adults joined the survey and answered questions regarding their walking behaviors and characteristics of their residential environments (at the site and neighborhood levels) before moving to assisted-living facilities. Based on the availability of data, a subset of 61 participants' residential environments was further assessed using GIS. To estimate older adults' neighborhood walking as a function of the environments, factor analysis, bivariate tests, and multivariate logistic regression models were used.

Multivariate analysis showed that yard landscaping and corner lot were significant site variables associated with older adults' walking; number of walking destinations, walking-route choices, safety from crime, and roadside benches/seating were significant neighborhood variables. Bivarate tests identified additional correlates including indoor sunshine, window view, and walkability at the site level; and interesting things to see, proximity to the nearest drugstore, street networks, sidewalks, safety from traffic, and lighting conditions at the neighborhood level.

VARIABLE DESCRIPTIONS

Seventy-four out of 110 sample buildings were one-story single-family houses and 63 had entrance steps or ramps. The average year in which buildings on the 61 GIS sample lots were built was 1965; 30 out of 61 sample buildings faced north-south; and 39 out of 61 sample buildings were parallel to their frontage streets. Twenty GIS sample lots were corner lots; 34 had transitional areas; 40 had more than one residential unit; 26 had two connecting paths. The average width of side-areas on GIS sample lots was 18 feet. The average building set-back was 36 feet. Lot sizes ranged from 0.05 to 14.73 square acres and gross floor areas ranged from 0.02 to 14.88 square acres. The average site coverage was 30%. The average distance between home and the nearest street intersection was 250 feet.

Fifty-two survey participants reported that they had at least one walking destination in neighborhoods. In GIS sample neighborhoods, the average number of utilitarian facilities was 4.3 within a ¼ mile, 14.6 within a ½ mile, 57.8 within a 1 mile, and 218.6 within a 2 mile radius of home. The average ratio of average areas occupied by roads was 0.296 within a ¼ mile / 0.172 within a ½ mile / 0.165 within a 1 mile / 0.191 within a 2 mile radius of home. The average distance between home and the nearest park was 7529 feet; between home and the nearest bank was 3936 feet; between home and the nearest post office was 15831 feet; between home and the nearest drugstore was 4285 feet; between home and the nearest healthcare facility was 6974 feet; between home and the nearest food facility was 3187 feet; between home and the nearest utilitarian facility was 1303 feet.

Descriptions of significant variables can be viewed in Table 6. Descriptions of other variables tested in this study can be viewed in Appendix A.

PRINCIPAL COMPONENT FACTORS

Factor analysis was conducted to uncover the underlying structure of environmental variables rated by older adults regarding their former neighborhoods, and remove unnecessary variables. Factor analysis was useful with this data set, as the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was at 0.76 and the Bartlett's Test of Sphericity Chi-Square value was significant.

Three principal component factors of ten neighborhood environmental variables were extracted and interpreted in the Pattern Matrix (Table 6). Based on the conceptual framework applied in this study (Figure 1), the three principal component factors were entitled: 1) Neighborhood Environmental Attractiveness, 2) Neighborhood Environmental Safety, and 3) Neighborhood Environmental Convenience. By using Thurstone's Simple Structure rules, one environmental variable: the presence of traffic signals for neighborhood pedestrians was not selected for further analysis.

Table 6: Pattern Matrix from the Factor Analysis of Neighborhood Features

	Component		
Environmental Features	1	2	3
1. Destinations	**.482**	.074	.094
1. Neighborhood interest	**.862**	-.075	-.027
1. Walking-route choices	**.870**	-.053	.094
2. Sidewalks	.280	**.486**	.195
2. Traffic	.061	**.750**	-.087
d. Traffic signals for pedestrians	.073	.319	.354
2. Crime	-.308	**.848**	.162
2. Lighting	.276	**.602**	-.310
3. Road-side benches or rest areas	.124	-.018	**.776**
3. Restrooms which neighborhood pedestrians can use	-.018	-.068	**.891**

Extraction Method: Principal Component Analysis. Rotation Method: Promax with Kaiser Normalization.
a Rotation converged in 5 iterations.

Nine neighborhood environmental variables were selected for further analysis and classified into three groups to represent the aforementioned principal component factors. Variables used to represent the factor of environmental attractiveness were the number of walking destinations, levels of walking-route choices, and neighborhood interest. Variables used to represent the factor of environmental safety were levels of safety from traffic, safety from crime, lighting systems, and the presence of sidewalks in the neighborhood. Variables used to represent the factor of environmental convenience were the presence of road-side benches or rest areas in the neighborhood and the presence of road-side restrooms which neighborhood pedestrians could use.

Results from the factor analysis of neighborhood environmental variables were compared to results from previous research and found to be generally similar, although some variables were not used in previous research. Principal component factors extracted in the factor analysis were same as the three neighborhood factors pre-classified in Chapter III, but variables used to represent these factors were different. In the pre-classification, levels of walking-route choice and the presence of sidewalks were used to represent the factor of neighborhood environmental convenience to pedestrians; based on the results of the factor analysis, levels of walking-route choice were used to represent the factor of environmental attractiveness and the presence of sidewalks in the neighborhood was used to represent the factor of environmental safety for older adults.

The underlying structure of neighborhood variables measured in GIS was also investigated by using factor analysis. In the analysis, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was at 0.76 and the Bartlett's Test of Sphericity Chi-Square value was significant. All GIS-based neighborhood variables collected in this study were selected for further analysis. These variables can be classified into three groups: 1) distances between home and the nearest park/ post office/ drugstore/ bank / healthcare facility/ commercial facility/ utilitarian facility, 2) numbers of commercial facilities within a ¼ mile / ½ mile / 1 mile / 2 mile radius of home and numbers of daily-life facilities within a ¼ mile / ½ mile / 1 mile / 2 mile radius of home, and 3) sizes of areas occupied by roads within a ¼ mile / ½ mile / 1 mile / 2 mile radius of home.

Site variables rated by older adults regarding their former residential sites/lots were also investigated by using factor analysis. In the analysis, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was at 0.60 and the Bartlett's Test of Sphericity Chi-Square value was significant. By using Thurstone's Simple Structure rules, the variable of site safety from traffic was not selected for further analysis.

SIGNIFICANT VARIABLES

Bivariate Test

By using bivariate tests, two personal, one social, five site-level, and ten neighborhood variables were found to be related to older adults' neighborhood walking frequency and/or duration. Significant site variables were levels of pleasant indoor sunshine, window view, lot walkability, landscaping, and lot type. Significant neighborhood variables were the number of walking destinations, levels of walking-route choices, safety from crime and traffic, lighting systems, neighborhood interest, road-side benches/seating, sidewalks, areas occupied by road within a ½ mile radius of home, and the distance between home and nearest drugstore (Table 7).

Table 7: Bivariate Correlates of Older Adults' Neighborhood Walking

	Significant variables identified by using Fishers' exact tests	Frequency		Duration	
		P value	Spearman Correlation	P value	Spearman Correlation
P+S	1. Self-estimated ability to walk 1mile	.000	.484	.000	.548
	2. Previous health	.002	.254	.008	.278
	3. Neighborhood social cohesion	.014	.243	.031	.194
E - Site	1. Pleasant indoor sunshine	.008	.268	.041	.206
	2. Good window-view	.011	.251	.047	.179
	3. Lot walkability	.007	.269	.002	.296
	4. Lot landscaping	.003	.294		
	5. *Lot type (Corner lot or not) – GIS variable*			.044	.252
E - Neigh	1. Number of walking destinations in neighborhoods	.001	.324	.000	.348
	2. Walking-route choices	.000	.436	.000	.464
	3. Safety from Crime	.000	.369	.014	.247
	4. Lighting systems	.004	.274	.004	.285
	5. Traffic	.014	.243	.034	.188
	6. Neighborhood interest - interesting things to see while walking	.028	.248	.002	.327
	7. Road-side benches/ seats	.046	.159	.044	.197
	8. Usable sidewalks			.003	.309
	9. *Areas occupied by roads within a ½ mile radius of home – GIS variable*	.012	.023		
	10. *Distance between home and the nearest drugstore – GIS variable*			.033	-.079

Note: Walking frequency was measured as dichotomies: whether or not walked at least once per day. Walking duration was measured as dichotomies: whether or not walked at least 10 minutes per occurrence. GIS-based variables are italic. Distances were measured in 100-feet and recoded in six levels. Areas were measured in 30x30 Square Ft and recoded in six levels. Survey variables were measured in ordinals. The variable of road-side benches was significant in 1-side tests and all other variables were significant in 2-side tests. P+S: personal and social variables. E – Site: Environments at the site level. E – Neigh: Environments at the neighborhood level.

Binary Logistic Modeling

In binary multivariate logistic modeling, two site-level variables and four neighborhood variables were selected by using the stepwise function of SPSS. By including significant variables identified by the aforementioned bivariate tests in the modeling, the multivariate analysis further showed the influence on older adults' walking of two site features: yard landscaping and corner lot, and four neighborhood features: number of walking destinations, walking-route choices, safety from crime, and roadside benches/seating. Tables 8 and 9 interpret eight significant logistic models predicting the likelihood of waking at least once per day and ten minutes per occurrence in older adults. Descriptions of these significant variables can be viewed in the table on page 77.

