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Title(English)	Effects of Physical Environment on Outdoor Activities in Newly Developed Residential Communities in China
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ABSTRACT

World Health Organization conducted Health Cities project from last century, the physical, mental, and social health development are the tasks. Since the Chinese government initiated a commodity housing policy in 1998, it has been said that social interactions in China's residential communities have drastically decreased. Evidences indicated that outdoor activities in residential communities may promote social interactions and mutual support between neighbors, helping maintain the residents' physical and mental health and prevent crime within a community. Thus, promotion of outdoor activities can be seen as one important part of community health development.

With this background, this paper aims to elucidate relevant factors of the physical environment that enhance residents' outdoor activities and build statistical models for outdoor activities which potentially contribute to social interactions.

Systematic observation was used to collect the data of physical environment and outdoor activities. The survey sites were chosen from the city of Tianjin because it is one of the first cities to implement the commodity housing policy and has developed many new residential communities. Prior to visiting the survey sites, documents and aerial photographs were used to examine the urban texture of new residential communities in Tianjin. After seven candidate communities were selected, a pilot survey was conducted to examine the social environments of these communities. Since this paper focuses on the physical environment, the selected communities should be similar in social conditions. Finally, four communities were chosen to do intensive survey.

Prior to the intensive survey, 33 representative subspaces of all outdoor spaces were defined by behavioral barriers such as building walls and/or edge of wide roads/water using general community maps. For each subspace, the residents' staying activities as well as passing activities were observed 10 times where each session lasted between 10-20 minutes (morning and afternoon on three weekdays and two weekends), providing a total of 7668 behaviors. For the physical environment, we postulated three physical factors, accessibility, facilities, spatial configuration; and defined five, four, and two variables, respectively. Because staying activities supposed to contribute to social interactions, the effects of physical factors on staying activities were emphasized. Eleven physical variables were proposed including accessibility in community scale level as measured by spatial visual step depth (SVSD) or accumulative distance (AD), accessibility in subspace scale level as measured by visual accessibility (VAS), physical accessibility (PAS), and vehicle intervention score (VIS); facilities as measured by playing objects (PO), shops/activity centers (SAC), seating capacity (SC), and exercise equipment capacity (EEC); as well as spatial configuration as measured by area of usable zone (AUZ) and width to length ratio (WLR). Linear regression analysis using these variables reveals that the physical characteristics of community are related to the density of different staying activities (DSA). Variables of the physical environment are related to staying activities, but the magnitude of the effect differs significantly by age group or activity category.

The results indicated the variation of influential factors in terms of different staying activities. On our premise that staying activities contribute to social interactions, the current results suggest that space design concerned with promoting staying activities may increase social interactions. Furthermore, community design targeted at promoting staying activities might be more effective if the design is tailored to a particular activity category. Therefore, this study can be a first step to create a guideline for community design for promoting social interactions between neighbors, and consequently create opportunities for accumulating evidence-based activity data to modify community design.

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CHAPTER 1 Introduction

1.1 Background of the Study

1.1.1 Importance of community health

In recent years, WHO's (World Health Organization) Health Cities project has gained increasing attention. There are several levels of spatial scale in this project, health development in community scale is one crucial component of this project (WHO, 1985). WHO defined health in its broader sense in 1946 as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO, 2006). Physical, mental, and social health are three aspects of city health as well as community health.

Chinese government has begun to work on health problem for several years and has promoted deeper cooperation with WHO. China even established Health City Cooperation Center in 2013, Shanghai. In their plan for healthy community, the activities among neighbors are emphasized. There is a growing body of evidence that improving a neighborhood's physical environment can increase community health (e.g., Belon et al., 2014) or active lifestyles (Ferdinand et al., 2012). Approaches targeting the influence of physical environment on activities have been evaluated from several perspectives, including health outcomes (Zick et al., 2009) or quality of life (Edwards and Tsouros, 2006). It has been suggested that activities in a community may positively impact community health.

Semenza (2005) indicated that activities in residential communities promote social interactions and mutual support between neighbors, helping maintain residents' physical and mental health as well as prevent crime within a community. This study examines the link between community physical environment and outdoor activities to address the issue of how to encourage residents to partake in various outdoor activities within their communities.

1.1.2 Present issue of housing in China

China's residential communities have changed drastically since the Chinese government initiated a commodity housing policy in 1998. Before this policy, although there were some commodity houses in big cities, the amount was few. Most Chinese citizens from the same company lived in houses provided by governmental organizations within one community.

Because workers from the same company lived together, they were familiar with each other, and social interactions were inherently strong. There are many significant features of this kind of communities: first, the area for a single household was small and most of the housings had little living room for family communications; second, the communal space effected greatly on social interactions, such as sharing public kitchens led to more chances of communication; third, the outdoor spaces were not well designed, the arrangement of landscape was arbitrary. These physical characteristics compelled residents to be active outdoors somehow. People used to have dining together, cooking together, playing together, and they trusted each other very much. If it was needed they even kept neighbors' keys. Although there were not decent official social network in the communities, residents went to outdoor place frequently, and liked to share living resources and supported each other.

However, afterwards new communities were developed as commodities, many people with different backgrounds started to buy these commodity houses. Most new houses were developed by private companies. The physical characteristics have changed and also to the activities. First, there are complete set of rooms including living room, kitchen, shower room and so on. People began to distinguish private space and public space unconsciously. Second, public kitchen and other communal spaces are disappeared and instead of them activity centers and other public facilities are designed. Third, the outdoor spaces are well designed and tended, special plaza for neighbors and other public spaces for communication are installed. Although newly developed communities have improved physical attributes, such as more sophisticated building and open space designs, it has been said that social interactions in these new communities have drastically decreased due to the increased diversity and unfamiliarity with neighbors (Sun, 2010). Social interactions among neighbors are not active like before. People even do not know the name of neighbors. Actually the decrease of social interactions got more and more serious in China. This problem generated physical, mental, and social problems including negative communication, outdoor inactive behavior, and social isolation etc. Hence, a serious issue in China is how to promote social interactions in newly developed communities.

1.1.3 Objectives

As mentioned before, the outdoor activities help to promote social interactions, which contribute to community health. Promotion of outdoor activities supposed to be a crucial way for community health development. Therefore, it is important to explore the user's needs that make a decision to be active outdoors. This study examines the link between neighborhood environment and outdoor activities to address the issue of how to encourage residents to partake in various outdoor activities within their communities. Many researches have explored the specific attributes of the neighborhood environment that meet the outdoor activity needs.

Evidence indicates that improving neighborhood's environment can increase people's activities (Grrenberg, and Renne, 2005; Shamsuddin, Hassan, and Bilyamin, 2012). Dahlgren and Whitehead (1991) postulated that whether an individual, group, or whole community will be active is influenced by a variety of factors at different levels, including individual determinants, social environment, and built environment. However, this study does not discuss individual determinants or the social environment because China's society had developed homogeneously until 1980s, limiting significant cultural or socioeconomic differences without ethnic disparities. Thus, we have focused on the effects of the built environment, namely the objective physical characteristics, on outdoor activities of residents, especially activities that provide opportunities for social interactions.

Research regarding the relationship between physical environment and activity has employed multiple approaches. Some physical characteristics such as accessibility (Alfonzo, 2005; Franzini et al., 2010) and facilities (Robinson et al., 2014) have been demonstrated to affect people's activities. However, the effects of physical characteristics in the context of Chinese society have yet to be explored in depth. This paper aims to elucidate relevant factors of the physical environment that enhance residents' outdoor activities via an intensive survey of newly developed residential communities in China. We also examine the physical characteristics of outdoor spaces that affect activities of different age groups or activity categories. Eventually we can provide environmental design suggestions to promote outdoor activities and then social interactions.

1.2 Previous Researches

Increasing evidence suggests that physical environment plays an important role in promoting physical activities (Abd-Latif et al., 2012). Physical activities mentioned in most past researches refer to any physical movements that help improve or maintain physical fitness (WHO). McKenzie and Cohen (2006) listed the physical activity modes even including sedentary activities, that is to say, the scope of physical activity does not limit vigorous activities. The outdoor activities in this paper include the physical movements and sedentary activities that occur outdoors.

There are two main categories of the literature on investigating the relationships between physical environment and physical activity or outdoor activities. The first category of the literature is concerned with structuring general relationships. Alfonzo (2005) developed an operational social-ecological framework to explain the mechanism of walking, which contribute to build framework of this paper. He proposed some significant environment needs for walking such as feasibility, accessibility, safety, comfort, pleasurability. He explicitly elaborated these needs within the context of his framework. Franzini et al. (2010) then modified Alfonzo's framework for outdoor physical activity (Fig. 1.1).

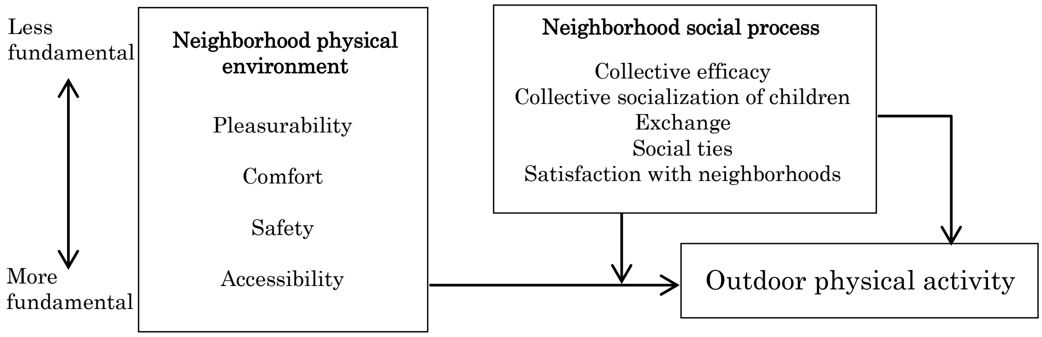


Figure 1.1 Social-ecological framework for outdoor physical activity

(Source: Franzini et al., 2010)

Both Alfonzo and Franzini considered that the decision to be active outdoors is decided not only by physical environment but may be moderated by the social environment. However, China's society had developed homogeneously until 1980s, limiting significant cultural or socioeconomic differences without ethnic disparities. I then excluded social environment and focused on physical environment associated with outdoor activities.

Franzini et al. considered that accessibility, safety, comfort, and pleasurability are the important physical factors, and there is a hierarchy of these factors. Some factors supposed to be more fundamental than others when deciding to be active outdoors. At the most fundamental level, the decision to be active outdoors may depend on accessibility. Safety is the next level of needs, and then the comfort and pleasurability. In the context of China's development, safety issue is not so important like other countries in the wars or where purchasing guns is legally permitted. Therefore, we will not discuss safety in this paper. Further, comfort and pleasurability associate with subjective personal perception and/or cognition. The two factors are excluded for that they are descriptive data which is hard to be described objectively. Moreover, Alfonzo explained the perception of affordance may act as a mediator between accessibility and the behavior outcomes. *Affordances* was proposed by James J. Gibson (1966) as a term to explain the phenomenon that environment consists of action possibilities perceived by users. I postulated that affordances is an influential factor for outdoor activities in this paper.

The second research category focuses on certain cases. A large of body of work was devoted to the environmental properties associated with physical activities including studies of spatial capacity needs (Cohen et al., 2010), accessibility (Aytur et al., 2008; Vine et al., 2013), urban form (Frank et al., 2005), and spatial configurations (Eck et al., 2005). Some work focused on certain groups of people such as adolescents' activities (Bocarro et al., 2012; Motl et al., 2007; Martensson et al., 2014), considerations about elderly's health (Cunningham and Michael, 2004; Li et al., 2005), and women's behaviors (Eyler et al., 2003; King et al., 2005; Stahl et al., 2001). Many researches emphasized the health outcomes of physical activity such as obesity problem (Frank and Andresen, 2004; Zick et al., 2009; Poortinga, 2014), mental health (Mitchell, 2013), blood pressure (Coulon et al., 2013).

In summary, the past researches gave me several hints. I believe that *affordances* associated with supportive function, and accessibility referred as proximity are crucial factors of physical environment. I then separated *affordances* of physical environment into two items: facilities and spatial configuration. Finally, the physical environment will be discussed from three aspects in this paper: accessibility, facilities and spatial configuration.

We learned how to do analysis, and how to observe outdoor activities through these literature reviews. However, we see from these reviews a similarity in basic assessment of physical activities, which is personal physical intensity of activities. This paper investigates outdoor activities in newly developed residential communities in China by statistical measurements, such as number of users, density. Further, categorization of outdoor activities concerning degree of environment dependence will help us discuss the activities related more with social interactions.

1.3 Research Procedure

This research uses an intensive field survey to obtain empirical evidence to analyze influential physical factors and build statistical models. The procedure of this research is shown in Fig. 1.2.

Chapter 1 clarifies the significance and objectives of this study through a discussion of background and literature reviews. Chapter 2 introduces how to select survey sites with clear criteria, how to collect qualitative and quantitative data with an observation method synthesized by methods of behavioral mapping and SOPARC. Chapter 3 summarizes the data obtained. The activities observed are grouped into two categories, and Auto CAD is used to preserve the numerical data such as number of users, and spatial data such as locations. The results of field survey are visually represented by activity maps. Chapter 4 analyzes the influences of accessibility in community scale level. Some relevant variables of accessibility are identified and proved to be influential to outdoor activities. Chapter 5 analyzes the influences of physical characteristics of a subspace on staying activities which is the most important type of outdoor activities. Several physical variables are examined by correlation analysis, and the significance of those variables is elaborated. Chapter 6 proposes regression model for all staying activities. In addition, the models for different age groups as well as activity categories are also developed. Finally, Chapter 7 summarizes what we learned from this study, and describes the perspective of future research.

