

# Residential Site Environments and Yard Activities of Older Adults

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## I. Introduction

### 1.1 Global aging and implications

The phenomenon of global aging is increasing at an accelerated rate. Life expectancy at birth has increased from 47.3 years at the beginning of the 20th century to nearly 77 years today; the current life expectancy for individuals aged 65 years is 18 more years on average (DHHS, 2001). As a result, the population group 65 and older grew globally by 795,000 per month in 2000 and the growth will be 847,000 in 2010 (Kinsella & Velkoff, 2001). From 2000 to 2030 in the U. S., this population segment will increase from 35 million to 71.5 million or 20 percent of the total population (Older Americans, 2004).

In their daily life after retirement, older adults suffer the physiological pain of aging, the feeling of role loss, and the sense of discomfort that results from nonproductive use of time (Myers, 1999). Their contact with the outside world is generally reduced; they typically have sedentary lifestyles and spend a lot of time indoors at home. According to the U. S. Department of Health and Human Services, more than 60 percent of older Americans are physically inactive (DHHS, 1996).

## 1.2 Physical, social, and nature-related activity

For older adults, the U. S. Surgeon General recommends at least 30 minutes of moderate physical activity most days of the week (DHHS, 2001). To achieve the recommended level of moderate exercise, it is thought best to combine multiple physical activities. Walking, gardening, and yard work are inexpensive, require minimal equipment, and adapt flexibly to different schedules; they are known to be the most popular physical activities among older adults (DHHS, 1996). By doing these physical activities, older adults are reducing the risks of heart disease, diabetes, colon cancer, and high blood pressure, and promoting the strength of bone, joints, and muscles (DHHS, 1996). By being physically active in the yard or on the property in which they live, older adults could gain health benefits not only from the increased physical activities, but also from the improved sense of control, social interactions, and access to nature.

Being outdoors in the familiar environments of their residential sites may help older adults confirm their social identities and psychological links with the surroundings, leading to enhanced sense of control and emotional wellbeing (Marcus, 1995; Scheidt & Norris, 1999; Stokols, 1992). Residential site environments are appropriate settings for older adults to interact with their family members and neighbors. Family-centered environments benefit health by fostering social interactions (Shepley, 1998). A longitudinal study found that older adults can reduce the risk of dementia by engaging in social interactions (Wang et al., 2002). Being outdoors, older adults can access nature; viewing delightful nature scenes may tend to increase positive emotions and reduce depression (Ulrich, 1991). A brief outdoor experience can improve older adults' cortisol level, which is an indicator of stress reduction (Rodiek, 2002). It may satisfy the 'biophilia' needs of human beings (Kellert, 1993). Walkable green spaces in residential communities were found to be valued highly by older adults and related positively to their longevity (Takano et al., 2002; Talbot & Kaplan, 1991).

## 1.3 Environmental supports

As their competence declines, older adults are typically more environmentally docile and less environmentally proactive than younger adults (Lawton, 1985, 1989; Lawton & Simon, 1968). If the environments in which they live make physical activities more feasible, attractive and safe, older adults may be more physically active. Neighborhood environments have been found to influence older adults' physical activities such as walking (Humpel et al., 2002; Owen et al., 2004; Patterson & Chapman, 2004), but the impact of immediate residential site environments such as yards remains under-explored.

Traditional urban neighborhoods, where pedestrians have access to recreational and utilitarian destinations for daily living, have high levels of outdoor physical activities among older adults (Patterson & Chapman, 2004; Saelens et al., 2003; Wister, 2005). Having desirable destinations within walking distance of home may make the environments attractive and motivate older adults to walk outdoors. Having functional pedestrian facilities, such as comfortable sidewalks along walking routes, provides convenience to pedestrians; these could be classified into environmental features related to walking paths at different levels (Cunningham & Michael, 2004; Suminski et al., 2005). Levels of neighborhood safety are also related to levels of older adults' outdoor physical activities (Humpel et al., 2002; Owen et al., 2004). Environmental safety from traffic and crime could be a critical concern of less-competent older adults going outside. They may hesitate to go outdoors if their residential sites are close to vehicular traffic.