Table 8: Likelihood of Walking in Neighborhoods at Least Once a Day

	Variables in the models	M1: R^2=36.9% N=110 OR (CI)	M2: R^2= 46% N=110 OR (CI)	M3: R^2= 59.4% N=61 OR(CI)	M4: R^2=56.9% N=61 OR (CI)
P+S	**1. Self-estimated ability to walk 1mile**	3.43 (1.90, 6.19)***	3.26 (1.77, 6.02)***	3.69 (1.34, 10.15)*	3.64 (1.34, 9.92)*
	2. Previous health	1.04 (.56, 1.95)	1.06 (.59, 2.01)	.59 (.20, 1.80)	.62 (.20, 1.89)
	3. Neighborhood social cohesion	1.93 (.74, 5.02)	2.00 (.75, 5.35)	5.41 (1.03, 28.33)*	4.81 (.89, 26.14)
ES	**1. Lot landscaping**	3.42 (1.10, 10.60)*			
EN	**1. Number of walking destinations**		3.03 (1.17~7.84)*		
	2. Safety from Crime		4.31 (1.66, 11.15)**	13.98 (2.93, 66.79)**	12.88 (2.68, 61.89)**
	3. Road-side benches/ seating			7.14 (1.28, 39.80)*	6.61 (1.17, 37.21)*

Note: Walking frequency was measured as dichotomies: whether or not walked at least once per day. Three significant personal and social variables identified by bivariate tests were entered as the first block.
Model 1 was the result of stepwise modeling testing significant site features including no GIS variables.
Model 2 was the results of stepwise modeling which tested significant neighborhood features including no GIS variable.
Model 3 was the results of stepwise modeling which tested significant neighborhood features including GIS variables.
Model 4 was the result of the stepwise modeling testing both significant site and neighborhood features including GIS variables.
*: p<=0.05; **: p<=0.01; ***: p<=0.001. ES: Site-level environments. EN: Neighborhood environments.

Table 9: Likelihood of Walking in Neighborhoods at Least Ten Minutes per Occurrence

	Variables in the	M1: R^2=54.6% N=61 OR (CI)	M2: R^2= 50.2% N=110 OR (CI)	M3: R^2=62% N=61 OR(CI)	M4: R^2=65.1% N=61 OR (CI)
P+S	**1. Self-estimated ability to walk 1mile**	6.18 (2.20, 17.34)***	3.43 (1.78, 6.61)***	5.35 (1.82, 15.74)*	7.78 (2.34, 25.89)***
	2. Previous health	.52 (.18, 1.49)	1.11 (.58, 2.12)	.57 (.18, 1.75)	.43 (.12, 1.48)
	3. Neighborhood social cohesion	4.54 (1.86, 23.93)	1.60 (.59, 4.37)	5.42 (1.02, 28.75)*	6.56 (.85, 50.50)
ES	***1. Lot type (Corner lot or not) – GIS var.***	7.49 (1.42, 39.47)*			12.88 (1.48, 112.42)*
EN	**1. Number of walking destinations**		3.12 (1.13, 8.59)*		
	2. Walking-route choices		2.40 (1.23, 4.66)*		
	3. Safety from Crime			10.62 (2.14, 52,70)**	14.19 (2.43, 83.01)**
	4. Road-side benches/ seating			7.48 (1.12, 49.95)*	

Note: Walking duration was measured as dichotomies: whether or not walked at least 10 minutes per occurrence. Three significant personal and social variables identified by bivariate tests were entered as the first block.
Model 1 was the result of stepwise modeling testing significant site features including a GIS variable: lot type.
Model 2 was the results of stepwise modeling which tested significant neighborhood features including no GIS variable.
Model 3 was the results of stepwise modeling which tested significant neighborhood features including GIS variables.
Model 4 was the result of the stepwise modeling testing both significant site and neighborhood features including GIS variables.
*: p<=0.05; **: p<=0.01; ***: p<=0.001. S: Site-level environments. N: Neighborhood environments.

Significant Site-level Environmental Variables

Corner Lot

Older adults who lived on corner lots were more likely to walk at least 10 minutes per occurrence than older adults who lived on interior lots.

Lot Walkability and Landscaping

The higher the lot walkability perceived by older adults, the more likely they walked in neighborhoods at least once per day and ten minutes per occurrence. The higher the levels of lot landscaping, the more likely older adults walked in neighborhoods at least once per day.

Pleasant Indoor Sunshine and Window View

The higher the levels of pleasant indoor sunshine and window view, the more likely older adults walked in neighborhoods at least once per day and ten minutes per occurrence.

No significant association was found between older adults' neighborhood walking and either of lot size/ coverage/paving, number of residential units on the residential site/lot, year built, building/street orientation, building type/size/height, indoor-outdoor structures, average building setback from streets, average width of side-areas, presence of transitional areas, number of connecting paths at the site level, and distance between home and the nearest street intersection.

Significant Neighborhood Environmental Variables

Walking Destinations: The number of walking destinations reported by older adults regarding their neighborhoods was positively related to both the frequency and duration of their neighborhood walking per occurrence. In addition, the number of neighborhood walking destinations was positively associated with the number of utilitarian facilities and the size of areas occupied by roads within a ½ mile radius of home. The number of walking destinations was also found to be positively associated with the distance between home the nearest utilitarian facility and negatively associated with the distance between home and the nearest healthcare facility (Table 10). Furthermore, Older adults who lived close to drug stores were more likely to walk at least 10 minutes per occurrence.

Table 10: Bivariate Correlates of Report Walking Destinations

	Significant GIS variables identified by using Fishers' exact tests	P value	Spearman Correlation
GIS var.	*1. Areas occupied by roads within a ½ mile radius of home*	.006	.04
	2. Number of utilitarian facilities within a ½ mile radius of home	.042	.065
	3. Distance between home and the nearest utilitarian facility.	.015	-.27
	4. Distance between home and the nearest healthcare facility	.011	.24

Note: Number of walking destinations was measured as dichotomies: whether or not had at least one. All variables were significant in 2-side tests.

Street Networks and Pedestrian Facilities

The more the walking-route choices, the higher the levels of neighborhood walking older adults engaged in. Levels of walking-route choices were positively related to both the frequency and duration of older adults' neighborhood walking per occurrence. Additionally, the more the roads within a ½ mile radius of home, the more likely older adults walked in neighborhoods at least once per day. Furthermore, the higher the usability of sidewalks in neighborhoods, the more likely older adults walked in neighborhoods at least 10 minutes per occurrence. The presence of road-side benches or seating was positively related to both the frequency and duration of older adults' neighborhood walking per occurrence.

Neighborhood Interest

The more the interesting things to see while walking in neighborhoods, the more likely older adults walked in neighborhoods at least once per day and 10 minutes per occurrence. Levels of neighborhood interest were also found to be positively associated with the number of self-report walking destinations and levels of walking-route choices ($p<0.01$).

Neighborhood Safety and Lighting Systems

The higher the levels of neighborhood safety perceived by older adults, the more likely older adults walked in neighborhoods at least once per day and 10 minutes per occurrence. Lighting systems in neighborhoods were also positively related to both the walking frequency and duration.

No significant association was found between older adults' neighborhood walking and either of numbers of utilitarian facilities within a ¼ mile / 1 mile / 2 mile radius of home, distances between home and the nearest park/ bank/ food facility, and areas occupied by roads within a ¼ mile /1 mile / 2 mile radius of home. The number of utilitarian facilities and the size of areas occupied by roads with a ½ mile radius of home were related to older adults' walking in the neighborhood.

Significant Personal and Social Variables

Levels of self-estimated ability to walk one mile, self-reported previous health, and neighborhood social cohesion were positively associated with both the frequency and duration of older adults' neighborhood walking per occurrence. No significant association was found between older adults' neighborhood walking and either of their age, marriage status, levels of education, income, received mobility support, types of living arrangement, longevity-in-place in previous community dwellings before moving to senior-living facilities, and years of facility stay.

The descriptions of walking variables, significant personal, social, and environmental variables at the site and neighborhood levels can be viewed in Table 11.

Table 11: Description of Significant Variables

	Significant variables identified by using Fisher's exact tests	Coding	%
Walking	1. Walking frequency	11: less than once per day 12: at least once per day	46.5% 53.5%
	2. Walking duration per occurrence	11: less than 10 minutes per occurrence 12: at least 10 minutes per occurrence	43.9% 56.1%
Personal / Social	1. Self-estimated ability to walk 1mile	11: strongly disagree 12: somewhat disagree or agree 13: strongly agree	35.1% 26.3% 37.7%
	2. Previous health	11: good or lower 12: very good 13: excellent	32.5% 36.0% 31.5%
	3. Neighborhood social cohesion	11: score was 3.6 out of 4 or lower. 12: score was higher than 3.61 out of 4.	52.2% 47.8%
Environment - Site	1. Pleasant indoor sunshine	11: not strongly agree with 'my room had pleasant sunshine.' 12: strongly agree	33.3% 66.7%
	2. Good window-view	11: not strongly agree with 'my room had good window view.' 12: strongly agree	28.8% 71.2%
	3. Lot walkability	11: not strongly agree with 'I had places to walk on the lot.' 12: strongly agree	42.5% 57.5%
	4. Lot landscaping	11: not strongly agree with 'It was well landscaped.' 12: strongly agree	23.1% 76.9%
	5. Lot type (Corner lot or not)- GIS var.	0: not a corner lot 1: corner lot	65.6% 34.4%
Environment - Neighborhood	1. Number of walking destinations	11: no neighborhood walking destination 12: at least one neighborhood walking destination or more.	54.4% 45.6%
	2. Walking-route choices	11: strongly disagree with 'I can choose different walkways.' 12: somewhat disagree or agree 13: strongly agree	24.6% 36.8% 38.6%
	3. Safety from Crime	11: not strongly agree 12: strongly agree with 'I was not bothered by the fair of crime.'	50% 50%
	4. Lighting systems	11: not strongly agree 12: strongly agree with 'Neighborhood streets were well-lit at night.'	42.1% 57.9%
	5. Traffic	11: not strongly agree 12: strongly agree with 'I was not bothered by the street traffic.'	47.4% 52.6%
	6. Neighborhood interest - interesting things to see while walking	11: strongly disagree 12: somewhat disagree or agree 13: strongly agree with 'I could look at interesting things while walking there.'	31.6% 29.8% 38.6%
	7. Road-side benches/ seats	11: not strongly agree 12: strongly agree with 'Along the walkways, there were usable benches or seats.'	67.5% 32.5%
	8. Usable sidewalks	11: strongly disagree 12: somewhat disagree or agree 13: strongly agree with 'There were sidewalks I could use on most of the streets.'	28.9% 26.3% 44.7%
	9. Areas occupied by roads within a ½ mile radius of home – GIS variable measured in30x30 square feet.	11: area sizes ranged from 1869 to 2463 in 30x30 square feet. 12: area sizes ranged from 2464 to 3505 in 30x30 square feet. 13: area sizes ranged from 3506 to 4104 in 30x30 square feet. 14: area sizes ranged from 4105 to 4811 in 30x30 square feet. 15: area sizes ranged from 4812 to 5230 in 30x30 square feet. 16: area sizes ranged from 5231 to 6811 in 30x30 square feet.	9.8% 14.8% 24.6% 24.6% 14.8% 11.5%
	10. Distance between home and the nearest drugstore – GIS variable measured in100 feet.	11: distances ranged from 401 to 1100 feet. 12: distances ranged from 1101 to 3000 feet. 13: distances ranged from 3001 to 4400 feet. 14: distances ranged from 4401 to 6100 feet. 15: distances ranged from 6101to 7600 feet. 16: distances ranged from 7601 to 16500 feet.	9.8% 16.4% 23% 24.6% 16.4% 9.8%