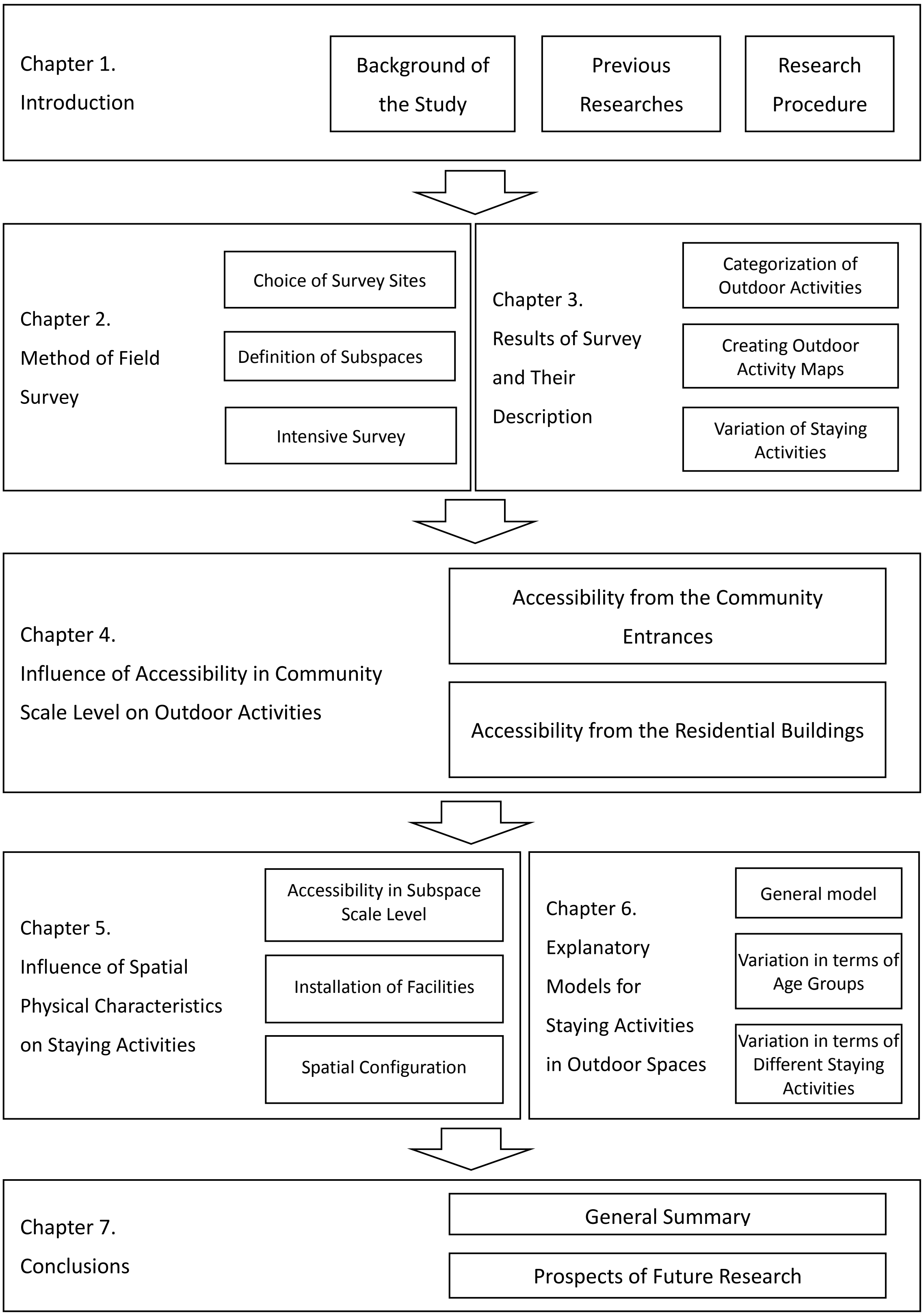


Figure 1.2 Research Procedure

CHAPTER 2 Method of Field Survey

2.1 Introduction

To discuss the effects of physical factors on residents' activity in a scientific manner, a reliable data collection method must be applied. Several methods have been proposed to examine outdoor activities, including statistical analysis using quantitative and qualitative data collection through interviews, observations, and document analysis (Kawulich, 2012). Observations allow existing situations to be described by providing a "written photograph" of the situation under study (Erlandson, 2010). Actual outdoor activity information contains both qualitative content such as occurrence location and quantitative content such as the number of participants. Therefore, an intensive field survey is conducted to collect data with useful direct first-hand information about space use via a systematic observation method.

One of the most notable and widely used systematic observation methods is behavioral mapping, which tracks behavior over space and time (Lippman, 2010). Tracking may focus on a particular place or an individual's movements. Further, McKenzie and Cohen developed an observation instrument for play and recreation in communities called SOPARC (System for Observing Play and Recreation in Communities). SOPARC uses forms to record direct first-hand information about the characteristics of the environment and users. However, this system lacks detailed information about qualitative descriptions such as place relevance. Thus, I combined behavioral mapping with qualitative data, and tools of SOPARC with quantitative data together, and conducted this systematical observation in newly developed communities in China.

The main body of this chapter includes three sections. The first section introduces how to choose the survey sites, the second one talks about a preliminary survey for defining subspaces, and the third one introduced the intensive survey.

2.2 Choice of Survey Sites

The final goal of this paper is to promote social interactions in newly developed residential communities. Furthermore, the objective is to elucidate influence of the physical environment on outdoor activities. Therefore, the survey sites selected should include two features: the communities should be generally different in physical layouts for comparing or extracting relevant physical factors, and the social environment of those communities should be similar for minimizing its effects.

2.2.1 Choice of a city

The survey sites were selected from the residential communities in Tianjin, China because it is one of the first cities to implement the commodity housing policy. It has developed many new residential communities with various physical layouts. In addition, we collaborated with a research group from Tianjin University, who has previously conducted several surveys on the residential communities with us.

2.2.2 Choice of candidate communities based on documents and aerial photographs

Prior to visiting the individual sites, the newly developed residential communities were identified by the documents of Tianjin's urban planning (Fig. 2.1), and their general physical layouts were examined using Google aerial photographs. The communities in newly developed area were examined with a schematic diagram by simplifying the physical layouts based on the aerial photographs (Fig. 2.2).

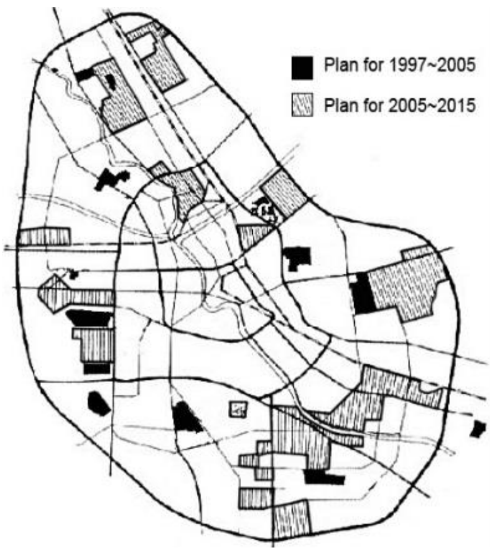


Figure 2.1 Planning of Tianjin's residential area in 1996 (Source: Du et al., 2004)

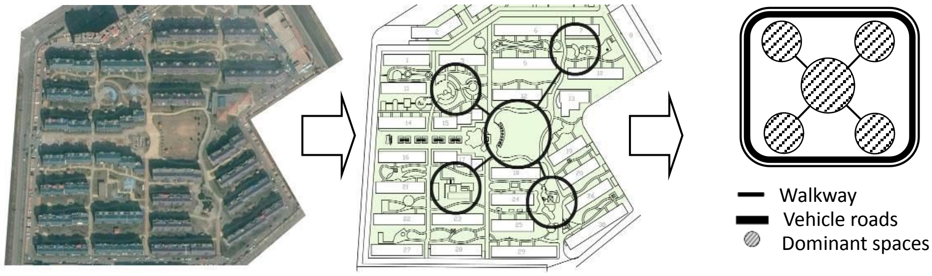


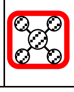
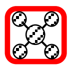
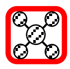
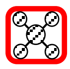
Figure 2.2 An example of schematic diagram of physical layouts

There are two basic types of community physical layouts: one where buildings divide outdoor spaces into several similarly sized pieces and peripheral vehicle roads do not disturb interior pedestrian paths and the one with a large central space surrounded by smaller spaces that are usually separated by vehicle roads. (Fig. 2.3).

Figure 2.3 Two basic types of physical layouts

Moreover, there are two periods of community development in Tianjin, and seven candidate communities were chosen based on their history and types of physical layouts.

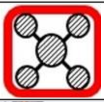
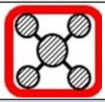
Table 2.1 Basic information of seven candidate communities

Community	Tianhuali	Jiuhuali	Xiangshuiyuan	Fangshuiyuan	Bandaohaoting	Liutianyuanbei	Shuijingcheng
Established year	1998	1999	2002	2002	2004	2004	2005
Types of physical layouts							

2.2.3 Selection of communities based on a pilot survey

As mentioned before selecting proper communities should not only base on the physical layouts. We then examined other data for each community (e.g., size and population). Similarities between size and population were considered to compare the physical differences of outdoor spaces. Furthermore, the communities selected should be similar in social environment. A pilot survey in the candidate communities was conducted in March 2013. Interviews of community managers and some residents revealed that comparatively young communities generally have inactive outdoor space usage due to unfamiliarity within the community and immature social networks. Thus, we selected the four older communities: Xiangshuiyuan (XS), Fangshuiyuan (FS), Tianhuali (TH), and Jiuhuali (JH), while excluding the four younger ones (Table 2.2). In addition, general maps of the selected communities were drawn based on aerial photographs and improved through the onsite pilot survey.

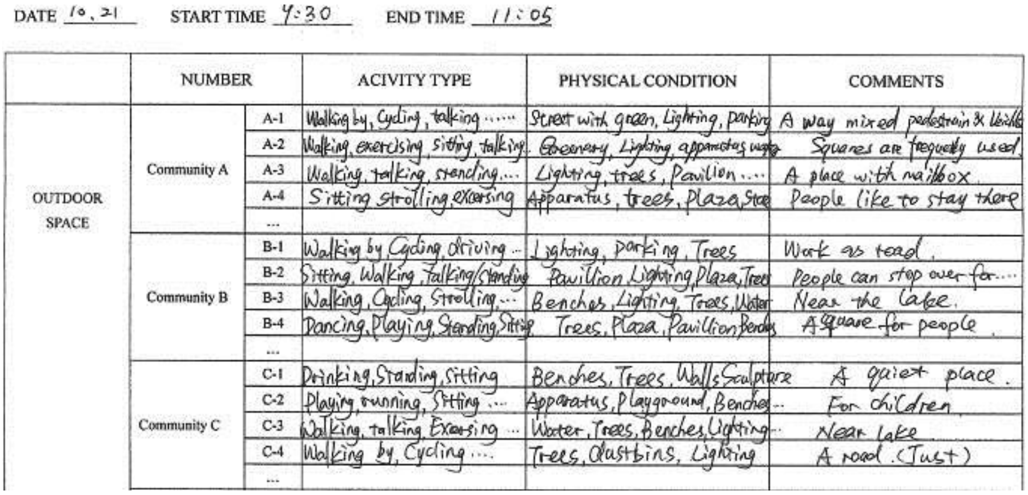
Table 2.2 Basic information of selected residential communities

Community Items	TH	JH	XS	FS
Established year	1998	1999	2002	2002
Population	8000	3800	4300	3500
Area (M^2)	1553	3800	4300	3500
Voluntary activities (○have; ×haven't)	○	○	○	○
Types of space layouts				
Site photos				

2.3 Definition of Subspaces Based on a Preliminary Survey

Because observing all the outdoor spaces in these four communities is infeasible and many outdoor spaces have similar physical characteristics, next representative spaces to observe were selected. First I drew community maps based on aerial photographs. Since this research focuses on activity, a subspace's boarder should be behavioral barriers. I then defined an area of subspaces by behavioral barriers such as building walls and/or edge of wide roads/water using general community maps. This yielded a total of 111 subspaces (20–40 subspaces for each community).

Then I conducted a preliminary survey between 1 and 8 October 2013 to observe and record the basic physical characteristics with regard to outdoor activities. The basic physical characteristics of subspaces including size, boundary conditions (facing to buildings, roads or water), existence of such physical elements as paly equipment, benches, lampposts; were recorded in a datasheet. Figure 2.4 shows an example of the datasheets. Based on these records authors discussed and determined the representative subspaces according to their similarities. Eventually 33 subspaces were selected for the intensive survey (Fig. 2.5).



DATE 10.21 START TIME 9:30 END TIME 11:05

	NUMBER		ACIVITY TYPE	PHYSICAL CONDITION	COMMENTS
OUTDOOR SPACE	Community A	A-1	Walking by, Cycling, talking	Street with green, Lighting, parking	A way mixed pedestrain & Veihle
		A-2	Walking, exercising, sitting, talking	Greenery, Lighting, apparatus ...	Squares are frequently used
		A-3	Walking, talking, standing ...	Lighting, trees, Pavilion ...	A place with mailbox
		A-4	Sitting strolling, exercising	Apparatus, trees, Plaza, Sto	People like to stay there
		...			
	Community B	B-1	Walking by Cycling driving ...	Lighting, parking, Trees	Work as road.
		B-2	Sitting, Walking, Talking/Standing	Pavillion Lighting Plaza, Trees	People can stop over for...
		B-3	Walking, Cycling, Strolling ...	Benches, Lighting, Trees, Water	Near the lake.
		B-4	Dancing, Playing, Standing, Sitting	Trees, Plaza, Pavillion Benches	A square for people
		...			
	Community C	C-1	Drinking, Standing, Sitting	Benches, Trees, Walls Sculpture	A quiet place.
		C-2	Playing, running, Sitting ...	Apparatus, Playground, Benches ...	For children
		C-3	Walking, talking, Exercising ...	Water, Trees, Benches, Lighting ...	Near lake
		C-4	Walking by, Cycling	Trees, Dustbins, Lighting	A road. (Just)
		...			