Outdoor environments visited by community-dwelling older adults in their daily life are not only neighborhood environments, but also residential site environments. Immediately adjacent to home, residential site environments such as yards are both origins of outdoor trips and destinations on the way back to home. These environments are the very first places people enter if going outside. Since older adults are environmentally docile, they may be more physically active if the environments are senior-friendly and inviting for physical activities.

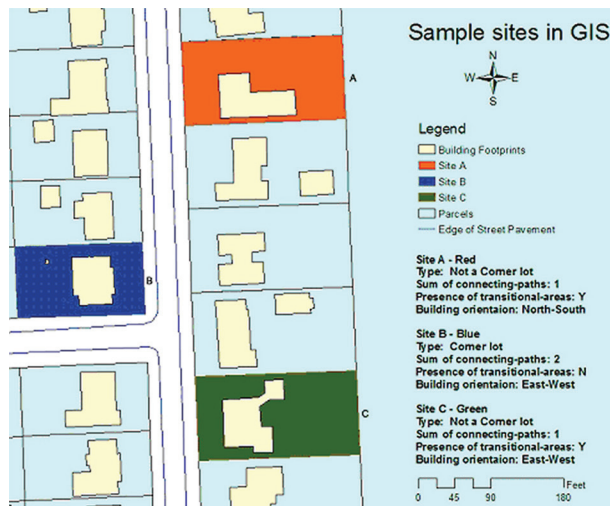


Figure 1: Sample sites in GIS

There is very limited evidence to indicate the specific site environmental features which influence yard activities. This study addresses this gap by studying twenty environmental features on and around residential sites which are thought to be related to older adults' yard activities. Yard activities are distinguished from necessary physical activities (such as walking to bus stations for a daily commute) by the fact that most yard activities are optional. The quality of residential site environments is an important concern in promoting yard activities, which may themselves in turn improve the quality of the outdoor environments. Residential site environments for yard activities of older adults should be attractive, functional and safe, as perceived by older adults both from the indoors and in the outdoor settings. Based on the results of previous research on neighborhood environments, site environmental features were classified into four categories: 1) Typology, 2) Motivators, 3) Functionality, and 4) Safety, and studied at the building level and at the site level.

Early in the design process of site planning, appropriately dealing with issues of building orientation, ground plan, configuration, and placement has a significant impact on the quality of site environments. In the process of design development, decisions on building arrangement, height, room depth, color, materials, and window size and location, are also critical. Design guidelines for site plans could be created and used to improve the quality of residential site environments for yard activities of older adults, potentially leading to higher levels of physical activity and better health outcomes.

## 2. Methods

### 2.1 Definitions

This study focuses on the physical environments adjacent to residential buildings, which older adults can access without crossing streets or vehicular traffic. These environments may be more attractive to older adults if they could pass through multiple spaces while traversing the site, and be more functional 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 inviting outdoor spaces. 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 1- A and C) and proper spatial relationships between the main building and accessory buildings (Figure 8- C). 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  $\geq$  ten feet), a *connecting-path* could be developed to link separated areas around the building (Figure 1- A and C). Connecting-paths facilitate yard walking and provide flexible choices of environments for yard activities. If a site has at least two streets on different directions along its edges, it could be classified as a *corner lot* (Figure 1- B).

Personal		Social	
Variables	Data collection method	Variables	Data collection method
<b>1. Age*</b>	Survey	<b>1. Living arrangement</b> (alone or not)	Survey
<b>2. Gender</b>	Survey	<b>2. Building ownership*</b>	Survey
<b>3. IADLs</b> (a measure of functional competence)	Survey	3. Environmental safety from traffic	Survey
4. Self-efficiency	Survey	<b>4. Environmental safety from Crime</b>	Survey
<b>5. Education*</b>	Survey		

Table 1: Personal and Social Factors studied

\*Significant variables, p<0.05. Bold: test variables filtered from all variables of interest by correlation tests.