Table 11 Continued

Significant variables identified by using Fisher's exact tests	Coding	%
11. Distance between home and the nearest utilitarian facility – GIS variable measured in100 feet.	11: distances ranged from 90 to 300 feet.	9.8%
	12: distances ranged from 301 to 500 feet.	14.8%
	13: distances ranged from 501 to 1000 feet.	24.6%
	14: distances ranged from 1001 to 1800 feet.	24.6%
	15: distances ranged from 1801to 2400 feet.	16.4%
	16: distances ranged from 2401 to 4300 feet.	9.8%
12. Distance between home and the nearest healthcare facility – GIS variable measured in100 feet.	11: distances ranged from 501 to 1600 feet.	9.8%
	12: distances ranged from 1601 to 3600 feet.	14.8%
	13: distances ranged from 3601 to 6600 feet.	24.6%
	14: distances ranged from 6601 to 9400 feet.	23%
	15: distances ranged from 9401to 11500 feet.	18%
	16: distances ranged from 11501 to 18700 feet.	9.8%
13. Number of utilitarian facilities within a ½ mile radius of home	11: none.	9.8%
	12: 1 or 2 utilitarian facilities.	14.8%
	13: 3 to 9 utilitarian facilities.	27.9%
	14: 10 to 22 utilitarian facilities.	23%
	15: 23 to 32 utilitarian facilities.	14.8%
	16: 33 to 86 utilitarian facilities.	9.8%

Note: GIS-based variables are italic. Distances were measured in 100-feet and recoded in six levels. Areas were measured in 30x30 Square Ft and recoded in six levels.

THE ENVIRONMENT AND YARD ACTIVITY ANALYSIS

Data used in the environment and yard activity analysis were collected in Houston, TX, by using survey and GIS instruments. A total of 114 assisted-living older adults joined the survey and answered questions regarding their walking behaviors and characteristics of their residential site environments before moving to assisted-living facilities. Based on the availability of data, a subset of 61 participants' residential environments was further assessed using GIS. To estimate older adults' yard activities as a function of site environments, multivariate regression analyses were used. Including personal factors and social factors in modeling, the frequency and/or the duration per occurrence of yard activities were positively associated with three site features ($p<0.05$): transitional-areas, connecting-paths, and levels of pleasant indoor sunshine. Higher site walkability and less yard paving were also associated with higher levels of yard activities ($p<0.03$).

SIGNIFICANT ENVIRONMENTAL VARIABLES

Levels of perceived site walkability, rated by older adults about their former residential sites, were significantly higher among active older adults who had engaged in yard activities at least one time per day or at least ten minutes per occurrence than among the less active older adults ($p<0.02$). Older adults who had engaged in yard activities at least ten minutes per occurrence were less likely to report their residential site environments being paved than the counterpart ($p<0.03$) (Figure 14).

Along with personal and social variables, site variables could predict 37% of the frequency of older adults' yard activities ($p<0.1$). Personal and social variables could predict 28% of the duration of older adults' yard activities per occurrence ($p<0.05$), and the power of prediction was significantly increased to 34% after adding the variable of sunshine in modeling ($p<0.05$). Levels of pleasant indoor sunshine were positively related to the duration of older adults' yard activities per occurrence ($p<0.05$, Table 12).

In full models entered with all test variables (i.e., personal & social, site, and building), the presence of transitional-areas on site was positively related to the duration of older adults' yard activities per occurrence (Table 13: $p<0.05$). Without the variable of transitional-areas in full models, it was found that the sum of connecting-paths in residential site environments was positively associated with both the frequency (Table

14: $p<0.05$) and the duration of older adults' yard activities per occurrence (Table 15: $p<0.05$).

Figure 14: Yard Activities related to Perceived Site Walkability and Presence of Paving

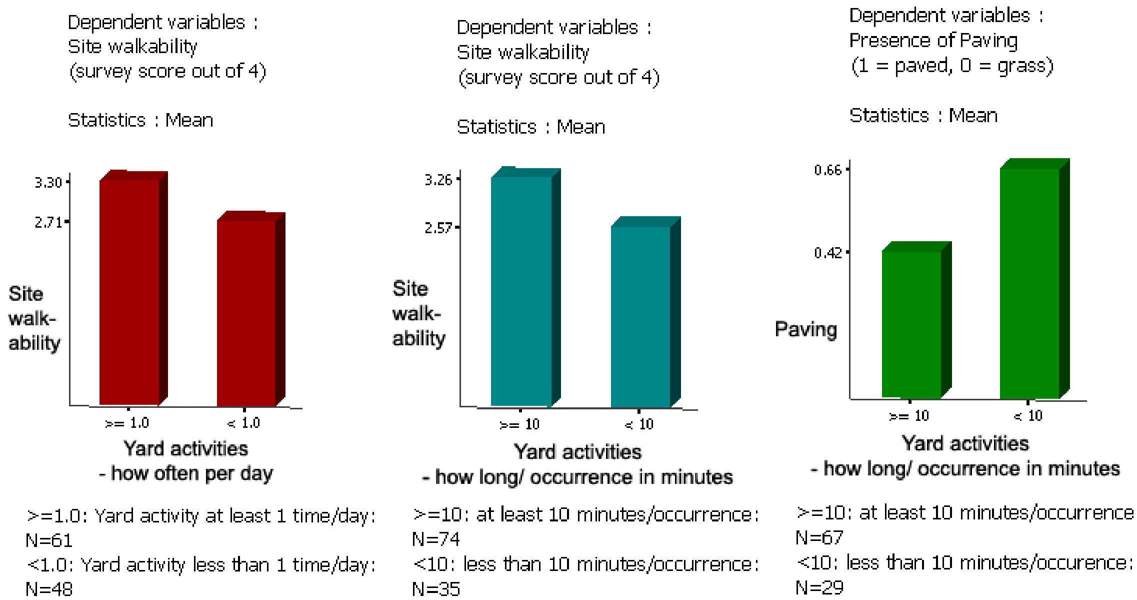


Table 12: Duration of Yard Activity Predicted by Personal & Social Variables and Indoor Sunshine

Predictors		Unstandardized Coefficients	Standardized Coefficients	Significance
	(Constant)	-7.978		.041
Personal & Social Factors	Age	.063	.227	.079
	Gender	-.073	-.013	.917
	IADL (a measure of functional competence)	.148	.059	.630
	Education	.173	.068	.593
	Building ownership	**2.058**	.419	**.002**
	Living arrangement	.534	.118	.353
	Neighborhood Crime	-.030	-.015	.905
Sunshine	**Pleasant indoor sunshine**	**.819**	.269	**.038**

The duration of yard activities was counted in ten-minute spans.

Table 13: Duration of Yard Activity Predicted by Study Variables

Predictors		Unstandardized Coefficients	Standardized Coefficients	Significance
	(Constant)	-11.942		.016
Personal & Social variables	**Age**	**.096**	.350	**.012**
	Gender	-.381	-.070	.601
	IADL (a measure of functional competence)	.390	.157	.205
	Education	.435	.172	.220
	Building ownership	**2.241**	.456	**.012**
	Living arrangement	.274	.060	.664
	Neighborhood crime	.285	.145	.320
Site variables	Building setback from street	.012	.099	.477
	Sum of connecting-paths	.843	.260	.053
	Shading of tree canopies	-.269	-.117	.425
	Presence of transitional-areas	**1.201**	.268	**.040**
	Distance from site entrance to street intersection	-.001	-.121	.407
	Indoor-outdoor connections	-.146	-.061	.670
	Perceived walkability	-.226	-.127	.385
	Presence of paving	-.242	-.054	.695
Building variables	Building orientation toward sun	-.051	-.030	.830
	Building orientation toward frontage street	.793	.171	.237
	Height of building (# of stories)	-.596	-.167	.272
	Pleasant indoor sunshine	.630	.207	.164

Building orientation is represented by the long sides of building. The duration of yard activities was counted in ten-minute spans.