Figure 2.4 An example of datasheets in the preliminary survey

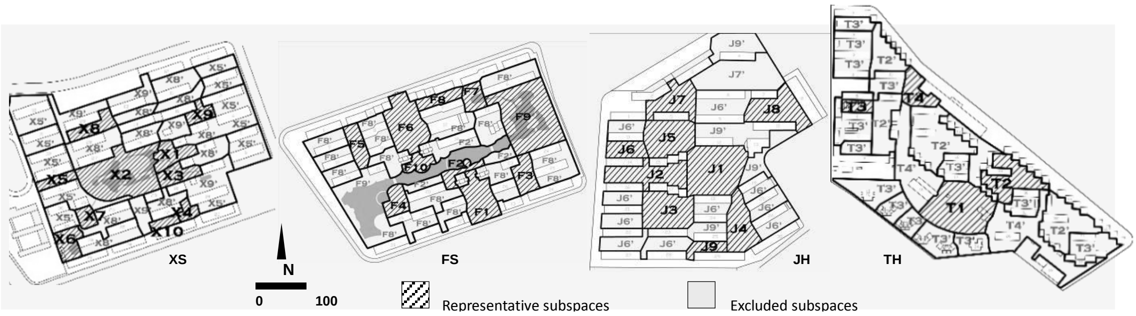


Figure 2.5 Selected subspaces in the four communities

2.4 Intensive Survey

Considering the influences of climate and weather, the intensive survey was conducted on 12 clear days between 10 and 30 October 2013. The temperature during the observation time (9:00-17:00) was 13~20℃. Considering the influence of time of the day on outdoor activity, we divided observation time into 4 time periods (9:00-10:30, 10:30-12:00, 13:00-15:00, and 15:00-17:00), and observed each subspace more than 2 times in every time period. Intensive survey had two steps: investigate the physical environment and observe outdoor activities.

2.4.1 Investigation of physical environment

We investigated the physical environment of each subspace initially using an environment datasheet (Fig. 2.6) to collect the data with a detailed site plan, information of the physical elements, and facilities.

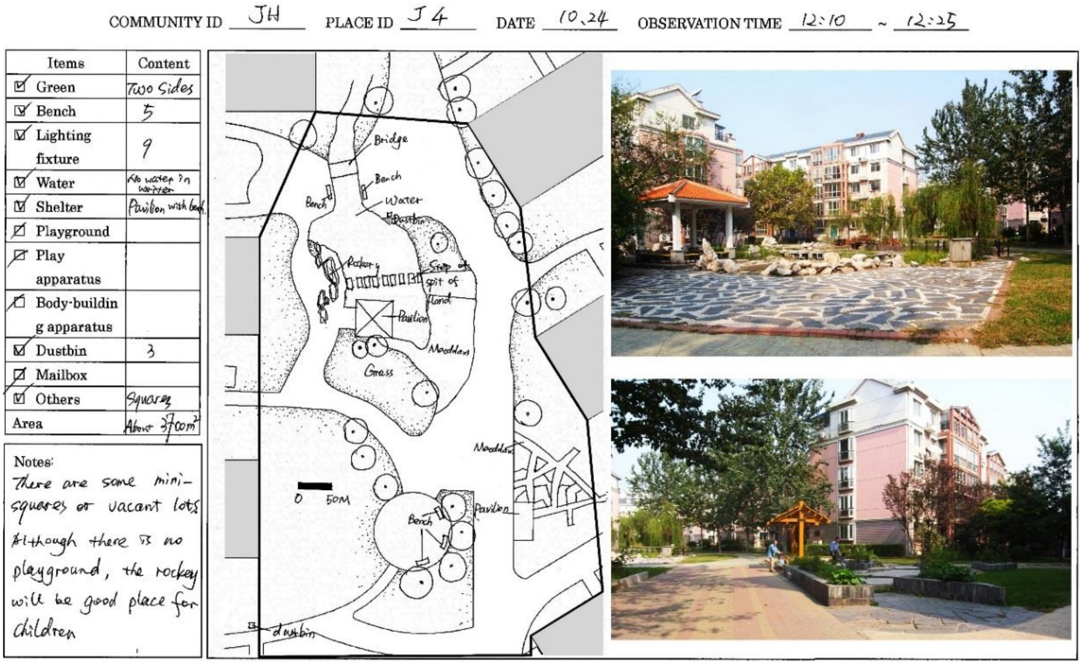


Figure 2.6 An example of environment datasheets

The data included information such as the plan of subspaces, the physical elements, site photos, and some comments. We also took site photos of unobserved subspaces. Auto CAD was used to draw the plans to preserve vector information, the general plans of unobserved subspaces were completed by aerial photographs and environment datasheets.

2.4.2 Systematic observation of outdoor activities

On the other hand, activity data were recorded using an activity observation datasheet (Figure 2.7), which is a synthesized tool for behavioral mapping and a statistical activity observation system named SOPRAC (Mckenzie and Cohen, 2006).

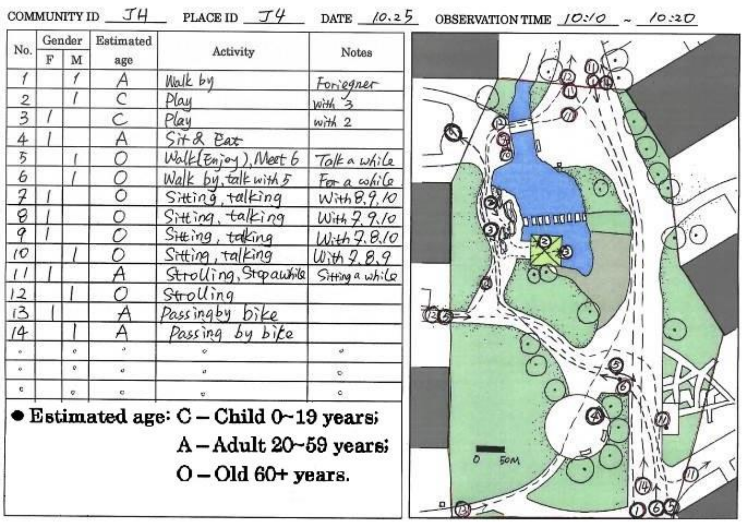


Figure 2.7 An example of activity observation sheets

The data included information such as activity contents, users' behavioral maps, and individual attributes (gender and estimated age). A typical observation session lasted about 10 minutes, but depending on the subspace size some sessions lasted about 20 minutes. Each subspace was observed twice (once in the morning and once in the afternoon) on five different days (three weekdays and two weekends). Thus, ten activity observation datasheets were collected for each subspace.

2.5 Summary

The first part of this chapter explained how I selected survey sites with criteria at different levels. Until proper communities were chosen based on a pilot survey, I defined and divided the outdoor spaces into subspaces through preliminary survey. The last part introduced how to collect qualitative and quantitative data. The observations recorded direct first-hand information about the environment and outdoor activities, which synthesized conventional observation tools such as behavioral mapping and SOPARC. The results of field survey caught the movements of people and their attributes under specific spaces.

CHAPTER 3 Results of Survey and Their Description

3.1 Overall Result of Intensive Survey

The 330 activity observation datasheets (33 subspaces × 10 times) contained data for 7668 users' activities. Table 3.1 shows the obtained data according to the attributes of the users. In addition, 33 physical environment datasheets were obtained, which help to complete detailed site plans.

Table 3.1 Results of the activity observations

Attributes		N	%
Gender	Female	3649	47.6
	Male	4019	52.4
Estimated age	0-19	1104	14.4
	20-59	4242	55.3
	60+	2322	30.3
Total		7668	100

3.2 Categorization of Observed Outdoor Activities

Several researchers have defined activities according to their own research needs. In this paper, outdoor activities include both physical movements and sedentary activities that occur outdoors, which are generally divided into passing and staying activities, respectively. In the former, a user traverses through a subspace, whereas in the latter, a user stops or remains in a subspace. Hanazato and Kim (2011) also grouped observed activities into passing and staying activities, and argued that staying activities are more related to social life. Similarly, we hypothesize that a staying activity may contribute to social interactions. Furthermore, we proposed a more detailed categorization of outdoor activities as shown in Table 3.2.

Table 3.2 Categorization of outdoor activities

Category	Subcategory		Environment dependence	Symbol
Passing activities	Cycling through		Participants have little concern about environmental quality, while passing through a subspace.	⟶
	Walking through			
	Strolling		Participants may enjoy the environmental quality, while passing through a subspace on foot.	- - - - ->
Staying activities	Occasional stoppings			- - ● ->
	Longtime staying	Sedentary activities	Participants do something or remain in a subspace. Their activities are supported by the environment.	○
		Vigorous activities		○↓

There are three subcategories of staying activities: 1) occasional stoppings refer to activities that users stop in the subspace for a short time (less than 1 minute); 2) sedentary activities refer to such activities as sitting, standing that users remain in a subspace more than 1 minute without locomotion; and 3) vigorous activities refer to such activities as exercise, playing football that users remain in a subspace more than 1 minute with locomotion.

3.3 Creating Outdoor Activity Maps

Because the outdoor activities were generally divided into passing and staying activities, I developed two types of activity maps (passing and staying activity maps) to visualize the data.

3.3.1 Passing activity map

Since the passing activities occur along with paths. Thus, to create a passing activity map, each site map was simplified into a path network where the path nodes were labeled and each path was defined by the node name of its two ends (Fig. 3.1). Then the flow of passing activities were summarized in the path network.

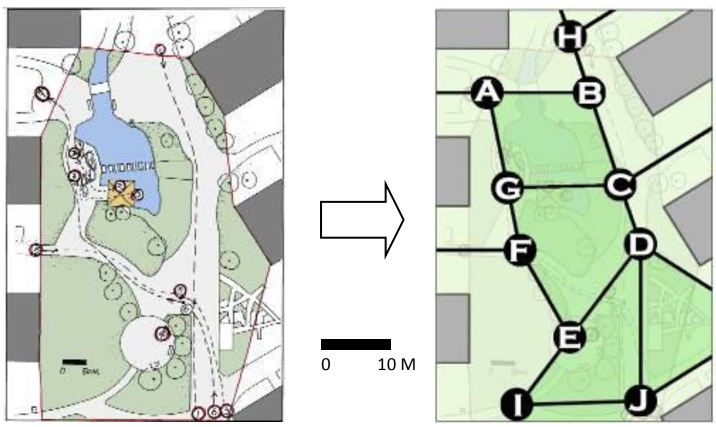
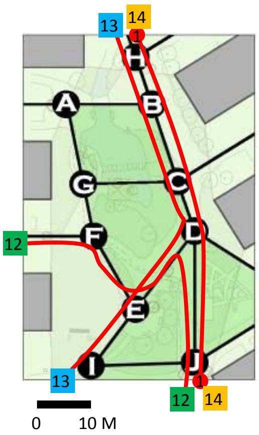
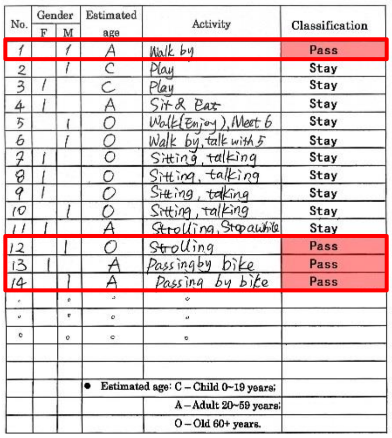


Figure 3.1 An example of simplifying path network of subspaces

The next step of creating passing activity maps is to give line thickness to the paths in the network with numerical information. First, we calculated the number of users for each path according to the activity observation sheets in which passing activities were separately tabulated (Fig. 3.2).





No.	Gender F	Gender M	Estimated age	Activity	Classification
1		1	A	Walk by	Pass
2		1	C	Play	Stay
3	1		C	Play	Stay
4	1		A	Sit & Eat	Stay
5		1	O	Walk(Enjoy), Meet 6	Stay
6		1	O	Walk by, talk with 5	Stay
7	1		O	Sitting, talking	Stay
8	1		O	Sitting, talking	Stay
9	1		O	Sitting, taking	Stay
10		1	O	Sitting, talking	Stay
11	1		A	Strolling, Stop awhile	Stay
12		1	O	Strolling	Pass
13	1		A	Passing by bike	Pass
14		1	A	Passing by bike	Pass

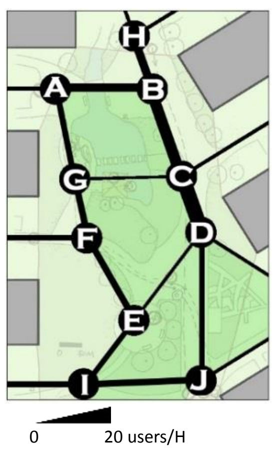
● Estimated age: C – Child 0~19 years; A – Adult 20~59 years; O – Old 60+ years.

User No. / Paths	1	12	13	14	Users in other sheets	Total
H-B	1		1	1	…	8
B-C	1		1	1	…	7
C-D	1		1	1	…	9
D-E		1	1		…	5
D-J	1	1		1	…	4
E-I			1		…	3
E-F		1			…	4
F-		1				2
A-						3
J-	1	1		1		15
I-			1			6
…	…	…	…	…	…	…

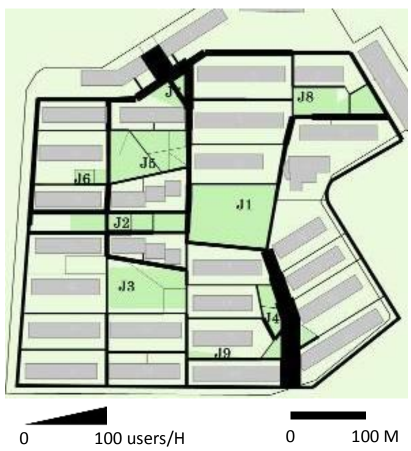
Tabulation of passing activities

Figure 3.2 An example of calculating flow of passing activities

Because the total observation time varied from 100 to 200 minutes (10 times), we converted the number of observed passengers into the estimated number of people per hour (person/h). Varying the line thickness allowed the traffic flow due to passing activities to be visualized on the map. Since the selected subspaces are representatives of similar subspaces in a community, activities in subspaces not directly observed were estimated using the data from the group representative. Eventually a map of passing activities was constructed using actual and estimated data (Fig. 3.3).