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

## 2.2 Sample

Study participants were randomly recruited from five assisted-living facilities of one of the largest long-term care management systems in Houston, TX, this made it possible to control confounding variables such as different facility policies of entry admissions. All participants were screened by facility caregivers to verify their cognitive competence for answering survey questions, and included only if they agreed to join the study. Response rates were 25 percent to 30 percent in different facilities. The sample size was 20 to 30 per facility, with a total of 110. The average age of participants was 84.2 years and 82 percent of them were female. Seventy-two out of the 110 sample residential sites were single-family homes; 25 were apartment buildings or condominiums; 13 were townhouses, row-houses, or other types.

## 2.3 Variables

Based on the Social Ecological Model, which describes a theory regarding the structure of relationships among personal factors, social factors, physical environmental factors, and physical activities (Zimring et al., 2005), this study investigated the value of physical environmental factors on residential sites in predicting levels of older adults' yard activities, along with personal factors and social factors. Personal factors and social factors thought to be related to older adults' yard activities are listed in Table 1.

Level Category	Building		Site	
	Variables	Data collection methods	Variables	Data collection methods
Typology	1. Building Type	GIS, Survey	1. Site Type (corner lot or not)	GIS
	2. Building Size	GIS	2. Parcel Size	GIS
	<b>3. Height of building (# of stories)</b>	GIS, Survey	3. Lot coverage	GIS
	<b>4. Building orientation toward Sun</b>	GIS	<b>4. Building setback from streets</b>	GIS
	<b>5. Building orientation toward the frontage street (parallel or not)</b>	GIS		
Motivators	<b>6. Pleasant indoor sunshine*</b>	Survey	5. Yard landscaping	Survey
	7. Good window-views	Survey	<b>6. Presence of transitional-areas*</b>	GIS
Functionality	<b>8. Indoor-outdoor connections</b>	Survey	<b>7. Perceived site walkability*</b>	Survey
			<b>8. Sum of connecting-paths*</b>	GIS
			9. Average width of side-areas	GIS
			<b>10. Presence of paving*</b>	Survey
			<b>11. Shading of tree canopy</b>	GIS, Survey
Safety			<b>12. Distance from site entrance to the nearest street intersection</b>	GIS

Table 2: Physical Environmental Factors studied

\*Significant variables, p<0.05. Bold: test variables filtered from all variables of interest by correlation tests.

*Physical environmental features of residential sites were studied at two levels (Table 2):*

- **Building level** – issues related to the building, including the building type, size, orientation, indoor-outdoor connections, and two environmental indicators of the building: pleasant indoor sunshine and good window-views.
- **Site level** – issues related to the site, including the site type, size, coverage, setback, transitional-areas, connecting-paths, site walkability, width of side areas, yard landscaping, shading of tree canopy, paving, and the distance from site entrance to the nearest street intersection.

*Physical environmental features of residential sites were classified into four categories (Table 2):*

- **Typology** – The building type, size, height in number of stories, orientation toward sun, orientation toward the frontage street, setback from streets, site type, size, and lot coverage.
- **Motivators** – Environmental amenities encouraging older adults to go outdoors, including pleasant indoor sunshine and good window-views at the building level, and yard landscaping and inviting transitional-areas at the site level.
- **Functionality** - Environmental features convenient to older adults’ yard activities, including feasible indoor-outdoor connections, connecting-paths, side-areas, site walkability, paving, and shading.
- **Safety** – An environmental feature thought to be related to the safety perceived by older adults in the yard or on the property: the distance from site entrance to the nearest street intersection.

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


 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
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				

Figure 2: Examples of questionnaire items used in surveys

## 2.4 Data Collection – Questionnaire surveys and GIS instruments

Environmental perceptions of older adults regarding their former residential sites were collected by questionnaire items. Based on results of previous research, the questionnaire was specifically developed for this study. There were three parts. Part 1 focused on participants’ age, gender, and former addresses before moving to a retirement community; part 2 collected data on perceived environmental features and previous yard activities; part 3 on previous IADLs, living arrangement, education, and other personal factors. Questionnaire items of site features were created; icons of smiling or sad faces were used to help older adults indicate how much they agreed or disagreed with given statements (Figure 2). The questionnaire was refined after a pilot study in an assisted living facility in College Station, TX.