Table 14: Frequency of Yard Activity Predicted by Study Variables

Predictors		Unstandardized Coefficients	Standardized Coefficients	Significance
	(Constant)	-.368		.878
Personal & Social variables	Age	.002	.017	.909
	Gender	-.374	-.149	.316
	IADL (a measure of functional competence)	.000	.000	.999
	Education	**-.415**	-.354	**.023**
	Building ownership	.195	.086	.653
	Living arrangement	.160	.076	.621
	Neighborhood Crime	.015	.017	.918
Site variables	Building setback from street	-.008	-.133	.387
	Sum of connecting-paths	**.452**	.301	**.043**
	Shading of tree canopies	-.168	-.158	.329
	Indoor-outdoor connections	.186	.169	.292
	Perceived walkability	.201	.244	.134
	Presence of paving	-.352	-.169	.266
	Distance from site entrance to street intersection	.001	.171	.289
Building variables	Building orientation toward sun	-.130	-.167	.282
	Building orientation toward the frontage street	.586	.273	.090
	Height of building	-.060	-.037	.826
	Pleasant indoor sunshine	.335	.238	.143

Building orientation is represented by the long sides of building. The duration of yard activities was counted in ten-minute. The variable of transitional-areas was NOT included in predictors.

Table 15: Duration of Yard Activity Predicted by Study Variables

Predictors		Unstandardized Coefficients	Standardized Coefficients	Significance
	(Constant)	-10.235		.041
Personal & Social variables	**Age**	**.081**	.294	**.036**
	Gender	-.211	-.039	.780
	IADL (a measure of functional competence)	.328	.132	.304
	Education	.274	.108	.447
	Building ownership	**2.036**	.414	**.026**
	Living arrangement	.291	.064	.660
	Neighborhood Crime	.237	.121	.426
Site variables	Building setback from street	.013	.101	.486
	Sum of connecting-paths	**.919**	.284	**.044**
	Shading of tree canopies	-.181	-.079	.603
	Indoor-outdoor connections	-.188	-.079	.600
	Perceived walkability	-.218	-.122	.422
	Presence of paving	-.103	-.023	.873
	Distance from site entrance to street intersection	-.001	-.103	.499
Building variables	Building orientation toward sun	.007	.004	.978
	Building orientation toward frontage street	.690	.149	.322
	Height of building (# of stories)	-.614	-.172	.278
	Pleasant sunshine in rooms	.804	.265	.086

Building orientation is represented by the long sides of building. The duration of yard activities was counted in ten-minute spans. The variable of transitional-areas was NOT included in predictors.

Building type was significantly correlated with the height of building in number of stories ($p<0.01$) and not controlled in this study. There was no significant association between levels of yard activities and either of building size/ type/ height, parcel size, and lot coverage. Age and building ownership were positively related to the duration of yard activities per occurrence ($p<0.05$); participants in an older age who owned his or her previous residence were likely to have longer yard activities per occurrence than counterpart older adults. Older men reported higher levels of self-efficiency and environmental safety, and had more frequent yard activities than older women ($p<0.05$). Participants in lower education levels had engaged in yard activities more frequently than participants in higher education levels ($p<0.05$).

THE ENVIRONMENT & INDEPENDENT LIVING ANALYSIS

A total of 220 survey participants were recruited from eleven assisted-living facilities in Houston, College Station, Bryan, and Brenham, Texas (TX). According to the U. S. Census Bureau, Houston had 1,953,600 people as of 2000. College Station, Bryan, and Brenham are cities within a 100-mile radius of Houston. These cities had population ranging from 67,900 to 13,500 as of 2000. Based on their previous home addresses before moving to senior-living facilities, 170 out of 220 participants were found to live in Houston, College Station, Bryan, or Brenham, TX and included in the study. The rest participants lived in elsewhere and were not included in this study for further analysis, in order to control confounding variables such as local climates. The average age of the 170 participants was 85.2 years and their average facility stay was 2.5 years. The number of their years of living at home was 82.66 on average, with a range from 60 to 101. Participants' longevity-in-place in previous community dwellings before moving to senior-living facilities was 24.68 years on average. More than 70% of participants were female and 91% were non-Hispanic white.

Due to limited GIS data availability, a subset of 117 older adults' residential sites was studied with GIS measures. ANOVA analyses were conducted to investigate relationships between the factors and older adults' years of living at home. Canopy shading and semi-enclosed outdoor areas (e.g., side-yards) at the site level, and walking destinations in the neighborhood were found to positively influence older adults' years of living at home (p<0.05). The average years of living at home in older adults who had one of the features was three-years longer than their peers. No personal or social factor was found to be significant in relation to the years of living at home.

SIGNIFICANT VARIABLES

One-way ANOVA

By conducting one-way ANOVA, two site variables (the presence of canopy shading and half-open areas) and one neighborhood variable (the presence of walking destinations in the neighborhood) were found to be associated with older adults' years of living at home (p<0.05) (Table 16).

Table 16: Statistics for Years of Living at Home by Environmental Factors

	Significant variables identified by one-way ANOVA tests	Number	Mean	SD	Min	Max	F value	P value
Neigh.	1. Walking destinations in the neighborhood	167	82.65	7.571	60	101	5.837	.017
	No destination	104	81.57	7.849	60	101		
	At least one destination	63	84.44	6.773	68	99		
Site	2. Canopy shading on residential sites	142	82.75	7.752	60	101	4.853	.029
	Not shaded	38	80.41	8.379	60	96		
	Shaded	104	83.61	7.368	68	101		
	3. Transitional areas on residential sites – GIS var.	108	83.42	7.530	61	101	4.763	.031
	No transitional area	42	81.48	8.652	61	99		
	At least one transitional area	66	84.66	6.489	68	101		

Note: Site - Environments at the site level. Neigh - Environments at the neighborhood level.

The average years of living at home for older adults who had at least one walking destination in their neighborhoods was 2.87-year longer than their peers, who did not have neighborhood walking destination. The average years in older adults who had canopy shading on their residential sites/lots was 3.2-year longer than their peers whose sites/lots were not shaded. The average years in older adults who had half-open site areas was 3.18-year longer than their peers who had no half-open areas on the site. No personal or social factor was found to be significant in relation to the years of living at home.

Factorial ANOVA

Interactions among the variables of walking destinations, canopy shading, and half-open areas were considered to influence the years of living at home. The interaction effects were investigated by using a factorial ANOVA. Interactions between the variable of walking destinations and the variable of half-open areas were found to be significant in relation to the years. Interactions among the three variables were also found to be significant (Table 17). However, interactions between the variable of canopy shading and the two other variables were found to be un-significant.

Table 17: Tests of Between-subjects Effects on Years of Living at Home

Dependent Variable: Years of living at home

Source	Type III Sum of Squares	df	Mean Square	F value	P value
Walking destinations in the neighborhood*	304.994	1	304.994	5.604	.020
Canopy shading	1.001	1	1.001	.018	.892
Half-open areas *	273.660	1	273.660	5.029	.028
Walking destinations & Canopy shading	66.612	1	66.612	1.224	.272
Walking destinations & Half-open areas *	249.187	1	249.187	4.579	.035
Canopy shading & Half-open areas	5.297	1	5.297	.097	.756
Walking destinations & Canopy shading & Half-open areas *	227.634	1	227.634	4.183	.044

Note: R Squared = 0.170. The F test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Multivariate Logistic Modeling

In multivariate logistic modeling, the variable of half-open site areas was found to significantly influence older adults' years of living at home ($p<0.01$) (Table 18).

Table 18: Years of Living at Home Predicted by Environmental Variables

Variables entered in the models	Coefficients	CI	P value
1. Walking destinations in the neighborhood	3.102	-0.1 ~ 6.3	.057
2. Canopy shading on residential sites	.391	-3.5 ~ 4.3	.843
3. Half-open areas on residential sites**	4.467	1.18 ~ 7.75	.008

Note: R Squared = 0.105; Sample size = 108.

CHAPTER V

DISCUSSION

ENVIRONMENT AND NEIGHBORHOOD WALKING

Both site-level environments and neighborhood environments influenced older adults' neighborhood walking. Environmental features, such as pleasant indoor sunshine, window view, landscaping, and walking destinations, can promote older adults' neighborhood walking.

NEIGHBORHOOD ENVIRONMENTS

Based on the results of statistical analysis, areas traveled by survey participants by foot in their previous neighborhoods were within ½ mile of airline distance from home. Their walking frequency was significantly related to levels of street networks within ½ mile of airline distance from home. The number of their walking destinations was significantly related to the number and types of daily-life facilities within ½ mile of airline distance from home. One-quarter mile is the distance that average Americans would rather walk than drive (Atash, 1994). Older adults may walk longer distances in neighborhoods than young adults, as they typically have more free time and their ability to drive diminishes.

If older adults had walking destinations in neighborhoods, they walked more and reported high levels of neighborhood interest. Based on the results of previous research, popular walking destinations among older adults are post offices, drugstores, restaurants, banks, grocery stores, convenience stores, and malls (Kealey et al., 2005; King et al., 2003; Michael et al., 2006). In this study, the proximity to drugstores was found to promote older adults' neighborhood walking duration. In addition, the more daily-life facilities within ½ mile of airline distance from home and the shorter the distance between home and the nearest daily-life facility, the more likely older adults reported having at least one walking destination. In contrast, older adults living close to hospitals or medical centers were less likely to report having at least one neighborhood walking destination. These phenomena may be related to different psychological influences on older adults of drugstores or other daily-life facilities compared to hospitals or medical centers. As older adults' ability to drive tends to decline with age, they may choose to walk to drugstores and other daily-life facilities for daily services. The number of walking destinations in neighborhoods is closely related to measures of neighborhood location, land-use mix, residential density, and neighborhood design orientations.