Subspace passing activity map



Community passing activity map

Figure 3.3 An example of creating community passing activity maps

3.3.2 Staying activity map

Because staying activities data are related to the location in the subspaces (recorded in sedentary and vigorous activities), user locations in one hour were marked on the staying activity map using dots (Fig. 3.4 (a)). Similar with the passive activity maps, the staying activity maps were constructed using actual and estimated data (Fig. 3.4 (b)).

● User location ● User location

(a) Staying activity map of subspace (b) Staying activity map of community

Figure 3.4 An example of creating staying activity maps

3.4 Variation of Staying Activities

In this paper staying activities mean that a user stops or remains in a subspace, which potentially contribute more to social interactions and depend on environment more. Since the long-term goal of this paper is to promote social interaction among residents for rebuilding healthy residential communities, it is precise to say that staying activities are the main subject of this research. I presume that more passengers passing through a subspace increase the likelihood of staying activities, therefore passing activities can be used to test potential influential factor for staying activities.

At first the number of users involved in staying activities was calculated according to activity observation datasheets. However, the numerical data of staying activities for individual subspaces cannot be directly compared because the community populations differ. Therefore, we used the proportion of the number of users to the total community population to determine the density of staying activities (DSA) calculated as below:

$$\mathrm{DSAn} = {Pn}/{P}$$

Where DSAn: Density of users of staying activities in subspace N;

P: Community population;

Pn: Number of users (staying activities) per hour in subspace N.

The density of staying activities (DSA) will be used to examine the variation of staying activities in different subspaces.

3.4.1 Variation of staying activities in different activity category

Staying activities have been divided into three subcategories: occasional stoppings, sedentary activities, and vigorous activities. Occasional stoppings refer to activities that users stop in the subspace for a short time (less than 1 minute) when he/she traverses through a subspace. Sedentary activities and vigorous activity refer to activities that users remain in a subspace more than 1 minute. While in the former, users remain in a subspace without locomotion such as sitting, standing, whereas in the latter, users remain in a subspace with locomotion such as exercise, playing football and so on.

Using formula proposed for DSA, I calculated the densities of staying activities (DSA) for different subcategories, then arranged the order of total DSA from big to small (Fig. 3.5).

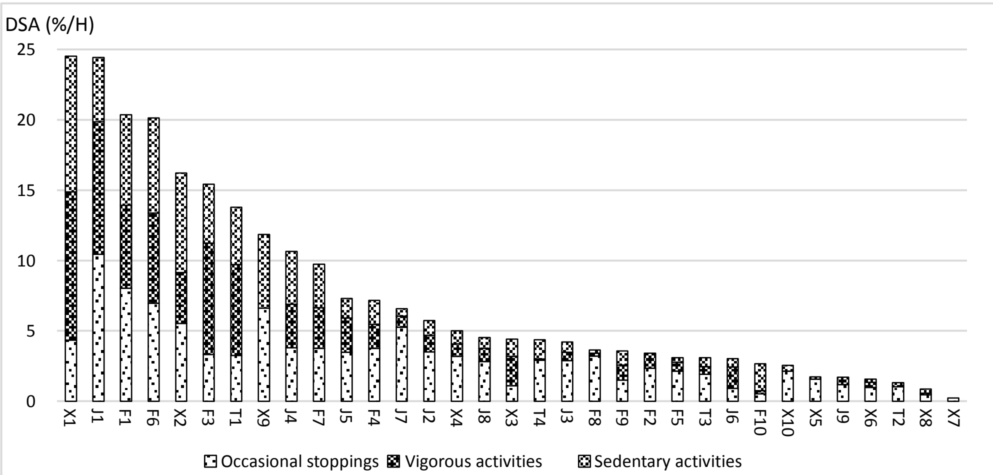


Figure 3.5 Density of different staying activities in 33 subspaces

From Fig. 3.5 we can understand the quantitative data of staying activities in different subspaces. First the popularity of subspaces presents change. There are some subspaces effectively used such as X1, J1, F1 and so on, there are also some subspaces not popular such as X7, X8, T2 etc. The subspaces not well used cannot explain the change of staying activities because the data were too small. Therefore, comparatively not well used subspaces (DSA<5%/H) are excluded.

Then, the disparities of different staying activities in comparatively well used subspaces (DSA ≧5%/H) are discussed to explain the activity feature of subspaces. Although there are three subcategories of staying activities, the staying activities can be summarized into two groups: occasional stoppings, and longtime staying (including sedentary and vigorous activities). As mentioned sedentary/vigorous activities supposed to spend more time in a subspace than occasional stoppings, I call them “longtime staying” as a whole. Fig. 3.6 shows the activity data of occasional stoppings (OSA) and longtime staying (LSA) in comparatively well used subspaces.

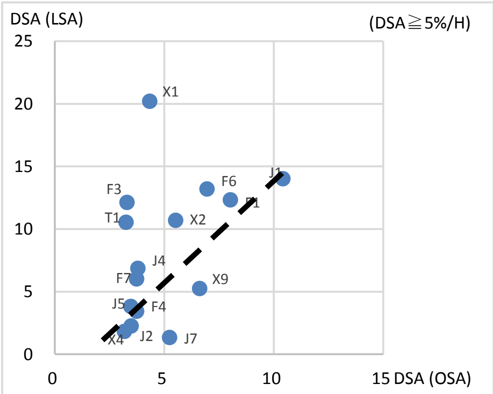


Figure 3.6 DSA of occasional stoppings and longtime staying in active subspaces

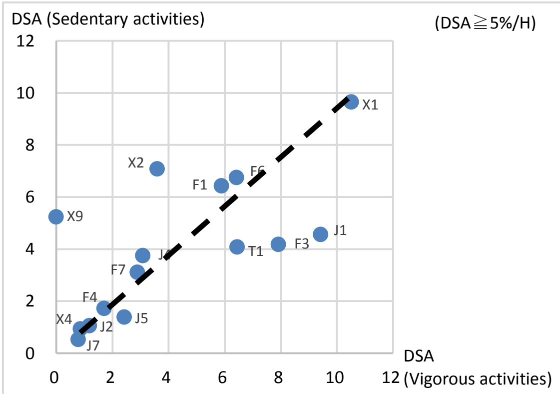


Figure 3.7 DSA of sedentary activities and vigorous activities in active subspaces

Fig. 3.6 suggests that occasional stoppings (OSA) usually occur more than longtime staying (LSA) in active subspaces, which means that occasional stoppings (OSA) are the dominant type of staying activities. Interestingly the ratio of OSA to LSA are similar in most of the active subspaces, implying that OSA may associate with LSA. However, some subspaces have much more LSA than OSA such as X1, T1, and F3, and some subspaces have more OSA than LSA such as X9, and J7. I then found that there are some common points between these different subspaces. Both X1, T1, and F3 have play equipment and playground, whereas J7 and X9 are mainly composed of paths or roads.

Further, the composition of longtime staying (LSA) in active subspaces is examined (Fig. 3.7). The result suggests that the users of sedentary activities and vigorous activities are almost the same in most of active subspaces, but some subspaces are different. In the subspaces named X2 and X9, more users did sedentary activities like sitting, standing (including talking) etc. I found that X2 has lots of seats which attract people staying sedentarily, and X9 have a shop attracting people standing and talking. By contrast, in the subspaces called J1, T1, and F3, vigorous activities occur more than sedentary ones. J1, T1, and F3 have play ground or objects for playing such as play equipment, or rockery stones.

The disparities of different staying activities can help us understand the activity characters of subspaces. The results suggest some potential influential variables of physical environment such as playing object (including play equipment), shops, playground, roads, and seats. The following chapters will explore influential variables of physical environment, and their influences on staying activities will be elaborated.

3.4.2 Variation of staying activities in terms of time

The observation of outdoor activities was scheduled. A typical observation session lasted about 10 minutes, but depending on the subspace size some sessions lasted about 20 minutes. Each subspace was observed twice (once in the morning and once in the afternoon) on five different days (three weekdays and two weekends). Since the selected subspaces are representatives of similar subspaces in a community, the data of unobserved subspaces were estimated same with the group representative. Eventually the density of all staying activities in terms of time could be calculated.

First, I examined the disparities in the morning and afternoon. It is found that community JH and TH are more active in the morning, whereas community XS and FS are more active in the afternoon (Fig. 3.8). The reason may relate with individual determinants of residents such as daily routine.

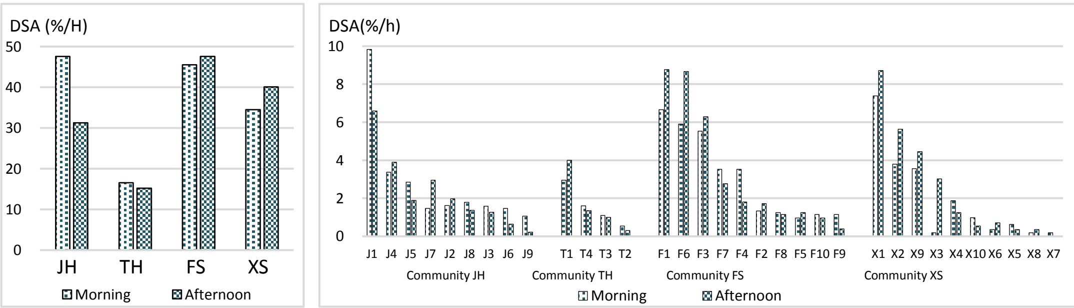


Figure 3.8 Disparities of staying activities in the morning and afternoon

For individual subspace, some changes had been found. Although community JH is more active in the morning, some subspaces seem to go in opposite such as J2, J4, and J7. I then found that both of the three subspaces are directly connected with community entrances. Whereas it is different for community TH. T4 connected with community entrance is in line with community trend, and T1 in the center part of community is opposite to community trend – being active in the afternoon. About community FX and XS, F4, F7, F9, F10, X4, X5, and X10 present differently with community trend – being active in the morning. Both of these subspaces are not directly connected with community entrances. Although there are not common trends of staying activities among subspaces, the disparities in morning and afternoon suggested that the location of subspaces may effect on staying activities.

Second, I examined the disparities of staying activities in the weekdays and weekends. It is found that community JH and TH are more active in the regular days, and community XS and FS are more active in the weekends (Fig. 3.9).

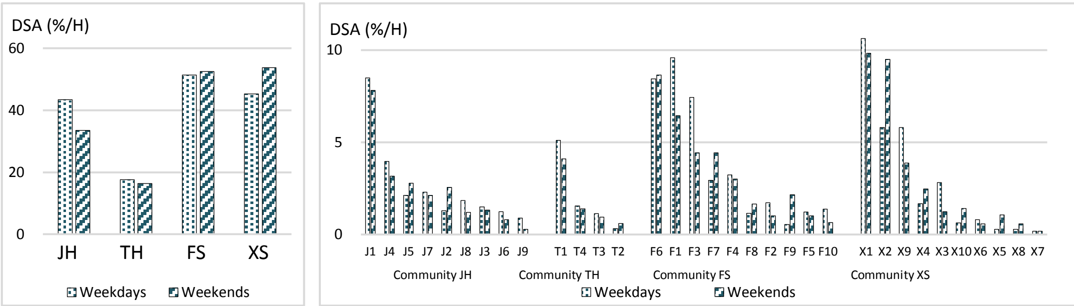


Figure 3.9 Disparities of staying activities in the weekdays and weekends

For community JH and TH, some subspaces seem to go in opposite such as J2, J5, and T2. Whereas for community FS and XS, opposite to community trend many subspaces are more active in regular days, such as F1, F2, F3, F4, F5, F10, X1, X3, X6, and X9. All of these subspaces locate in different place. Some are near community entrances such as J2, F1, and X9; some are in the center part of the community like X1; some have play equipment such as J5, F3, and X1. There are not obvious similarities among their activities and physical characteristics.

Although it is found that some physical characteristics such as location may have potential influence on disparities of staying activities, the environmental influences and activity disparities do not show obvious common trends in terms of time. Therefore, the relationships between physical factors and staying activities in terms of time will not be discussed more in this paper.

3.5 Summary

7668 user's activities were obtained through intensive field survey. Basically I drew the outdoor activity map by Auto CAD files, the numerical and spatial data in the PC memory can be used to analyze the physical environment quantitatively. For instance, the number of passengers on a particular path, which is presented as the width of the path, can be used for analytical purposes. The methods used in this chapter combining behavioral mapping with conventional observation tools (behavior mapping and SOPARC), provides direct information about residents' space use. Outdoor activities are defined and classified into passing and staying activities in terms of environment dependence. For each activity type, we developed a new way to visualize data in the form of qualitative and quantitative maps, which allow information to easily be ascertained.

Further, disparities of staying activities were examined. Some common tendency has been found among different staying activities, and some potential physical variables have been suggested which will be discussed for staying activities. There is not significant common tendency between the staying activities in different time, the change in terms of time will not be discussed.

CHAPTER 4 Influence of Accessibility in Community Scale Level on Outdoor Activities

4.1 Introduction

Basically the intensive survey provided two groups of data: one is outdoor activity maps, and the other is detailed site maps with physical information. The former one is preserved in the PC memory contain numerical activity data, and I will abstract physical data according to needs from the latter one. In other words, I need to translate the detailed site maps into quantitative data of physical environment to explain activity data.