Objective measures of 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 from site entrance to the nearest street intersection were studied in GIS. Fifty-seven out of the 110 sample sites were in Harris County, TX, which had GIS data available for this study. The 57 sites were normally distributed in the area and studied with GIS measures (Figure 3: Location of sample sites 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 (Figure 4, 5). 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:

- Identify individual sample sites in GIS by geocoding addresses or selecting address attributes in parcel data;
- Find measures of environmental features of interest in attribute tables of GIS layers;
- Measure distances of interest in GIS by using GIS measure tools;
- Analyze DOQs and satellite photos of sample sites to reconfirm measures;
- Record measures in EXCEL and generate studymaps 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.

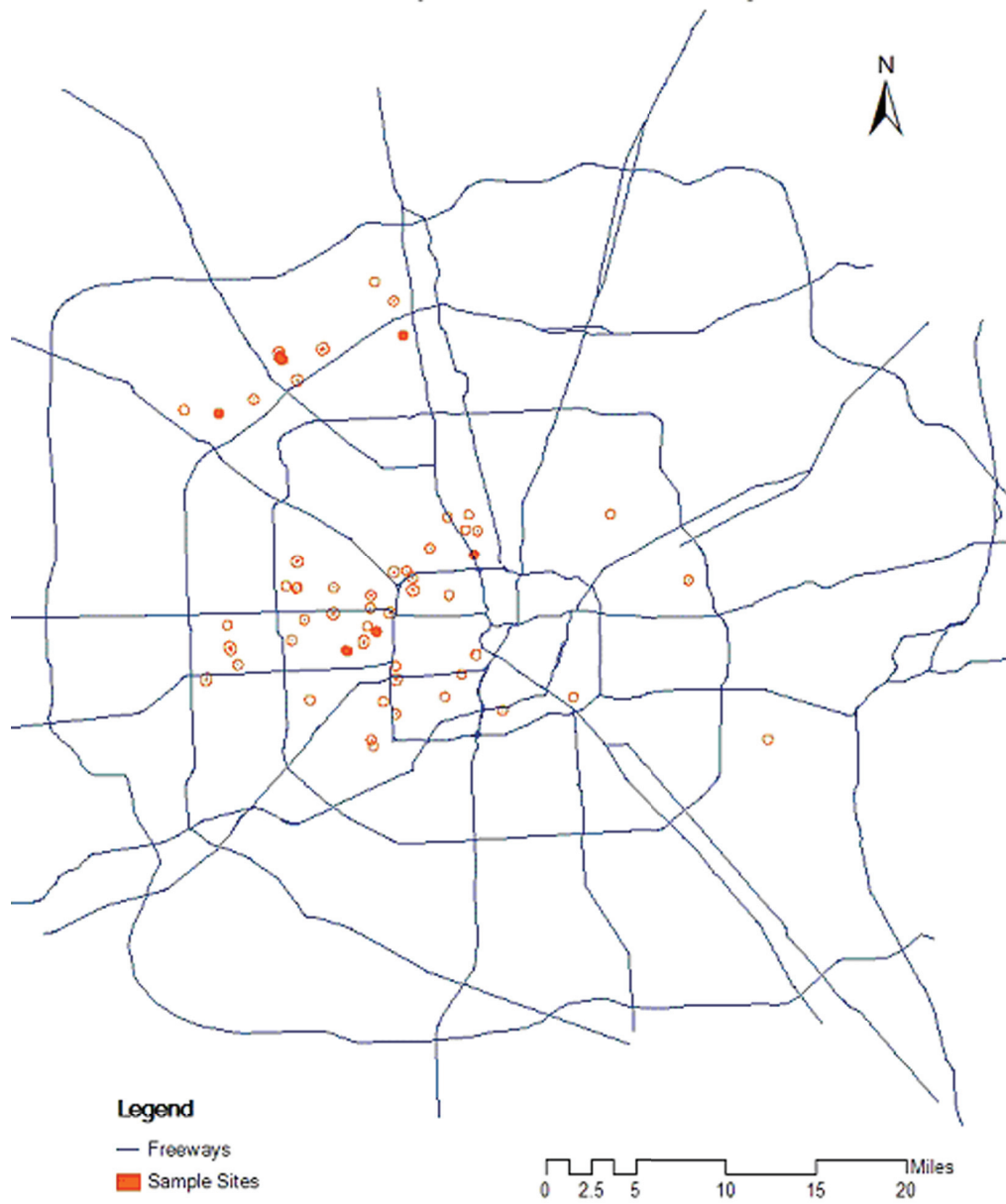


Figure 3: Location of sample sites in GIS – Harris County, TX



### 3. Measures and Analysis

*Measures of personal and social factors* - In this study, age was measured in years; gender was represented as 1 for female and 0 for male. Levels of previous IADLs, self-efficacy, and neighborhood safety were rated in quartile, with 4th and 1st used to represent the highest and lowest level of functional independence, confidence and safety. 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. Living arrangement was classified as 1 if a participant was not living alone in his or her previous residence and as 0 if living alone.