If older adults had choices for walking-routes in neighborhoods, they reported high levels of neighborhood interest and walked more. Levels of walking-route choices are influenced by the continuity of streets and sidewalks. High levels of street connectivity (e.g., more four-way street intersections and fewer dead-end) promote neighborhood walking and can be created by grid street connectivity (Boer et al., 2007). Based on the results of this study, the size of areas occupied by roads within ½ mile of airline distance from home influenced the duration of older adults' neighborhood walking per occurrence. The larger the areas occupied by roads, the more route choices people typically have. In addition, sidewalks make neighborhood walking convenient and safe.

Road-side benches or seating also support older adults' neighborhood walking by allowing them opportunities to rest during the walking.

Neighborhood safety from traffic and crime is a critical concern among older adults walking in neighborhoods. Improving lighting systems in neighborhoods is expected to increase the perceived safety from crime.

SITE-LEVEL ENVIRONMENTS

Older adults who lived on corner lots engaged in higher levels of neighborhood walking than older adults who lived on interior lots. One possible explanation of this finding is that elderly residents on corner lots are more likely to view active streets and active street view motivates them to walk outside. Another consideration is individuals who purchased property on corner lots may be more active or extroverted than those who select interior lots. Further research is needed to fully understand this association.

Older adults who lived in well-landscaped site-level environments walked more frequently in their neighborhoods. In addition, high levels of lot walkability promoted both their neighborhood walking frequency and duration per occurrence. High-quality landscaping helps make people's outdoor experience enjoyable. Walkable environments make walking convenient. If older adults perceived that site-level environments were enjoyable and walkable, they were more likely to go outdoors and walked in neighborhoods. As many older adults spend the most of their day at home, whether or not site-level environments can motivate them to go outdoors influences their engagement in neighborhood walking.

Older adults who perceived high levels of pleasant sunshine and window view in their rooms walked more in neighborhoods. Levels of pleasant indoor sunshine perceived by older adults in their rooms depend on building orientations toward the sun and the specific locations of their rooms in the buildings. North-south facing elevations are suggested for residential buildings in the northern hemisphere, to ensure levels of pleasant indoor sunshine and to introduce more heat in during winter months and out during summer months, compared to east-west facing elevations (Alexander, 1977; Wang et al., 2006). Additionally, east-facing is preferred to west-facing for buildings for older adults, as older adults generally wake up earlier in mornings. Enjoying pleasant sunshine in rooms may be the most readily available method for older adults to access nature, as most of them spend most of their day in the interior due to declined health and mobility. Rooms for older adults should be placed along the south and/or east edge of buildings in the northern hemisphere (Wang et al., 2006). Furthermore, an appropriate distance should be maintained between the north and/or west sides of existing structures and the proposed building to reduce the opportunity that south and/or east-facing windows of the proposed building are shaded by existing structures during winter months (Wang et al., 2006). In context of environmental surroundings, window views can be created by orienting windows to active streets near home and/or developing high-quality landscaping on the site itself. Window view should be positive. Levels of fitness of views can be determined at the individual level. Negative window view such as views of garbage areas or discarded structures should be screened by using view-obscuring structures such as fences or walls.

LIMITATIONS OF STUDY

Participants' answers about their previous residential environments and neighborhood walking may have recall bias as they have already moved out of their previous environment. However, researcher found that older adults' long-term recall was reliable (Friedman et al., 1996; Umming et al., 1994). Additionally, in this study, the average length of participants' longevity-in-place in their previous neighborhoods was 10-times longer than their facility stay (21.8 Vs 2.4 years) and all participants had good cognitive skills, which were confirmed by their caregivers.

As 82% of participants in this study were non-Hispanic White women age 65 and older, the neighborhood walking of older White women may be more well-predicted by the study results than those of older men and those of other races. In addition, the GIS environmental analysis in this study focused on a high-density area: Houston, TX; the study results need to be further tested in low-density areas. The power of this study could be enhanced if GIS data on all sample sites and neighborhoods were available. Future research on older adults' neighborhood walking will enlarge the sample size and collect higher-quality GIS data. Additionally, possible self-selection bias on this environment-walking research can be reduced if more personal factors are included. To clarify causal relationships between older adults' environments and their walking, longitude studies may be needed.

<u>ENVIRONMENT AND YARD ACTIVITIES</u>

The following discussion utilizes the hypotheses and findings from this study to generate preliminary guidelines for designing residential sites for older adults. These design guidelines can be used as hypotheses to be tested in future studies.

ATTRACTIVE OUTDOOR ENVIRONMENTS

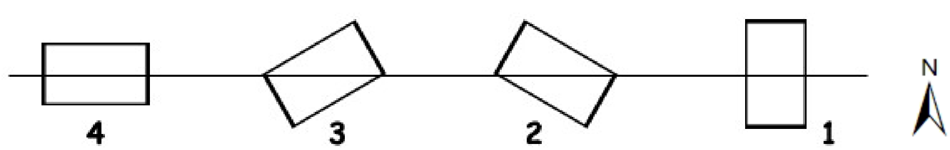
An attractive environment can be achieved by promoting environmental motivators on and around the site; these motivators could be expressed by *pleasant indoor sunshine* and good *window-views* perceived from the indoors, and addressed by fine-grained spaces with *transitional-areas* and inviting *yard landscap*ing in the outdoor settings. These could be generated by applying appropriate building orientation, a ground plan in a multi-edge shape (Figure 7 – B), and proper placement of the main building in harmony with accessory buildings and existing environments (Figure 7 – C).

Levels of *pleasant indoor sunshine* perceived by older adults was significantly related to the duration of their outdoor yard activities per occurrence, according to the statistical analyses in this study. Making a useful contribution to interior luminance, daylighting may be more comfortable than electronic lighting and evoke the feeling of 'biophilia.' In the northern hemisphere, the sun shines on the east side of building at a low altitude in the morning, on the south side of building at a high altitude in the midday, and on the west side of building at a low altitude in the afternoon. Strong afternoon sunshine often comes with the highest temperature of the day and causes glare indoors. Many older adults have early-bird lifestyles, which may relate to the biological clock in aging bodies.

To maximize pleasant indoor sunshine in the morning and midday, and to minimize un-pleasant indoor glare in the afternoon, north-south facing orientations are suggested for residential buildings for older adults, with a preference for somewhat east-facing to somewhat west-facing.

Building orientations could be classified into quartiles, with the 4th and 1st used to represent the highest and lowest level of the long sides of building facing north-south (as the long axis of building running east-west), and with a preference for somewhat east-facing to somewhat west-facing (Figure 15). Among the 57 sample sites analyzed in GIS in this study, 29 of them had main buildings facing north-south or close to it as scored in 4 or 3. No significant relationship was found between building orientations toward sun and levels of pleasant sunshine perceived by study participants in rooms; the relationship may be impeded by the specific locations of their rooms in the buildings. Placing rooms of older adults along the south edge of building is suggested. However, participants who lived in buildings classified as 4 or 3 valued their yard landscaping significantly higher than other participants ($p<=0.05$), and engaged in 31-minute yard activities per occurrence on average, given others had the average duration of 26 minutes.

Figure 15: Classification of Building Orientations



To maximize pleasant indoor sunshine in the northern hemisphere, a distance should be maintained from the north side of an adjacent structure to the proposed building. Assuming the sun enters at a solar-altitude angle of 45 degree for most of the day, the distance should be at least the height of the adjacent structure. Applying appropriate building overhangs to protect the interior from intense sunshine during summer months also need to be considered. Creating ‘south facing outdoors’ (Alexander, 1977) in harmony with the shadow caused by the proposed building should be addressed when making the decision of building placement on the site, for the sake of sunny places and yard landscaping. According to local climates, appropriately placed canopy trees can provide summer shading, increase levels of sunshine received during winter months, and reduce wind. Trees are commonly thought to be good for yard activities of older adults, but there was no significant relationship found between levels of tree canopy on residential sites and levels of older adults’ yard activities in this study. Some canopy trees may not be appropriately placed in harmony with buildings; inappropriately placed trees may screen pleasant indoor sunshine or block window-views.

Window-views play a very important role in sedentary older adults’ daily life. Older adults often stay indoors near the window so they can look outside. Levels of good window-views reported by study participants were found to be significantly associated with perceptions of pleasant indoor sunshine. Participants who had enjoyed more good window-views were likely to perceive more pleasant indoor sunshine.

For sedentary older adults, good window-views to the outdoors might offer psychological escape from the indoors and encourage them to go outdoors. Outdoor residential site environments should continuously maintain older adults' visual and sensory attention, and encourage walking, gardening, or yard work. According to the statistical analyses in this study, the presence of *transitional-areas* in residential site environments was significantly related to the duration of older adults' yard activities per occurrence; the average width of side-areas was significantly related to the presence of transitional-areas. The presence of transitional-areas could appropriately improve the complexity of site environments, along with *yard landscaping*.

Complexity should be considered as a means of increasing the attractiveness of site environments. Different from "coming/ going activities," such as neighborhood walking and shopping, most physical activities on residential sites of older adults are "staying-activities." The speed with which older adults move in the yard or on the property is slow and they have a lot of time to process detail. Similar to the complexity of streetscapes, which can be expressed by the number of differences noticeable to pedestrians per unit time (Rapoport, 1987), the complexity of site environments could be expressed by the number of differences noticeable to older adults per unit time while staying indoors near the window or outdoors on the site. The noticeable differences in residential site environments could be classified into three levels:

Building level: Details of building façade (e.g., colors, materials, protruded architectural parts and recesses) and building configuration (e.g., transitional parts: porches and balconies) could refine the building and also improve the visual texture of environments.