Franzini et al. (2010) suggested that accessibility is the most fundamental characteristic of neighborhood physical environment for outdoor physical activity, and the analysis of disparities of outdoor activities in terms of time suggested the location of subspace matters, related to accessibility. Herein I treated accessibility as one significant factor of physical environment for outdoor activities. The current study assesses accessibility at two levels: the community-level and the subspace-level. The community-level accessibility discusses the location of a subspace in a community, while the subspace-level accessibility discusses the spatial component associated with accessibility.

The accessibility in community scale refers to the ability from a point to access a space (Ingram, 1971), is defined as the easiness of access from a point to a target subspace in this paper. There are two start points considered: community entrances and residential buildings. This chapter will discuss the accessibility in community scale, and explain the associations between outdoor activities and accessibility in community scale.

4.2 Accessibility from the Community Entrances

Although we can intuitively understand the distribution of activities with the site maps, it is necessary to describe the relationship between accessibility and outdoor activities objectively. From the outdoor activity maps, the number of users seems to be related to the proximity to community entrances, which is named as the accessibility from community entrances. The qualitative data (spatial location) can be transferred into numerical data using a space syntax method (Hillier, 2007). There are three basic conceptions in space syntax analysis: convex space, axial space, and isovist space (Klarqvist, 1993). The convex space analysis examines the connections between convex spaces. A convex space is an occupiable void where no line between two of its points goes outside its perimeter. Axial space analysis depicts the least numbers of axial lines (sight line) possible to follow on foot covering all convex spaces of a layout and their connections. Isovist space analysis examines the visual step of convex spaces that are visible from a start point. Because the former two methods cannot analyze the depth from a point, isovist space analysis is used to calculate the visual depth from a point, which was considered as accessibility from a community entrance in this paper. The visual depth is not actual metric distance, it is psychological distance of vision, which can lead us to describe the community spatial characters with reference to accessibility and visibility (Tahar & Brown, 2003).

In this paper, a technic software of space syntax – UCL Depthmap (Pinelo and Turner, 2010) is used to measure visual depth. One of the function of the software named visibility graph analysis (VGA) can generate the visibility graph with visual step depth (VSD) data from an entrance to certain locations. We then use the VSD graph to calculate spatial visual step depth (SVSD) as a measure of accessibility from community entrances.

VSD data illustrates the number of visual steps necessary to go from one start point (such as an entrance) to another analysis point in the graph. An analysis point is a symbolized square generated by a grid, whose spacing is fixed as 20 centimeters in this study. The start point was set to the center of an entrance. Each visual step is shaded separately in the graph, and multiple VSD graphs are generated because multiple entrances typically exist for a community (Fig. 4.1 (a)). In order to synthesize the VSD data of each entrance into one graph, the weight of significance of each entrance was used to assess VSD from all entrances (EVSD). We presume that more passengers passing through an entrance increase the likelihood of its significance. Therefore, we estimated number of passengers in each entrance by the result of passing activity observation in the subspaces which is directly connected to the entrance, and the weight of significance of an entrance is calculated by the ratio of passengers of an entrance to the total as below. Then community visibility graph can be generated with EVSD data (Fig. 4.1 (b)).

$$\mathrm{EVSDm} = \sum \left(VSDn * Pn/_{P} \right)$$

Where EVSDm: Visual step depth from all entrances in community M;

VSDn: Visual step depth from entrance N;

Pn: Number of passengers of entrance N;

P: Total number of passengers of all entrances in community M.

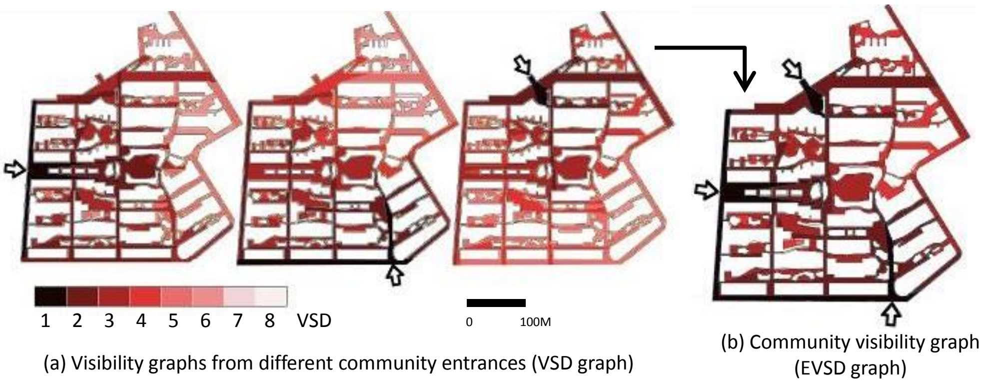


Figure 4.1 Synthesizing community visibility graph for community JH

However, EVSD is for an analysis point, and there are many points in a subspace. Therefore, I can define different VSD related variables in terms of analysis needs. There are two variables proposed for passing activities and staying activities respectively. The VSD data of paths named PVSD (paths' visual step depth) are for analyzing passing activities, and SVSD (spatial visual step depth) data are for analyzing staying activities.

4.2.1 Influences on passing activities

First, the influences of accessibility to community entrances on passing activities were considered. The EVSD graphs help to extract VSD data of paths (named as PVSD) by calculating average value of EVSD along the paths. Besides, the number of users per hour for each path can be read from passing activity maps. I then analyzed the influence of the PVSD on passing activities by correlation analysis. Fig. 4.2 shows the result for community JH.

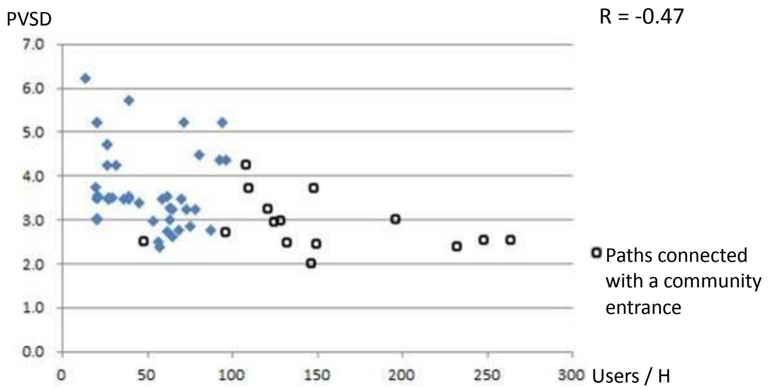


Figure 4.2 Relationship between PVSD and passing activities in community JH

The circles represent paths that directly connect to a community entrance. As expected, paths more close to an entrance may have more passengers. A similar tendency was observed in other communities, implying that the influence of accessibility to community entrances on the passing activities is fairly well described by applying the VGA method.

4.2.2 Influences on staying activities

I postulated that the location of a subspace in the community results in different distributions of staying activities, and more people passing through a subspace increase the likelihood of staying activities. As discussed in previous section, the effect of PVSD on passing activities is notable, implying that the visual step depth from all entrances (EVSD) may be influential to staying activities. Because EVSD data are for analysis points, and there are many points in a subspace. I then calculated the spatial visual step depth (SVSD) using the average value of EVSD inside a subspace. I then calculated VSD value for each subspace by community visibility graphs as below.

$$\mathrm{SVSDn} = \sum \left({}^{EVSDm}/_{M} \right)$$

Where SVSDn: Spatial visual step depth of subspace N;
EVSDm: Visual step depth from all community entrances to point M;
M: Number of analysis points in subspace N.

Using formula mentioned in Section 3.4, I calculated the density of all staying activities (DSAa) for each subspace, and then examined the relationships between DSAa and SVSD (Fig. 4.3).

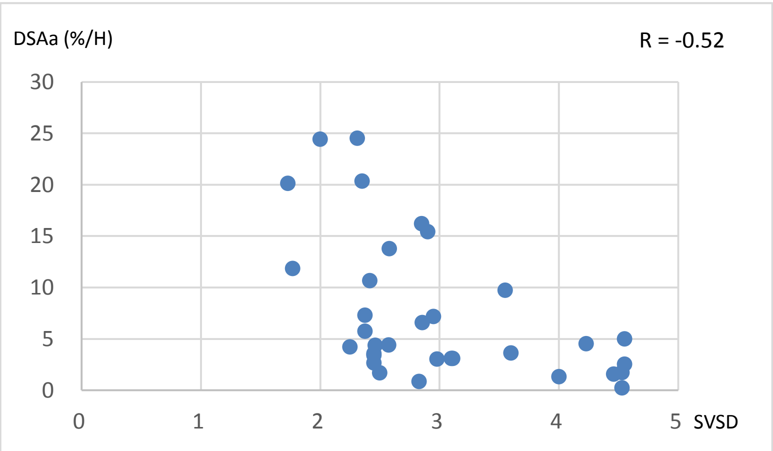


Figure 4.3 Influence of spatial visual step depth on all staying activities

From Figure 4.3 it is found that the SVSD is fairly well correlated to the staying activities, which suggests that a reduction of SVSD associates with an increase in staying activities. It means that the accessibility from community entrances may well describe staying activities. I will consider spatial visual step depth (SVSD) as an important variable for staying activities in

Chapter 5 and 6.

4.3 Accessibility from the Residential Buildings

The other point connect with outdoor spaces need to be considered that is residential buildings. By contrast, accessibility from residential buildings uses common measures of accessibility and distance (Makri and Folkesson, 1982). The shortest distance within usable paths from residential buildings is proposed as the indicator named accumulative distance (AD) to show accessibility from the residential buildings. AD was calculated by summing up all the shortest distances from the exit of every building in the community to a subspace as below.

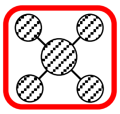
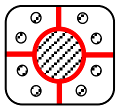
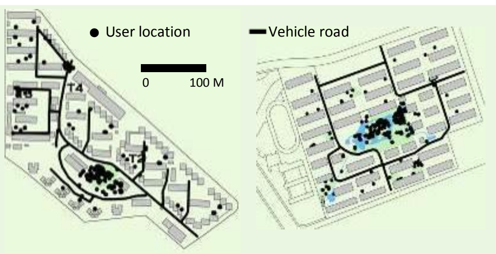
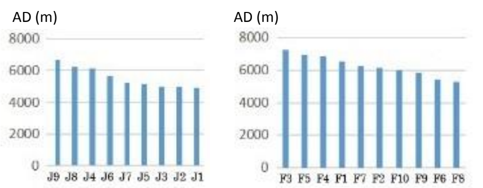
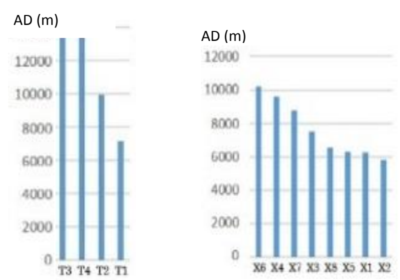
$$\mathrm{ADn} = \sum Dn$$

Where ADn: Accumulative distance of subspace N;

Dn: Shortest distance from a building to subspace N.

Table 4.1 shows the accumulative distance data of subspaces in the four communities with other information.

Table 4.1 Accumulative distance and other data of the four communities

	Community JH	Community FS	Community TH	Community XS
Type of physical layout	 Buildings divide outdoor spaces into several similarly sized pieces and peripheral vehicle roads do not disturb interior pedestrian		 A large central space surrounded by smaller spaces that are usually separated by vehicle roads.	
Staying activity map				
AD of subspaces				

Communities JH and FS shown in the left hand side in the Table 4.1 have the physical layout where buildings divide outdoor spaces into several similarly sized pieces and peripheral vehicle roads do not disturb interior pedestrian paths. By contrast, communities TH and XS shown in the right hand side have the physical layout with a large central space surrounded by smaller spaces that are usually separated by vehicle roads. For the first type of community, the AD are similar among the subspaces, while the AD greatly differ in the second type of community. It suggests that changes of AD in one community may explain the types of physical layout. So that if the influence of AD on staying activities was great, it will be possible to determine which type of space layout is beneficial to staying activities.

Then the influence of AD was examined by correlation analysis between AD and density of all staying activities (DSAa) of subspaces (Fig. 4.4).

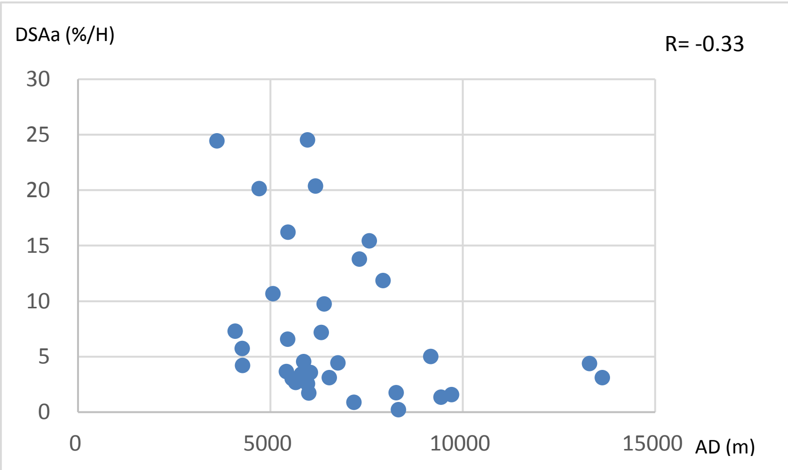


Figure 4.4 Influence of accumulative distance on all staying activities

For each subspace, the AD may be not so well correlated with user density (Fig. 4.4), suggesting that easy access into a subspace from a residence influences users' choice not so much as I expected. Thus, it is hard to measure which type of physical layout is beneficial to staying activities. The reason may be that residents are familiar with subspaces in their small communities, which make distance insignificant to residents' choice of staying, or that the community size selected is small which lead to little comparability of ADs.