*Measures of physical environmental factors* - 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. 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 quartile, with 4th and 1st used to represent the highest and lowest levels of the long sides of buildings facing north-south, and with a preference of somewhat east-facing to somewhat west-facing (Figure 7). Levels of building orientation toward the frontage street were rated as 1 if the long sides of buildings were 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 percent, 2 if the percentage was 25 percent to 50 percent, 3 if 50 percent to 75 percent, and 4 if more than 75 percent.



A

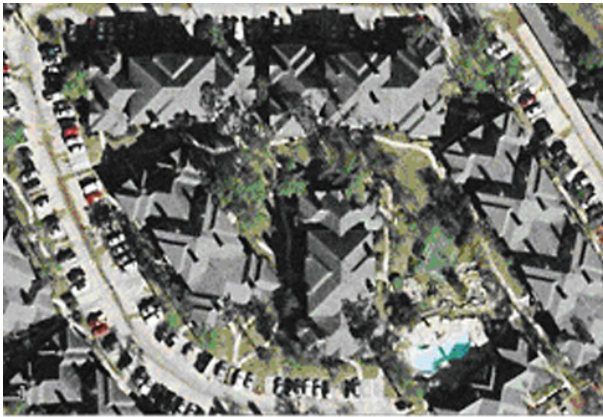


B

Figure 4: Sample sites of single-family houses



A



B

Figure 5: Sample sites of apartment buildings/ condominiums

*Quantitative data analyses* - The statistics package SPSS was used for quantitative data analyses in this 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 each other ( $p < 0.05$ , two tailed) was selected for multivariate analyses. Factor analyses were also conducted to analyze the relationships among variables. The 110 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 the sites of two groups were identified by independent sample t-tests. Hierarchical linear models were 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 the 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 applied. Test variables were filtered from all variables of interest by correlation tests and organized in three blocks: personal / social (Table 1: bold variables), site, and building (Table 2: bold variables).