Site level: On the site, the ground plan of building determines the internal outline of site environments. Appropriate ground plans of building could develop inviting transitional-areas. Compared with building ground plans in shapes of a single rectangle or close to it (Figure 16-A, Figure 17-A, Figure 18-A,), building ground plans in 'L', 'I', or other multi-edge shapes, may develop space changes at multiple levels and form transitional-areas (Figure 16-B, Figure 17-B, Figure 18-B,). Carefully placing an accessory building or structure in harmony with the main building could also compose transitional-areas (Figure 16-C). Transitional building parts (e.g., porches) linking the indoors and outdoors at the ground level could also refine the texture of space and create transitional-areas (Figure 12-C). Yard landscaping with seasonal plants could improve the variety in the outdoor settings and allow older adults to access nature.

Site surrounding level: Interesting views could be borrowed from site surroundings, such as nearby active streets or nature views. To enhance the optical transparency of window-views or site-views, the long sides of buildings may be parallel to active streets or face views. In addition to complexity, the fitness of window-views and site-views needs to be considered. From the perspective of environments for health, these views should be positive distractions to older adults. Negative distractions should be minimized, such as garbage areas, discarded structures, and depressing views. View-obscuring fences or solid walls of decorative brick may be used to screen negative distraction.

Figure 16: Comparison of Ground Plans on Interior Lots

FUNCTIONAL OUTDOOR ENVIRONMENTS

Residential site environments should be senior-friendly and have features convenient to older adults' yard activities, such as walkable areas, continuous walking paths, and good areas for gardening. These could be developed by placing the building properly on the site, applying a relative slim ground plan along the long axis of site, making a transparent building part or other mid-spaces connecting the front and back areas around the building, and keeping some sunny areas unpaved for gardening.

Walkable areas in residential site environments support yard activities. Levels of perceived walkability in the yard or on the property, rated by participants regarding their former residential sites, were significantly higher among older adults who had engaged in yard activities at least one time per day or at least ten minutes per occurrence than among the counterpart older adults ($p<0.02$). Participants who reported high levels of site walkability also reported high levels of indoor-outdoor connections ($p<0.05$). Compared to indoor-outdoor steps, 'none-needed' and ramps may help older adults traverse the site. Levels of perceived site walkability also positively related to levels of yard landscaping rated by study participants. Having high-quality landscaping in the yard or on the property may encourage people to walk and be active in these environments, and make yard walking and other yard activities enjoyable; people may then feel the environments is walkable and engage in activities there. Large lots and low lot coverages (defined as the ratio of the total lot area covered by structures) were assumed to provide more areas for walking, but parcel sizes and lot coverages were not significantly associated with levels of perceived site walkability, reported by participants in this study.

The *sum of connecting-paths* around the building, measured in GIS by analyzing parcel data and satellite photos, was positively associated with the duration of older adults' yard activities per occurrence ($p < 0.04$). Connecting-paths link separated areas around the building, and in turn allow older adults opportunities to pass different outdoor spaces while traversing the site. If there is no connecting-path around the building, areas in front of the building are separated from the back; indoor areas then become part of outdoor walking routes on the site and the continuity of yard walking trips could be reduced. One connecting-path could link separated areas around the building and two connecting-paths could make a continuous walking loop on the site. To save side-areas along the short axis of site for connecting-paths, building ground plans in relatively slim shapes along the long axis of site may be considered (Figure 19).

Side-porches are suggested to improve the attractiveness of side-areas and potentially encourage the development of connecting-paths. Transparent porches or other mid-spaces linking separated buildings or building parts are also suggested to not only develop transitional-areas, but also join separated outdoor spaces around the building (Figure 12- C).

Figure 17: Sample Sites of Single-family Houses

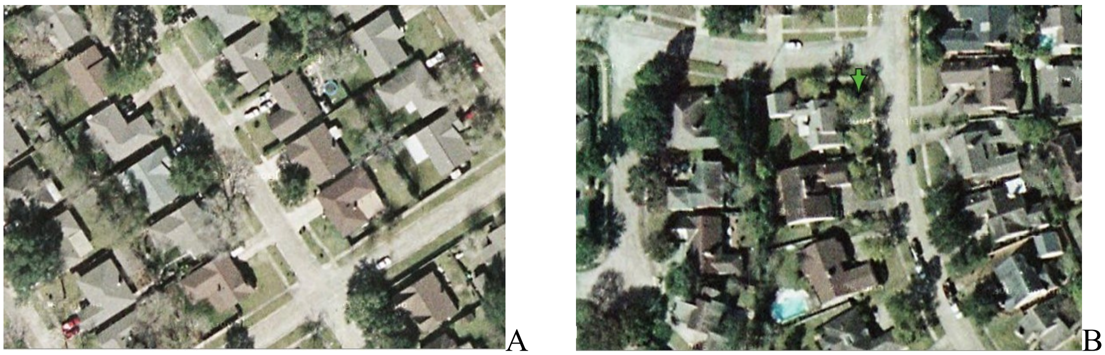


Figure 18: Sample Sites of Apartment Buildings/ Condominiums

Figure 19: Comparison of Ground Plans on Corner Lots

The type of corner lot, the lot size, and the average width of side-areas were positively correlated with the sum of connecting-paths ($p<0.01$). Buildings on corner lots set back from streets in more than one orientation; some side-areas are generated along streets. Large lots are more likely to have spaces for connecting-paths than small lots. Wide side-areas around the building could be the places supporting connecting-paths.

Un-paved areas in the yard or on the property may provide older adults opportunities to do gardening if they wish. Fifty-one percent of participants did gardening on their former residential sites. In the active group of older adults, who had engaged in yard activities at least ten minutes per occurrence, people were less likely to report the presence of paved areas on their residential sites than people in the counterpart group ($p<0.03$). While unpaved site areas may be used for gardening, walking paths usually need to be paved, for the sake of walking safety.

There was no significant relationship between building setbacks and older adults' yard activities; the relationship may be impeded by the location of parking areas on residential sites. Parking areas usually take most of the front areas of site near the frontage street; these areas are developed by building setbacks. The front areas may look like part of a parking lot and the environmental quality is reduced. Interesting view-obscuring fences or short walls could be used to screen parking areas.

SAFE OUTDOOR ENVIRONMENTS

The distance from site entrance to the nearest street intersection was not significantly related to levels of older adults' yard activities. The reported environmental safety from traffic and crime was relatively high. The average level was 3.23 out of 4 for traffic safety, and 3.04 out of 4 for crime safety, where 4 represented the highest level of safety. In the surveys, participants seemed to feel confident about their security on former residential sites. Most participants were in good health situations when living in their previous residences. Reported levels of previous IADLs (a measure of functional competence) had a mean of 3.4 out of 4, where 4 represented the highest level of competence.

LIMITATIONS OF STUDY

Because the majority of participants in this study were women (90 out of 110) and the majority of sample sites were single-family homes (72 out of 110), the yard activities of older women living in single-family houses may be better predicted by the study results than those of older men and those of older adults living in other types of residences. Limited by the availability and quality of GIS data, 53 out of the 110 sample sites did not have objective measures of environmental features and certain building features could not be analyzed in GIS. Some satellite photos were not in high resolution and data on building footprints may have minor errors. The power of this study could be enhanced if the quality of GIS data was higher and the sample size was larger. Older adults' reports regarding their previous residential sites and yard activities may need to be retested, since they had already moved away from the sites and may have forgotten some details.

Participants' answers about their previous residential environments and neighborhood walking may have recall bias as they had already moved out of the environments, although older adults' long-term recall had been found to be reliable (Friedman et al., 1996; Umming et al., 1994). However, in this study, the average length of participants' longevity-in-place in their previous neighborhoods was 10-times longer than their facility stay (21.8 Vs 2.4 years) and all participants had good cognitive skills which were confirmed by their caregivers. As 82% of participants in this study were non-Hispanic White women age 65 and older, the neighborhood walking of older White women may be more well-predicted by the study results than those of older men and those of other ethnicities. In addition, the GIS environmental analysis in this study focused on a high-density area: Houston, TX; the study results need to be further tested in low-density areas. The power of this study could be enhanced if GIS data on all sample sites and neighborhoods were available. Future research on older adults' neighborhood walking will enlarge the sample size and collect higher-quality GIS data.

ENVIRONMENT AND YEARS OF LIVING AT HOME

Helping older adults remain at their own homes contributes to age-in-place and reduces the need for institutional senior services. Older adults spend most of their day at home. Significant residential environment features, at the site and neighborhood levels, should be identified and used to promote older adults' years of living at home.

NEIGHBORHOOD ENVIRONMENTS

Having walking destinations in the neighborhood was found to be associated with longer years of living at home, compared to having no walking destination. Neighborhood walking is one of the most popular physical activities among older adults (DHHS, 1996). Physical activity benefits health and utilitarian physical activity (e.g., walking to and from transit stations) is also considered to help older adults remain the ability to access daily services (Wang et al., 2009). Compared to community-dwelling older adults in suburban areas, urban older adults in the community at-large were found to be more than twice likely to walk to utilitarian facilities for daily services and their longevity-in-place were 11-years longer (Patterson et al., 2004). Having destinations to walk to in neighborhoods encourages older adults to engage in the physical activity for health and daily services. Older adults may thereby have more years of living at home.

Popular walking destinations reported by participants in this study included post offices, restaurants, banks, convenience stores, groceries and malls, and were similar to findings of previous research (Kealey et al., 2005; King et al., 2003; Michael et al., 2006). The presence of walking destinations in the neighborhood is considered to be influenced by issues of land-use mix, population density, residential density, and neighborhood design orientations.

SITE-LEVEL ENVIRONMENTS

Having canopy shading and half-open areas in residential site environments may improve the environmental attractiveness and motivate older adults to go outdoors.