However, the community DSA (total user density) is much higher in the first type of community. JH and FS are 25.75%/H and 26.16%/H, while TH and XS are 10.49%/H and 19.45%/H, respectively. The result clearly demonstrates that the physical layout affects staying activities.

Moreover, if we focus on the comparatively well used subspaces (DSA≧11%/H), the accumulative distance (AD) may fairly well explain staying activities as shown in Fig. 4.5. It implies that most active subspaces are close to residential buildings.

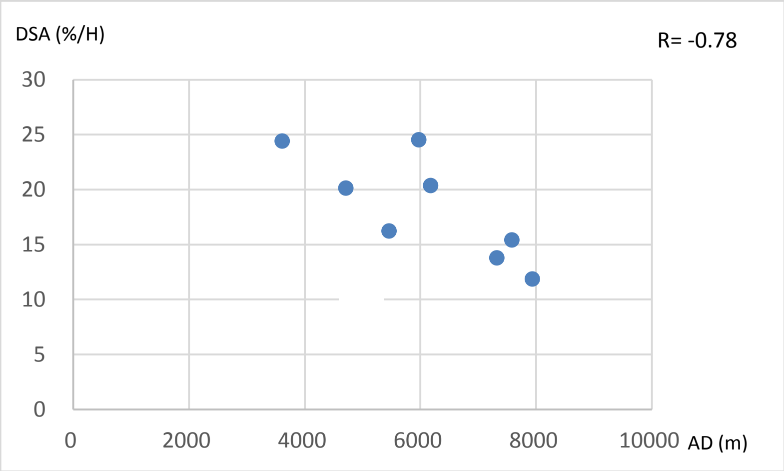


Figure 4.5 Influence of accumulative distance on all staying activities (N=8)

4.4 Summary

This chapter explored the relationships between the accessibility in community and outdoor activities. The results can be concluded as following:

(1) The accessibility from the community entrances including PVSD and SVSD could fairly well describe passing activities, and staying activities respectively. Further, SVSD may be influential variable for staying activities. Although the accessibility from residential buildings (AD) is not well correlated with staying activities, the relevance of AD and physical layout indicates that AD may well explain the type of physical layout.

(2) If we focus on the comparatively well used subspaces (DSA≧11%/H), the accumulative distance (AD) may be fairly well explain staying activities, and most active subspaces are close to residential buildings.

Although the results of this chapter generally examined the influences of accessibility in community scale level, potential effects of spatial physical characteristics cannot be neglected. As I believe that staying activities contribute to social interactions, that is to say, staying activities are the main object of this research. Thus, the next chapter will discuss more specific characteristics of individual subspace that effect on staying activities.

CHAPTER 5 Influence of Physical Characteristics of Subspace on Staying Activities

5.1 Introduction

The final goal of this paper is to promote outdoor activities especially the activities that contribute to social interaction among the residents and eventually to rebuild healthy social network of residential communities. I postulated that staying activities are beneficial to social interactions for their potential contribution to daily social life and help increase social interaction among neighbors. Therefore, it is precise to say that staying activities are the main focus of this research.

In Chapter 4, we discussed the influence of accessibility on staying activities in community scale level. This chapter discusses the influence of spatial physical characteristics in subspace scale level. Before I develop a comprehensive model to estimate staying activities, it is necessary to extract and examine potential physical variables.

As mentioned in Chapter 1, there is an operational social-ecological model for outdoor physical activity (Franzini et al., 2010) indicated that accessibility is fundamental or necessary in the decision to outdoor physical activity. As applied to staying activities, accessibility will help to determine whether the space is easy to approach. Therefore, I will introduce the accessibility in subspace scale as a potential variable of spatial physical characteristics.

Beside accessibility, another influential factors for staying activities are facilities and spatial configuration. Facilities refer to the environmental elements that support certain behaviors, spatial configuration refers to the shape of a subspace potentially effect or support certain action.

5.2 Accessibility in Subspace Scale Level

Accessibility in community scale level refers to the easiness of access from a point to a target subspace, whereas accessibility in subspace scale level refers to the spatial characteristics of a subspace, which can be generally examined by three variables: visual accessibility, physical accessibility, and vehicle intervention.

5.2.1 Visual accessibility of a subspace

For most past researches visual accessibility refers to the effectiveness of visual recognition of environment (Legge, et al., 2010), in this paper we excluded the influence of light, and extracted the factor of spatial characteristics which associated with effectiveness with which vision can travel. Visual accessibility of a subspace (VAS) in this paper is considered as a measure of visibility from the surrounding area, it shows how easy a subspace can be seen or found by people.

In my definition of visual accessibility of a subspace, the subspace has been seen as a whole. Thus, openings can explain the visual accessibility. Openings refer to the edge of a subspace which is not a barrier of vision, the opaque more than 2 meters high (like buildings, fences etc.) can be seen as a visual barrier in this paper. Some general considerations to measure VAS are proposed: total length of openings (Lo), and evenness of the openings' distribution (EOD) (Fig. 5.1).

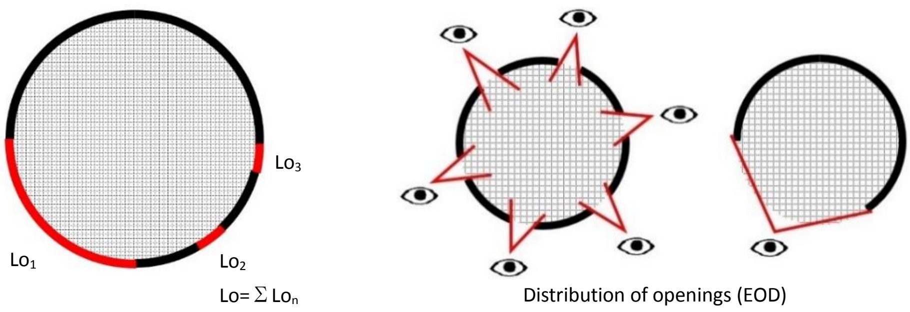


Figure 5.1 Diagram of conception of visual accessibility of a subspace (VAS)

In common sense, the longer the length of openings (Lo) is, the visual accessibility of a subspace (VAS) should be better. Further, the distribution of openings (EOD) is more even, people can find the subspace from more comprehensive directions, which means VAS will be better. Then I defined visual accessibility of a subspace (VAS) is measured statistically as below.

$$\mathrm{VAS} = \mathrm{Lo} * \mathrm{EOD}$$

Where Lo: Length of openings of a subspace;

EOD: Evenness of openings' distribution.

A stable assessment for Lo and EOD was used by projecting the openings onto the sides of a rectangle, which reflects a subspace's shape in plan (Fig. 5.2). The rectangle has the nearest area with original size, where the length of projected openings can be calculated into Lo by adding them altogether.

For EOD there are many ways to describe the evenness of openings' distribution such as the inverse number of standard deviation (SD). However, if there is only one opening of a subspace, SD will be 0, SD is not proper one. Thus, I defined general rules to assess EOD.

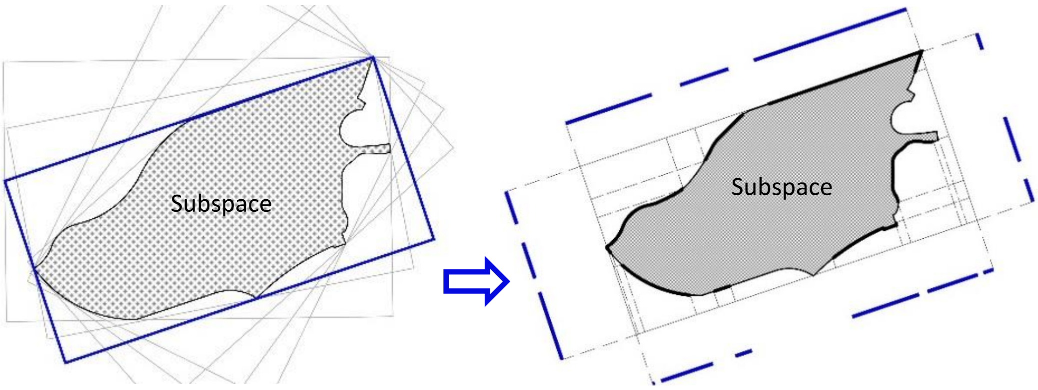


Figure 5.2 An example of projecting subspaces' openings onto four sides of a rectangle

First, I considered that the number of sides with projected openings should be suitable to explain EOD. If there is only one opening, I marked a low point of EOD as 1. If there are two openings which located in two adjacent sides, I marked 1.5 point. However, if there are two openings in two opposite sides, the evenness of openings' distribution (EOD) supposed to be better than former condition. I marked 2 point (Fig. 5.3). Similarly, all the different conditions of distribution were marked, which is used to calculate visual accessibility of subspace (VAS).

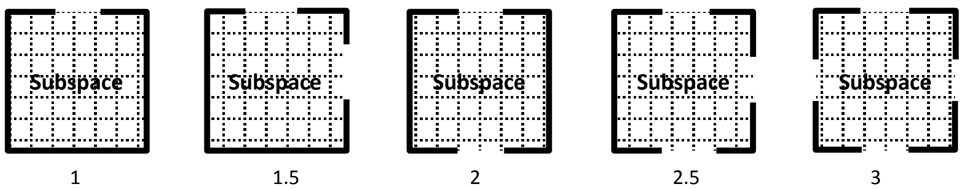


Figure 5.3 Evaluation of evenness of openings' distribution (EOD)

After projected all the openings on the sides of corresponding rectangles according to site maps, a series of VAS data were obtained (Fig. 5.4).

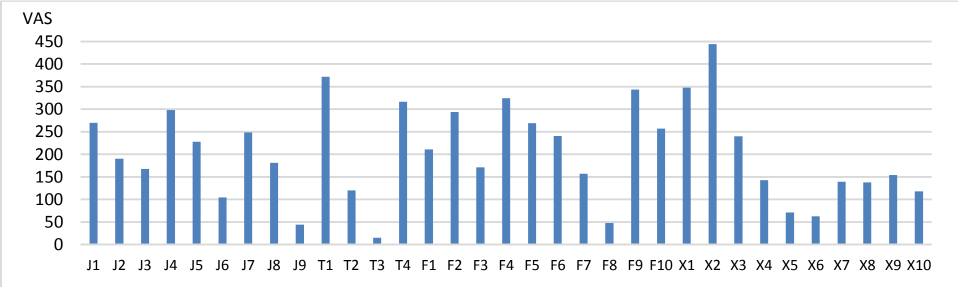


Figure 5.4 Visual accessibility (VAS) data of 33 subspaces

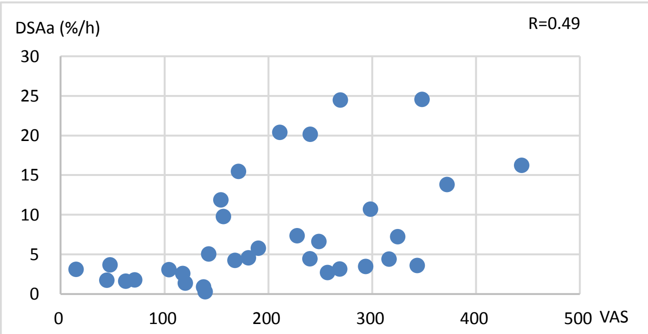


Figure 5.5 Influence of visual accessibility on all staying activities

Correlation analysis was used to examine the relationship between visual accessibility of subspace and density of all staying activities (DSAa) defined before. Fig. 5.5 shows that visual accessibility of subspace (VAS) can fairly well describe density of all staying activities. It implies that whether a space has or not good visual accessibility, in other words, open or closed, influences people's decision of staying.

5.2.2 Physical accessibility of a subspace

Physical accessibility of a subspace (PAS) was defined as a measure of the spatial characteristics associated with easiness of approach to a subspace. It shows how easy a subspace can be approached by people. Therefore, the entrance is the crucial factor of physical accessibility. Similar to visual accessibility, two considerations were determined to calculate PAS quantitatively (Fig. 5.6): the number of entrances (N) and evenness of entrances' distribution (EED).

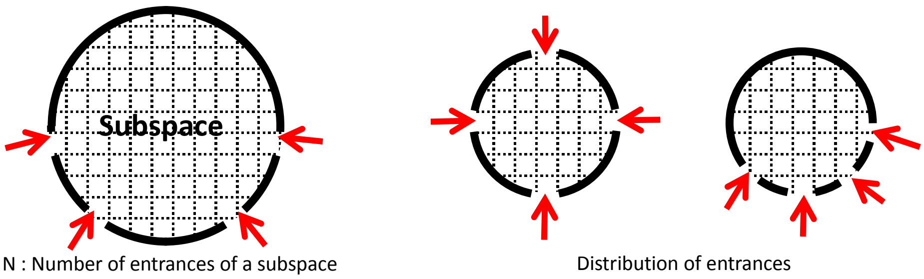


Figure 5.6 Diagram of conception of physical accessibility of a subspace (PAS)

In common sense, the more entrances are, the physical accessibility of a subspace (PAS) should be better. Further, the distribution of entrances is more even, people could approach the subspace from more comprehensive directions, which means PAS will be better. Then I propose an indicator namely EED to explain evenness of entrances' distribution. Physical accessibility of a subspace (PAS) can be measured statistically as below.

$$\mathrm{PAS} = \mathrm{N} * \mathrm{EED}$$

Where N: Number of entrances of a subspace;

EED: Evenness of entrances' distribution.

Like discussed in Section 5.2.1, the entrances are projected onto different sides of a rectangle, which reflects the trend of subspace's shape (Fig. 5.7), and some basic rules have been used to define EED. Two attributes are considerable: distribution of the sides with entrances (DE), and number of entrances on each side (NE).