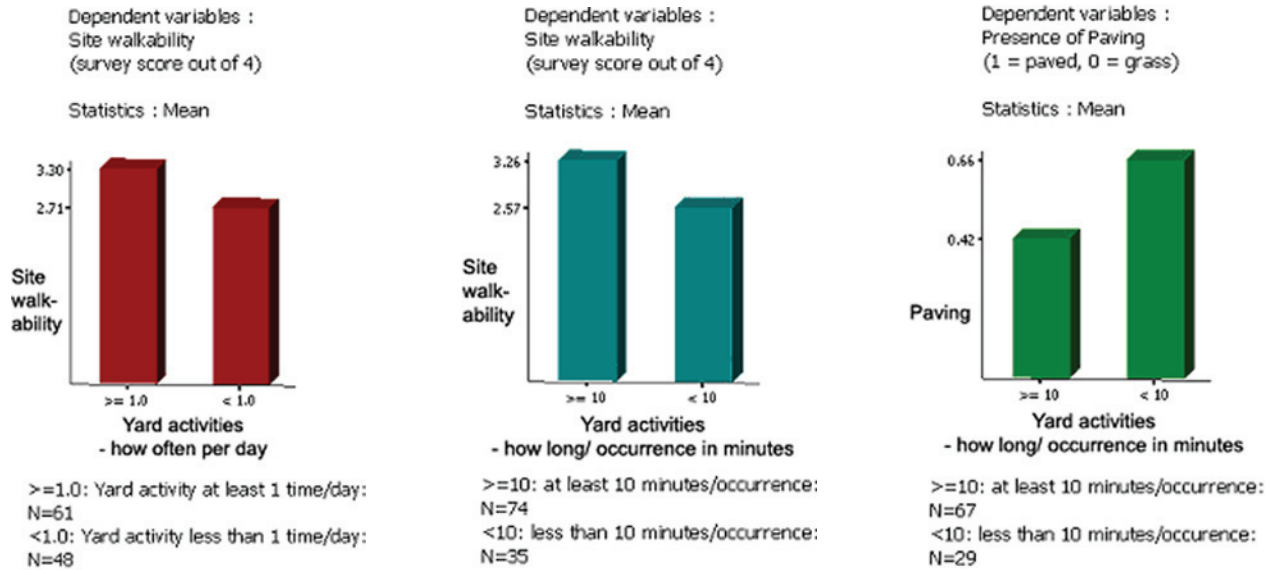


Figure 6: Yard Activities related to perceived site walkability and presence of paving

#### 4. Results

It was found that levels of perceived site walkability, rated by older adults regarding 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 sites being paved than the counterpart older adults ( $p < 0.03$ ) (Figure 6).

Along with personal and social variables, site variables could predict 37 percent of the frequency of older adults' yard activities ( $p < 0.1$ ). Personal and social variables could predict 28 percent of the duration of older adults' yard activities per occurrence ( $p < 0.05$ ), and the power of prediction was significantly increased to 34 percent after adding the variable of indoor sunshine in modeling ( $p < 0.05$ ). Levels of pleasant indoor sunshine were positively related to the duration of older adults' yard activities per occurrence (Table 3:  $p < 0.05$ ).

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

Table 3: Duration of yard activity predicted by personal/social factors and Indoor Sunshine  
 \*duration of yard activities was counted in ten-minute spans.

Predictors	Unstandardized Coefficients	Standardized Coefficients	Significance
(Constant)	-11.942		.016
Personal/ Social Factors			
Age	<b>.096</b>	.350	<b>.012</b>
Gender	-.381	-.070	.601
IADLs (a measure of functional competence)	.390	.157	.205
Education	.435	.172	.220
<b>Building ownership</b>	<b>2.241</b>	<b>.456</b>	<b>.012</b>
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
<b>Presence of transitional-areas</b>	<b>1.201</b>	<b>.268</b>	<b>.040</b>
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

Table 4: Duration of yard activities predicted by personal/social factors and environmental factors  
 \*duration of yard activities was counted in ten-minute spans.

In full models entered with all test variables (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 4: 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 of older adults' yard activities (Table 5: p<0.05) and the duration per occurrence (Table 6: p<0.05).

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 found between levels of yard activities and the building size, type, height of building in number of stories, parcel size, and lot coverage. Age and building ownership were found to be positively related to the duration of yard activities per occurrence (Table 3, 4, 6: p<0.05); older participants who owned their previous residences were likely to have longer-lasting yard activities per occurrence than younger participants who rented their previous residences. 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 (Table 5, p<0.05).

Predictors		Unstandardized Coefficients	Standardized Coefficients	Significance
	(Constant)	-.368		.878
Personal/ Social Factors	Age	.002	.017	.909
	Gender	-.374	-.149	.316
	IADLs (a measure of functional competence)	.000	.000	.999
	<b>Education</b>	<b>-.415</b>	<b>-.354</b>	<b>.023</b>
	Building ownership	.195	.086	.653
	Living arrangement	.160	.076	.621
	Neighborhood crime	.015	.017	.918
Site variables	Building setback from street	-.008	-.133	.387
	<b>Sum of connecting-paths</b>	<b>.452</b>	<b>.301</b>	<b>.043</b>
	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 frontage street	.586	.273	.090
	Height of building	-.060	-.037	.826
	Pleasant indoor sunshine	.335	.238	.143

Table 5: Frequency of yard activity predicted by personal/social factors and environmental factors

\*duration of yard activities was counted in ten-minute spans, variable of transitional-areas was NOT included in predictors.