Outdoor access has been found to benefit health by increasing the opportunities to access nature and reducing the risk of depression (Rodiek, 2002; Ulrich, 1999). Approximately 15% of older adults in the USA have depressive symptoms (FIFARS, 2004). Depression may lead to mental problems in a later time and finally result in the relocation from home to senior-living facilities. Accessing pleasant nearby-nature, such as canopy trees on residential sites, helps reduce the risks.

In addition, half-open site areas have been found to positively influence older adults' physical activity on the site (Wang et al., 2006). Given the health benefits of physical activity, half-open areas encourage older adults to engage in healthy behavior and extend the years of living at home. Furthermore, as older adults' competence tends to decline with age, they may like to seek higher-levels of protection from nearby environments. Having half-open areas on residential sites develop smooth spatial transitions between private and public spaces, and provide older adults opportunities to get used to environmental changes if going outside. Having half-open areas on residential sites may also meet older adults' psychological need for seeing and not being seen (Appleton, 1975). According to Appleton's prospect-refuge theory, if an environment has some characteristics ensuring the observer's ability to see without being seen, it can be an intermediate instrument to satisfy his or her biological needs of survival, leading to the aesthetic pleasure. Half-open areas can act as signs or symbols of prospect and refuge, which may be associated with perceived opportunities and safety necessary for daily life.

LIMITATIONS OF STUDY

Although survey participants in this study had already moved out their previous residential sites and neighborhoods, their recall regarding the environments was considered to be reliable based on findings of previous research (Friedman et al., 1996; Umming et al., 1994). The period of time during which participants lived in their previous community dwellings was 24.68 years on average, which was approximately 10-times longer than their facility stay (2.5 years on average). Their cognitive skills and ability to answer survey questions were confirmed by their caregivers.

As 81% of participants in this study were non-Hispanic White women, the years of living at home in older White women may be more accurately predicted by the study results than those of older men and those of other ethnicities. In addition, GIS environmental analysis in this study focused on site-level environments. The power of this study could be enhanced if GIS data on all sample sites and neighborhoods were available. Enlarged sample size and higher-quality GIS data will be needed in future research on the impact of years of living at home.

CHAPTER VI

CONCLUSION

SIGNIFICANT ENVIRONMENTS

Both site-level environments and neighborhood environments influenced older adults' neighborhood walking. Environmental features, such as landscaping on residential sites and walking destinations in the neighborhood, can promote older adults' neighborhood walking.

Site-level environments were related to older adults' physical activities on the site. Several features, including pleasant indoor sunshine perceived in the interior and interesting transitional-areas and convenient walkways on the site, may increase older adults' yard activities.

Both site-level environments and neighborhood environments influenced older adults' years of living at home. Amenities such as walking destinations in the neighborhood, and transitional-areas and canopy shading on residential sites, may help older adults live at their own homes longer, leading to higher levels of life satisfaction and reduced demands on society for senior services.

Future research should incorporate a larger, more gender and ethnically diverse sample size, and use higher-quality GIS data. Field trips to selected sample sites should be made to collect first-hand data on the environments and verify the quality of relevant GIS data. In addition to analyzing site and neighborhood plans, environmental elevations should be studied in relation to their impact on older adults' physical activity and years of living at home.

RESEARCH INSTRUMENTS

Survey items and GIS tools were used to investigate residential site environments and neighborhood environments in this research. Most instruments used to investigate neighborhood environments were developed in previous research by others. Instruments used to investigate site-level environments were created in the research project described here.

In the survey questionnaire, ten items regarding site-level environments were created, addressing perceptions of the outdoors from the interior and experiences of the environments. Site-level environments were typically scored high by older adults in this study. For instance, more than 75% of participants reported that the indoor-outdoor connections on their residential sites were smooth and the sites had well-developed canopy shading. This phenomenon may be related to strong psychological links between older adults and their homes. To further investigate site-level environments, questionnaire items about site features need to be more specific.

GIS measurement tools and geo-referenced aerial photos were used to measure site-level environments and confirm the existence of site features reported in the survey. The quality of parcel data influenced the GIS analysis. For instance, side-areas and building set-backs were measured on the layer of building footprints, which may not be available for low-density areas. To further research these variables, relevant questions regarding the existence of side-areas and the sizes of building set-backs may be asked in future surveys. High-resolution DOQs and satellite photos can help investigate site-level environments, although acquiring this GIS data is expensive.

Survey and GIS instruments used to investigate environments at the site level are also under-explored and should be refined in future research.

This research investigated the influence of nearby outdoor environments on older adults' daily physical activities and years of living at their own homes. Addressing gaps in previous studies, the influence of site-level environments on older adults was highlighted in this research. Findings of this research can be used to promote healthy living and senior independence, leading to reduced demands on society for long-term care.

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APPENDIX A

Description of Other Variables Tested in the Environment & Neighborhood Walking Study

	Variables	Coding	% or average
Personal and Social	1. Self-estimated ability to walk ½ mile	11: somewhat agree or less 12: strongly agree	38.6% 61.4%
	2. Mobility	0: used cane, walker, or wheelchair 1: used none	27.2% 72.8%
	3. Education	1: grade school or less 2: high school 3: college 4: graduate school or higher	11.4% 46.5% 28.1% 14.0%
	4. Previous income - household	1: $20, 000 or less 2: $20, 000 ~ 30,000 3: $30, 000 ~ 40,000 4: $40, 000 ~ 50,000 5: $50, 000 or more	12.3% 15.8% 36.0% 16.7% 19.3%
	5. Marriage status	11: others 12: married	29.8% 70.2%
	6. Living arrangement	11: not married 12: married	42.1% 57.9%
	7. Longevity in place	Log of years ranging from .5 to 70	21.8 years
	8: Facility stay	Log of years ranging from 0 to 14	2.4 years
Environment - Site	1. Building type	11: single family houses 12: others	66.7% 33.3%
	2. Building height	11: one story 12: two stories or more	67.9% 32.1%
	3. Land size (in square feet)	11: 2274 ~ 6000 12: 6001~ 7320 13: 7321~ 10725 14: 10726 ~ 36058 15: 36059 ~ 338209 16: 338210 ~ 641865	10.3% 13.8% 25.9% 24.1% 15.5% 10.3%
	4. Building gross floor areas (in square feet)	11: 796 ~ 938 12: 939 ~ 1487 13: 1488 ~ 2282 14: 2283 ~ 24752 15: 24753 ~ 245428 16: 245429 ~ 648353	10.5% 14.0% 24.6% 26.3% 14.0% 10.5%
	5. Lot coverage ratio	11: 0.06 ~ 0.14 12: 0.14 ~ 0.18 13: 0.18 ~ 0.24 14: 0.24 ~ 0.34 15: 0.34 ~ 0.56 16: 0.56 ~ 0.89	10.3% 15.5% 24.1% 27.6% 12.1% 10.3%
	6. Building Year built	11: 1910 ~ 1940 12: 1941~ 1951 13: 1952 ~ 1963 14: 1964 ~ 1979 15: 1980 ~ 1994 16: 1995 ~ 2000	10.0% 14.0% 26.0% 26.0% 18.0% 6.0%
	7. Building orientation toward the sun	11: West-east 12: North-south	50.8% 49.2%
	8. Frontage street orientation toward the sun	11: West-east 12: North-south	67.2% 32.8%

Description of Other Variables Tested in the Environment & Neighborhood Walking Study

	Variables	Coding	% or average
	9. Building long sides parallel to frontage streets	0: not parallel	36.1%
		1: parallel	63.9%
	10. Presence of transitional-areas	0: no transitional areas	42.6%
		1: had transitional areas	57.4%
	11. Number of residential units	11: 1 unit	71.4%
		12: 2 or more	28.6%
	12. Entrance steps, ramps, non-needed	11: ramp or steps	43.8%
		12: flat entrances areas	56.2%
	13. Lot paving	0: grass	50%
		1: paved	50%
	14. Number of connecting-paths	11: 1 path or less	57.4%
		12: 2 paths or more	42.6%
	15. Average width of side-areas (in square feet)	11: 4 ~ 5	8.2%
		12: 6 ~ 9	14.8%
		13: 10 ~12	26.2%
		14: 13 ~ 20	26.2%
		15: 21 ~ 32	14.8%
		16: 33 ~ 80	9.8%
	16. Average building-setback from streets(in square feet)	11: 10 ~ 18	6.6%
		12: 19 ~ 24	16.4%
		13: 25 ~ 30	31.1%
		14: 31 ~ 50	29.5%
		15: 51 ~ 70	11.5%
		16: 71 ~ 75	4.9%
	17. Distance between home and the nearest street intersection	11: 5 ~ 40	8.2%
		12: 41~ 90	11.5%
		13: 91 ~ 225	29.5%
		14: 226 ~ 350	29.5%
		15: 351 ~ 460	14.8%
		16: 461 ~ 650	6.6%
Environment - Neighorhood	*1.Number of utilitarian facilities within a ¼-mile radius of home*	11: 0	34.4%
		12: 1-9	45.9%
		13: 10 or more	19.7%
	2.Number of utilitarian facilities within a 1-mile radius of home	11: 6 ~ 11	9.8%
		12: 12 ~ 20	14.8%
		13: 21 ~ 51	26.2%
		14: 52 ~ 83	23.0%
		15: 84 ~ 103	16.4%
		16: 104 ~ 236	9.8%
	3.Number of utilitarian facilities within a 2-mile radius of home	11: 41~ 85	9.8%
		12: 86 ~118	14.8%
		13: 119 ~ 192	26.2%
		14: 193 ~ 278	24.6%
		15: 279 ~ 365	14.8%
		16: 366 ~ 770	9.8%
	4. Distance between home and the nearest park (in 100-feet)	11: 4 ~ 10	9.8%
		12: 11 ~ 33	14.8%
		13: 34 ~ 65	24.6%
		14: 66 ~ 101	26.2%
		15: 102 ~ 129	14.8%
		16: 130 ~ 207	9.8%