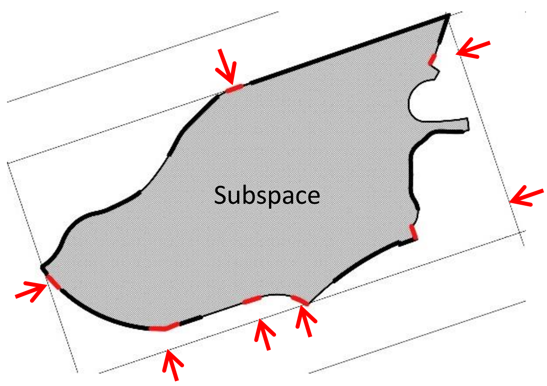


Figure 5.7 An example of projecting subspaces' entrances onto four sides of a rectangle

First, distribution of the sides with entrances (DE) was measured in the same manner as EED. If the entrances are on one side, I marked a low point of EED as 1. If the entrances are on two adjacent sides, I marked 1.5 point. However, if the two sides were in two opposite sides, the evenness of entrances' distribution (EED) will be better than former condition. I marked 2 point. Similarly, all the different conditions of distribution were marked (Fig. 5.8).

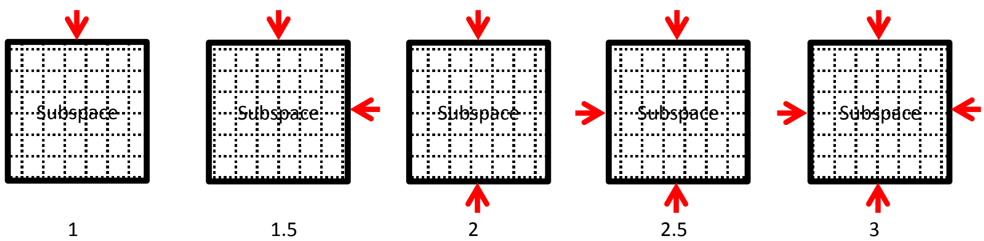


Figure 5.8 Evaluation of distribution of the sides with entrances (DE)

Second, number of entrances on each side (NE) also should be considered. If there was one entrance on a side, there is no additional value. If there were two entrances, I add 0.2 point to the basic point. However, the additional value should not increase until the number of entrances on one side more than 3, it will be calculated the same with 3 entrances (Fig. 5.9).

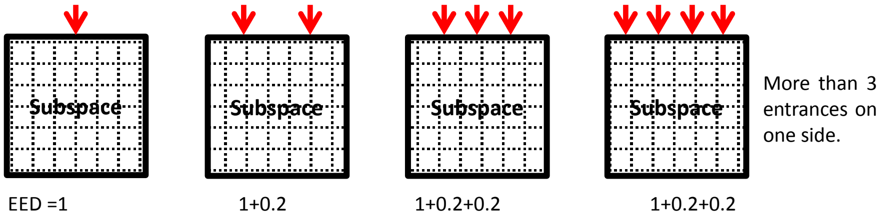


Figure 5.9 Evaluation of number of entrances on each side (NE)

With these rules, EED was calculated by the sum of NE and DE, then physical accessibility of subspaces (PAS) can be examined quantitatively by multiply N and EED (Fig. 5.10).

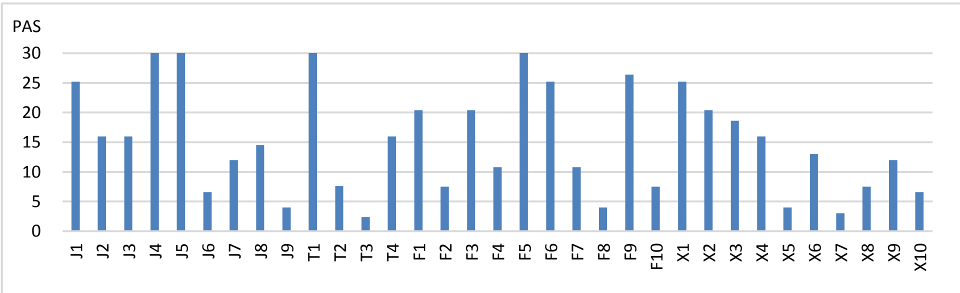


Figure 5.10 Physical accessibility (PAS) data of 33 subspaces

Correlation analysis was used to examine the relationship between physical accessibility of subspace (PAS) and density of all staying activities (Fig. 5.11).

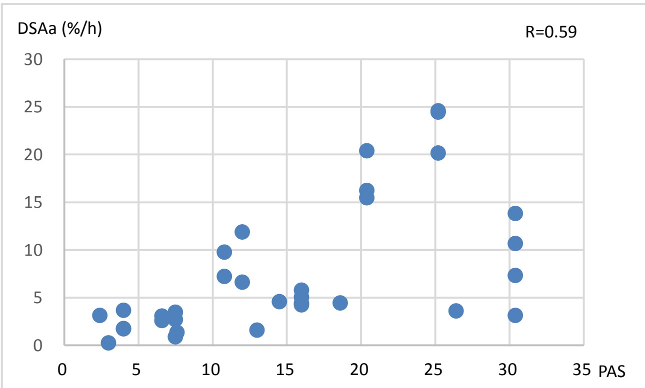


Figure 5.11 Influence of physical accessibility on all staying activities

Fig. 5.11 indicates that physical accessibility of subspace is fairly well related to all staying activities, which means that the number of entrances and their distribution influence the number of users who stay in the subspaces positively.

5.2.3 Vehicle intervention

Beside visual and physical accessibility, there is another important factor of accessibility that may affect staying activities. In most past researches traffic has been seen as a barrier of physical activity (Aytur et al., 2008; Clark and Hutton, 1991; Hine and Russel, 1993). Therefore, I examined the conditions of vehicle intervention in and around subspaces.

There are two basic cases: one is the vehicle road directly go through the subspace, and the other one is not. Furthermore, the latter case can be divided into two possibilities. As mentioned before, I defined an area of subspaces by building walls and/or edge of wide roads/water. Obviously whether a vehicle road adjoins the subspace or not can lead to the two possibilities. Thus we have three categories. For the sake of quantification of the impact of vehicle's intervention, we assign vehicle intervention score (VIS) to each of them (Fig. 5.12).

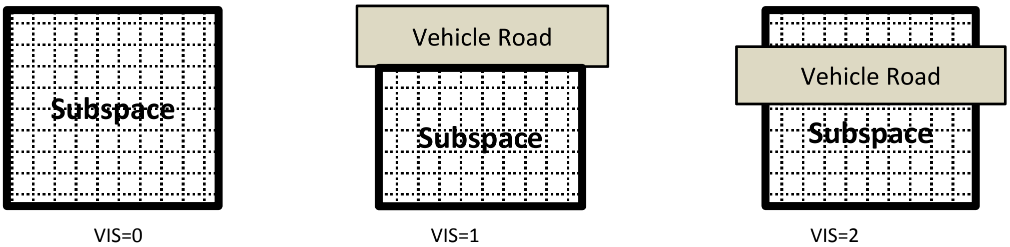


Figure 5.12 Three categories of vehicle road intervention

We assign 0 to the condition that there is no intervention by vehicles; we assign 1 to the condition that there is a vehicle road immediately adjoins the subspace, and we assign 2 to the condition that a vehicle road runs through the subspace. Fig. 5.13 shows the vehicle intervention score (VIS) for 33 subspaces.

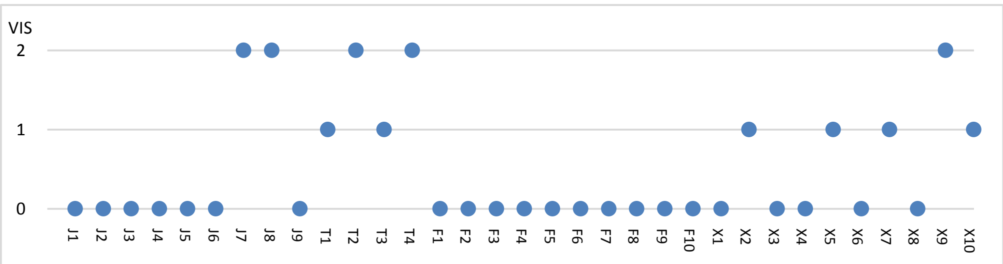


Figure 5.13 Vehicle intervention score (VIS) of 33 subspaces

Correlation analysis using all the data revealed that the relationship between vehicle intervention score (VIS) and density of staying activities (DSA) was not very clear (Fig. 5.14).

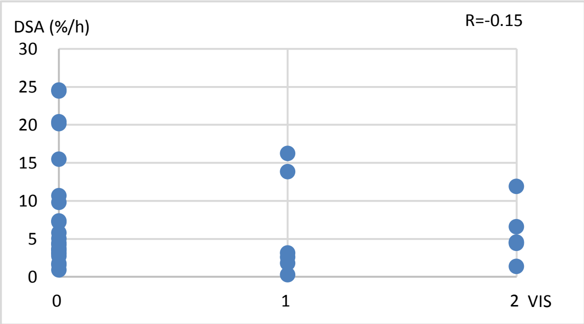


Figure 5.14 Influence of vehicle intervention score on all staying activities

However if we focused on the well-used subspaces (DSA≧11%/H), the vehicle intervention may well explain all staying activities as shown Fig. 5.15. It implies that more people staying the vehicle intervention may affect obviously on all staying activities.

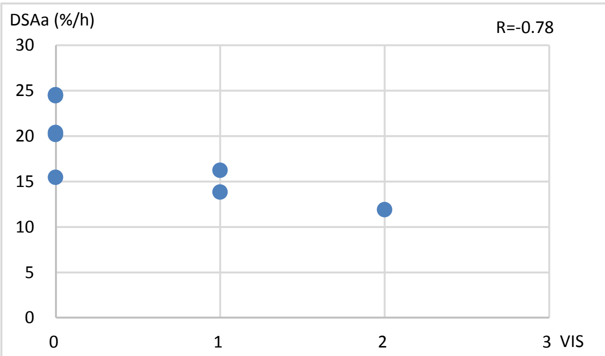


Figure 5.15 Influence of vehicle intervention score on all staying activities (N=8)

5.3 Installation of Facilities

Accessibility helps us to determine whether a subspace is easy to approach, it may affect the number of users, but it does not necessary mean that the subspace meets some functional needs of users. The supportive physical element -- facilities will be discussed in this part.

On our route to develop the important items of facilities, we examined all the items found in subspaces by correlation analysis including density of all staying activities (Table 5.1). The general data were simple amount of the items.

Table 5.1 General correlation analysis between different items of facilities

Coefficients	Seat	Exercise equipment	Playing object	Pavilion	Dustbin	Shop/activity center	Bulletin board	Court	Ground parking lots
Seat	1.00	0.66	-0.14	0.57	-0.15	-0.19	0.11	0.06	-0.17
Exercise equipment		1.00	0.03	0.04	-0.21	-0.03	0.36	-0.18	-0.04
Playing objects			1.00	-0.06	-0.21	-0.11	-0.11	0.07	-0.09
Pavilion				1.00	-0.06	0.03	0.27	0.38	-0.17
Dustbin					1.00	0.14	0.12	0.20	-0.16
Shops/activity center						1.00	0.64	0.49	0.17
Bulletin board							1.00	0.29	0.15
Court								1.00	-0.06
Density of all staying activities (DSAa)	0.35	0.29	0.56	0.23	0.13	0.44	0.63	0.32	0.02

I set up some general rules for choosing influential items. First, each item must be strongly correlated with all staying activities while not correlated with other items. From Table 5.1, the correlation coefficient between items and density of all staying activities (DSAa) can be used to identify items strongly correlated with staying activities. The items with more than 0.3 correlation coefficients are considered. Seat, playing object, shops/activity center, bulletin board, and court are chosen. However, both bulletin board and court are strongly correlated with the item of shop/activity center. Moreover, the former two items are also strongly correlated with other items, it is reasonable to remove the two items. Although the correlation coefficient of exercise equipment is 0.29, it is included for its significance in my research. Therefore, exercise equipment will be considered.

Finally four items of facilities will be discussed: 1) seat, 2) playing object, 3) exercise equipment, and 4) shop/activity center.

5.3.1 Seat

Within all the items of "seat", benches, chairs, and any other forms of outdoor furniture for seating are included. I proposed a variable named seat capacity (SC) to explain "seat", SC refers to the capacity of "seat". There are many types of furniture for siting, such as individual benches or chairs (Fig. 5.16) with fixed capacity of people, and some continuous benches (Fig. 5.17) whose capacity needs to be calculated.

Figure 5.16 Images of individual bench/chair or other individual seating furniture

Figure 5.17 Images of continuous benches

It is easy to calculate seat capacity for individual seating furniture, but for the continuous benches we need to set up the criteria of seat width for calculating. According to the book named *Human Dimensions of Chinese Adults* published by standardization administration of the people's republic of China in 1988, 600mm was decided as the criteria of seat width. The seat capacity of continuous benches was obtained through dividing the length of bench by 600mm. The data of seat capacity (SC) then can be calculated by adding capacity of individual seating furniture and continuous benches as below (Fig. 5.18).

$$SC=N+Ls/0.6$$

Where N: Number of individual seating furniture;

Ls: Length of continuous benches.

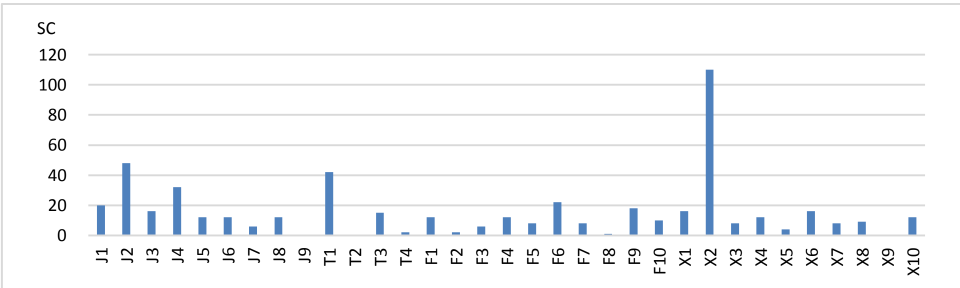


Figure 5.18 Seat capacity (SC) of 33 subspaces

Correlation analysis was used to examine the relationship between seat capacity and density of all staying activities (DSAa).