Predictors		Unstandardized Coefficients	Standardized Coefficients	Significance
	(Constant)	-10.235		.041
Personal/ Social Factors	<b>Age</b>	<b>.081</b>	<b>.294</b>	<b>.036</b>
	Gender	-.211	-.039	.780
	IADLs (a measure of functional competence)	.328	.132	.304
	Education	.274	.108	.447
	<b>Building ownership</b>	<b>2.036</b>	<b>.414</b>	<b>.026</b>
	Living arrangement	.291	.064	.660
	Neighborhood crime	.237	.121	.426
Site variables	Building setback from street	.013	.101	.486
	<b>Sum of connecting-paths</b>	<b>.919</b>	<b>.284</b>	<b>.044</b>
	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

Table 6: Duration of yard activities predicted by personal/social factors and environmental factors

\*duration of yard activities was counted in ten-minute spans, variable of transitional-areas was NOT included in predictors.

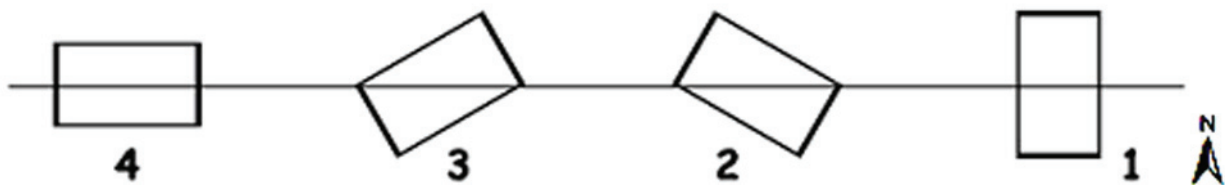


Figure 7: Classification of building orientations

## 5. Discussion

*What characterizes a high-quality residential site for older adults' yard activities?* The following discussion utilizes the hypotheses and findings from this study to generate some preliminary guidelines for designing residential sites for older adults. These design guidelines can be used as hypotheses to be tested in future studies.

### 5.1 An attractive outdoor environment as perceived from the indoors and outdoors

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 be addressed by fine-grained spaces with *transitional-areas* and inviting *yard landscaping* in the outdoor settings. These could be generated by applying an appropriate building orientation, a ground plan in a multi-edge shape, and a proper placement of the main building in harmony with accessory buildings and existing environments.

Levels of *pleasant indoor sunshine* perceived by older adults was significantly related to the durations of their outdoor yard activities per occurrence, according to the statistical analyses in this study. Making a useful contribution to interior luminance, natural 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 buildings at a low altitude in the morning, on the south side at a high altitude in the midday, and on the west side 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 unpleasant indoor glare in the afternoon, north-south facing is suggested for residential buildings for older adults, with a preference of somewhat east-facing to somewhat west-facing. The north-south facing of building is also suggested to keep the heat in during winter months and out during summer (Alexander, 1977).

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 of somewhat east-facing to somewhat west-facing (Figure 7). Among the 57 sample sites analyzed in GIS in this study, 29 had main buildings facing north-south or close to it as classified as 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 buildings is suggested. However, participants who lived in buildings classified as 4 or 3 valued their yard landscaping significantly higher than other participants ( $p \leq 0.05$ ), and engaged in 31-minute yard activities per occurrence on average, given others had the average duration of 26 minutes.

To maximize pleasant indoor sunshine in the northern hemisphere, a distance should be maintained from the north side of an existing structure to the proposed building. Assuming sun shines at the solar-altitude angle of 45 degrees for most of the day, the distance should be at least the height of the existing structure. 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 levels of pleasant indoor sunshine perceived by them. 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 could offer a chance of psychological escape from the indoors and then encourage them to go outdoors.