Description of Other Variables Tested in the Environment & Neighborhood Walking Study

Variables	Coding	% or average
5. Distance between home and the nearest bank (in 100-feet)	11: 1 ~ 12	6.6%
	12: 13 ~ 19	18.0%
	13: 20 ~ 33	27.9%
	14: 34 ~ 51	23.0%
	15: 52 ~ 62	14.8%
	16: 63 ~ 212	9.8%
6. Distance between home and the nearest post office (in 100-feet)	11: 16 ~ 51	9.8%
	12: 52 ~ 83	14.8%
	13: 84 ~ 131	24.6%
	14: 132 ~ 207	26.2%
	15: 208 ~ 336	14.8%
	16: 337 ~ 420	9.8%
7. Distance between home and the nearest food facility (in 100-feet)	11: 1~ 9	9.8%
	12: 10 ~ 14	14.8%
	13: 15 ~ 25	23.0%
	14: 26 ~ 46	26.2%
	15: 47 ~ 58	16.4%
	16: 59 ~ 88	9.8%
8.Areas occupied by roads within a ¼ mile radius of home (in 30x30 square feet)	11: 381 ~ 501	9.8%
	12: 502 ~ 787	14.8%
	13: 788 ~ 1008	24.6%
	14: 1009 ~ 1311	23.0%
	15: 1312 ~ 1562	16.4%
	16: 1563 ~ 1974	11.5%
9.Areas occupied by roads within a 1 mile radius of home (in 30x30 square feet)	11: 8056 ~ 11626	9.8%
	12: 11627 ~ 13524	14.8%
	13: 13525 ~ 15933	24.6%
	14: 15934 ~ 17550	26.2%
	15: 17551 ~ 19914	14.8%
	16: 19915 ~ 28692	9.8%
10.Areas occupied by roads within a 2 mile radius of home (in 30x30 square feet)	11: 27205 ~ 47108	9.8%
	12: 47109 ~ 54366	13.1%
	13: 54367 ~ 62764	24.6%
	14: 62765 ~ 67157	23.0%
	15: 67158 ~ 75849	14.8%
	16: 75850 ~ 96115	14.8%

Note: GIS-based variables are italic.

APPENDIX B

Survey Questionnaire about Seniors' Previous Homes and Neighborhoods

The survey questionnaire used in this research was developed for senior-living older adults and focused on their physical activities (yard activities and neighborhood walking) when they lived in their own homes and the residential environments at the site and neighborhood levels. The questionnaire was entitled "Survey Questionnaire about Seniors' Previous Homes and Neighborhoods."

ID

Survey of Seniors' Previous Homes and Neighborhoods

Hello!
We are trying to learn about the home and neighborhood where you lived **BEFORE moving to a retirement community.**

1. **My age is (___) years.** **I am** __Female __Male

2. **Overall, I have lived in retirement communities (current one and all previous ones), for (___) months (___) years.**

3. **BEFORE moving to a retirement community, I lived at:** (please print)

Street # / Apartment #

City State ZIP code

(It is the key of our Environmental Study on Map and will be kept confidential. Please specify it or ask facility staff. Thank you:)

4. **It was a** __Single-family House __Townhouse/ Rowhouse __Apartment/Condominium __Other

5. **It was (___) stories tall.**

6. **It was** __Owned __Rented __Other

7. **I was living there for (___) years.**

8. **I lived alone there.** __Yes __No

9. **At that time, I had physical or medical problems that usually limited my walking.** __Yes __No

I frequently used a . . . __None __Cane __Walker __Wheelchair __Power Scooter

Please use these faces to show how much you agree or disagree with the following statements.

__ Very happy for Strongly YES

__ Happy for somewhat YES

__ Sad for somewhat NO

__ Very sad for Strongly NO

Statements → Your answers

BEFORE moving to a retirement community, IN MY PREVIOUS HOME,	Strongly YES	somewhat YES	somewhat NO	Strongly NO
10. My rooms received pleasant sunshine.	__	__	__	__
11. My rooms had good window views.	__	__	__	__
12. It was easy to walk between my home and my yard or outdoor areas.	__	__	__	__
There were __Steps __Ramps __None needed				

Please check one face for each statement

BEFORE moving to a retirement community, IN MY PREVIOUS HOME,

Please check one face for each statement

	Strongly YES	somewhat YES	somewhat NO	Strongly NO
13. My yard or outdoor areas were well landscaped.	__	__	__	__
well maintained.	__	__	__	__
paved.	__	__	__	__
shaded.	__	__	__	__
14. It was easy to walk around the building outdoors.	__	__	__	__
15. I liked to spend time outdoors IN MY YARD or ON THE PROPERTY.	__	__	__	__

Usually, I liked to do __Walking __Gardening __Yard works __Sitting Other (________________)

Usually, Where? __front yard __back yard __side yard __porch or balcony Other (____________)

How often? __1 time/2 days or Less __1 time/day __1-3 times/day __more than 3 times/day

How long per time? __10 minutes or Less __10-30 minutes __30 minutes to 1 hour __Over 1 hour

	Strongly YES	somewhat YES	somewhat NO	Strongly NO
16. I was not bothered by the nearby traffic if walking out of yard.	__	__	__	__

I would like to add something about my yard or the outdoors and my walking:

IN MY PREVIOUS NEIGHBORHOOD,	Strongly YES	somewhat YES	somewhat NO	Strongly NO
17. Neighbors were willing to help others.	__	__	__	__
18. It was a close-knit neighborhood.	__	__	__	__
19. Neighbors could be trusted.	__	__	__	__
20. Neighbors generally got along with each other.	__	__	__	__
21. Neighbors shared the same values.	__	__	__	__
22. I liked to walk around in my previous neighborhood.	__	__	__	__

Please check one face for each statement

How often? __1 time/2 days or less __1 time/day __1-3 times/day __more than 3 times/day

How long per time? __10 minutes or less __10-30 minutes __30 minutes to 1 hour __Over 1 hour

How far away from home? __ less than 1/2 mile __1/2 mile __1 mile __more than 1 mile

23. IF I WALKED IN MY PREVIOUS NEIGHBORHOOD, I usually walked to. . . Please check all that apply.

__None	__Grocery stores/ Supermarkets	__Libraries/ Book stores
__Parks	__Convenience stores	__Churches/ Places of worship
__Post offices	__Retail stores/ Specialty stores	__Recreation Centers/ Walking trails
__Bus/ Transit stops	__Restaurants/ Coffee shops	__Pharmacy/ Drug Stores
__Senior centers	__Banks/ Credit union	__Clinics/ Health Centers

WHILE WALKING IN MY PREVIOUS NEIGHBORHOOD, 

Please check one face for each statement

	Strongly YES	somewhat YES	somewhat NO	Strongly NO
24. Usually, I felt confident to walk 1 mile.				
25. I could look at interesting things. (such as natural views or historical buildings).				
26. I could choose different ways to walk from place to place.				
27. There were sidewalks I could use on most of the streets.				
28. Along the walkways, there were usable benches or seats.				
there were usable restrooms......				
29. There were signals to help me cross streets.				
30. I was not bothered by the street traffic.				
31. I was not bothered by the fear of crime.				
32. The streets were well lit at night.				

I would like to add something about my previous neighborhood and my walking:

AFTER RETIREMENT, BEFORE I MOVED TO A RETIREMENT COMMUNITY,

33. Compared to other people my age, I would say my overall health was <u>previously</u> __Excellent __Very Good __Good __Fair __Poor

34. At that time,
I usually NEEDED HELP to. . .
(Please check all that apply)

__Handle finances __Walk across a room __Do the Laundry
__Shop __Do housekeeping __Use the telephone
__Prepare food __Take my medicines __Did NOT need these help

35. My race is __Non-Hispanic White __Hispanic __Black __Asian __Other

36. My marital status is __Never married __Married __Separated __Divorced __Widowed

37. I finished __Grade School or less __High School
__College __Graduate School or more

38. My primary job before retirement was

__Professional/ Managerial/ Technical __Sales/ Service __Clerical/ Administrative support
__Manufacturing/ Construction/ Maintenance, or Farming Other: (________________________)

39. Approximately, our <u>household</u> income per year was

__$20,000 or less __$20,000 ~ $30,000 __$30,000 ~ $40,000 __$40,000 ~ $50,000 __$50,000 or more

You are finished! Thank you so much for your time and effort.

VITA

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Education: U.S. Green Building Council - USGBC

U.S. Green Building Council - USGBC		
	Leadership Energy and Environmental Design Accredit Professional - LEED AP	2009
Texas A&M University, College Station, TX		
	Master of Architecture	2004
	Certificate in Health Systems & Design	2004
Zhengzhou University, Zhengzhou, China		
	Bachelor of Engineering in Architecture	1993

Summary of Qualification: Interdisciplinary Research - Architecture, Urbanism, Environment & Behavior, Active Living, Health and Sustainability; won the AIA RFP Research Grant.

Publications - Published first-author and single-author papers in the *AIA (American Institute of Architects) Report on University Research* (Vol. 2), the *Seniors Housing & Care Journal* - 16 (1), and the *Berkeley Planning Journal* - 22 (1); spoke at the *Environmental Design Research Association* international conference 38th, 39th,40th, and the *AIA National Convention* 2007, 2008.

Professional experiences - Nine planning and design works built in China and Singapore; Registered Architect in China, 1996 – present.

Teaching - Two design studios: PLAN 602 and ARCH 3256; three design communication courses: ENDS 102, 115, 353.