Once older adults go outdoors, residential site environments should be addressed to continuously maintain their visual and sensory attention, and encourage them to walk, do gardening, or engage in other 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 improve the complexity of site environments, along with *yard landscaping*.

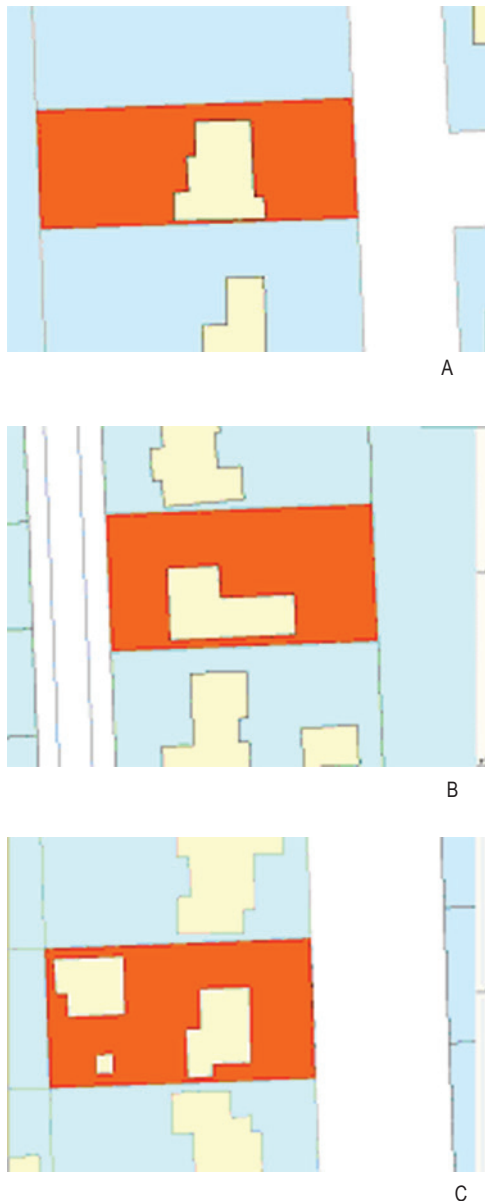


Figure 8: Comparison of ground plans on interior lots

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 happening 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 streetscape, 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 buildings ground plan determines the internal outline of the site environments. Appropriate ground plans could develop inviting transitional-areas. Compared with building ground plans in shapes of a single rectangle or close to it (Figure 4-A, Figure 5-A, Figure 8-A), building ground plans in ‘L’, ‘I’, or other multi-edge shapes may develop space changes at multiple levels and form transitional-areas (Figure 4-B, Figure 5-B, Figure 8-B). Carefully placing an accessory building or structure in harmony with the main building could also compose transitional-areas (Figure 8-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 1-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 building 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 distractions.

## 5.2 A functional outdoor environment for older adults engaged in yard activities

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 relatively slim ground plan along the long axis of the 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 environment, and make yard walking and other yard activities enjoyable; people may then feel the environments walkable and like to engage in activities there. Large lots and low lot coverages 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.



Figure 9: Comparison of ground plans on corner lots

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; 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 9). 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 1- C).

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 two orientations; 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.

*Unpaved* 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 found 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.

### 5.3 A safe outdoor environment for yard activities

The distance from the 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.

*Study limitations* – 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 more well-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 were higher and the sample size were 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.

*Future studies* - The next phase of this study will enlarge the sample size, and collect and use higher-quality GIS data. Assisted-living facilities located in suburban areas around the city of Houston will be randomly selected to increase the variation in environmental features. The differences in yard activities between urban and suburban older adults and the differences in environmental features between their residential sites will be investigated. Characteristics of neighborhood environments such as land-use mix and population density will be considered in predicting yard activities of older adults. Field trips to selected sample sites will be made to collect first-hand data on site environments and verify the quality of relevant GIS data. In addition to analyzing site plans, site elevations will be studied in relation to their impact on yard activities of older adults.

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