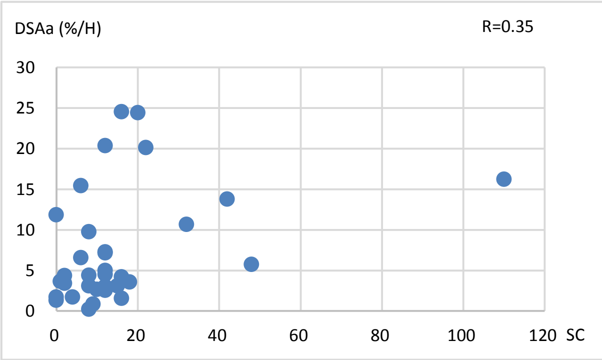


Figure 5.19 Influence of seat capacity on all staying activities

Fig. 5.19 indicates that seat capacity is correlated with staying activities not as I expected. The more seats exist in a subspace, the more people may tend to stay or remain in it.

5.3.2 Playing object

There are limited play equipment observed on survey sites, and the play equipment usually is installed one set in a playground for children. Firstly we just counted how many sets of play equipment in each subspace. However, we found that some other physical elements serve the same function as play equipment, such as artificial rock (Fig. 5.20), big trees or other objects which are easy to climb or slide.

Figure 5.20 Image of play equipment (left) and other elements for playing (right)

Children like to play with these kinds of elements, and little children behave similarly as in the place with play equipment. Therefore we counted these physical elements together, and named them with play equipment "playing object" as a whole. The data of playing object (PO) show how many place of the different types of playing object (Fig. 5.21).

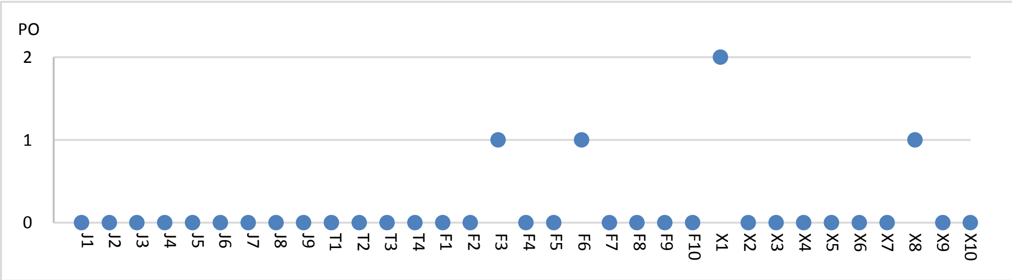


Figure 5.21 Playing object (PO) data of 33 subspaces (non-continuous data)

Like we did before, correlation analysis was used to examine the relationship between playing objects and density of all staying activities (DSAa).

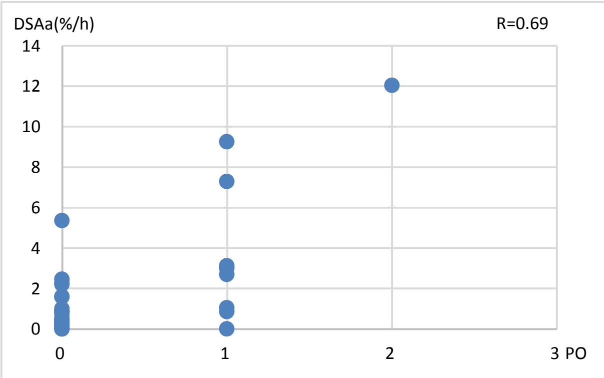


Figure 5.22 Influence of playing object on all staying activities

Fig. 5.22 indicates that playing objects are fairly well related to staying activities. It can be seen as a valid variable for explaining staying activities, and positively effects on the users who stay or remain in the subspaces.

5.3.3 Exercise equipment

Similar with play equipment, usually exercise equipment are fixed as one set in one place. However, exercise equipment can be divided into several individual items with fixed capacity of users. For instance, the item shows in Fig. 5.23 just can be used by one person once. Therefore, we considered that the capacity of exercise equipment may be a valid indicator to describe the condition of exercise equipment in the subspaces.

Figure 5.23 An example of items of exercise equipment

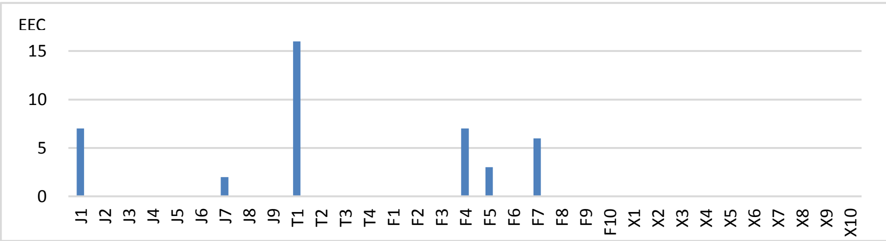


Figure 5.24 Exercise equipment capacity (EEC) data of 33 subspaces

Fig. 5.24 shows obtained the data of exercise equipment capacity (EEC), and correlation analysis was used to examine the relationship between exercise equipment capacity and density of all staying activities (DSAa).

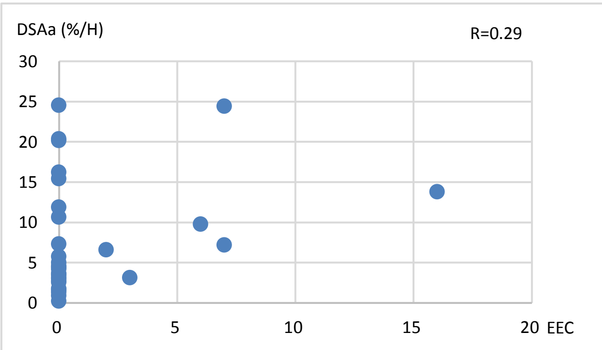


Figure 5.25 Influence of exercise equipment capacity on all staying activities

Fig. 5.25 indicates that exercise equipment capacity (EEC) are not significant to all staying activities. However, during the observation, exercise equipment seem to be used frequently by elderly people. It is necessary to discuss its influence on different people.

5.3.4 Shop and activity center

Tachibana (2009) indicated that the effects of shops on life quality and community regeneration are significant. Shops promote social interactions among neighbors. Not only shops also activity centers provide a stage for communication. Staying activities occur around there due to the functional content of place—small vendors, mail boxes etc. (Fig. 5.26). Therefore, we combined activity centers with shops as a single variable of facilities. As shop/activity center are limited in every community, the number of shop/activity center in one subspace usually is 0 or 1. The data of shop/activity center (SAC) are category scores (Fig. 5.27).

Figure 5.26 Images of staying activities occur around shop/activity center

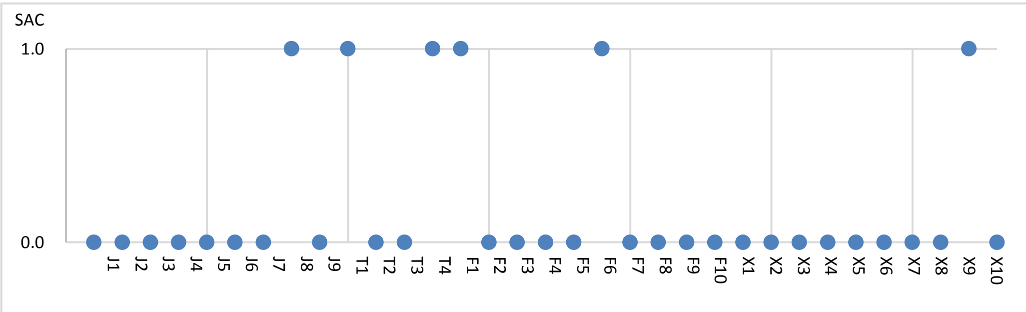


Figure 5.27 Shop/activity center (SAC) data of 33 subspaces

Correlation analysis was used to figure out how the presence of shop/activity center effects density of all staying activities (DSAa).

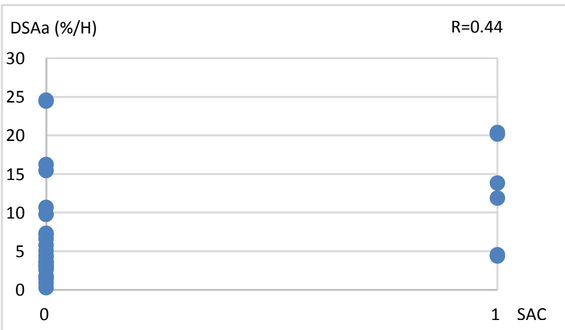


Figure 5.28 Influence of Shop/activity center on all staying activities

Although there are only two categories, shop/activity center seems to affect staying activities (Fig. 5.28), its effects may vary according to different age group or activity category.

5.4 Spatial Configuration

While facilities related to functional needs of staying activities, this section will discuss the influence of spatial configuration, which related to spatial component that support such staying activities as group gathering etc.

On our route to explore the contents of spatial configuration, two items were extracted. The first one is the area of usable zone, which is related to ground usage of subspaces; the second one is spatial width to length ratio, which shows the degree of spatial integration.

5.4.1 Area of usable zone

There is increasing evidence that ground usage can either encourage or discourage activities (Frank and Engelke, 2001). Ground usage can be linked to residents' behavior in several ways. Applied as one variable of spatial configuration, the size of effective area may help to understand observed staying activities. Generally the ground usage of subspaces can be divided into 3 groups: green area, water area, and paved ground (Fig. 5.29).

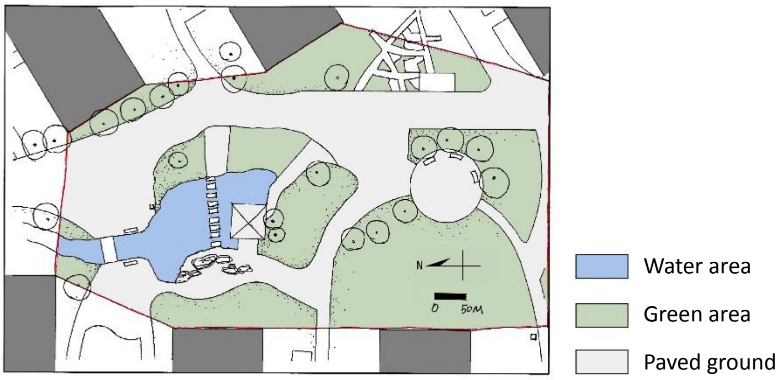


Figure 5.29 An example of the ground usage of a subspace

We calculated the area of those spaces separately, the data were tabulated in Table 5.2.

Table 5.2 Area of different ground usage for each subspace (Unit: M^2)

Subspaces	Water area	Green area	Paved ground	Subspaces	Water area	Green area	Paved ground
J1	390	4894	1908	F5	0	813	912
J2	54	1264	2803	F6	0	1921	2337
J3	134	3230	1177	F7	327	611	488
J4	294	1612	1545	F8	0	829	653
J5	298	2453	1560	F9	2951	4949	1221
J6	0	1059	639	F10	0	463	544
J7	0	847	1804	X1	94	876	1067
J8	0	2513	1160	X2	2551	2102	2050
J9	0	740	163	X3	193	1935	1033
T1	0	4854	4115	X4	157	110	398
T2	0	2847	1863	X5	0	760	437
T3	0	421	991	X6	334	820	623
T4	0	245	1660	X7	77	749	294
F1	71	774	1935	X8	84	1187	529
F2	0	310	255	X9	0	352	785
F3	0	894	635	X10	0	365	700
F4	114	537	959				

When we examined residents' behavior by the activity maps, it is easily found that most staying activities occur in the paved ground, especially in the comparatively big paved ground. I proposed four ways of measuring area of different ground usage: total area of subspace, the area of subspace without water, the area of paved ground, and the area of usable zone. The area of usable zone (AUZ) was defined as effective area of paved ground associated with staying activities, which usually have wider space than other paved place.

Edward T. Hall (1966) proposed interpersonal distance to describe the communication. He believes space speaks to us just as loudly as words, and he introduced the concept of *proxemics* to designate "the interrelated observations and theories of man's use of space as a specialized elaboration of culture (Hall, 1966)." Furthermore, the size of proxemics zone in Asian countries may change due to cultural disparity. Nishide Kazuhiko (1985) revised and redefined the proxemics zone in Japan. We adopted his classification of interpersonal distances to define "usable zone" for staying activities. As to apply to our research, the paved ground more than 3 meters wide will be seen as "usable zone", and Fig. 5.30 show the data of AUZ.

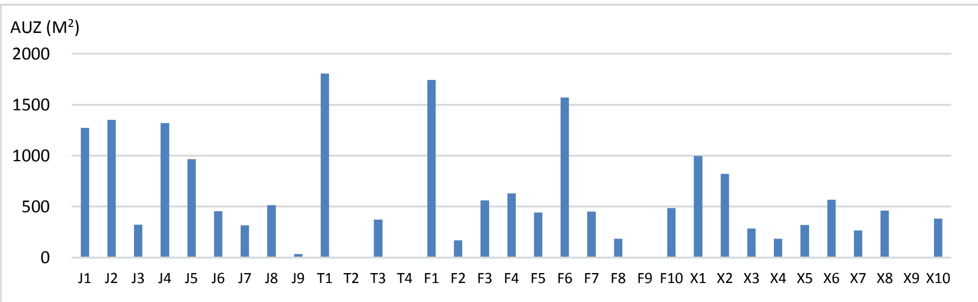


Figure 5.30 Area of usable zone (AUZ) of 33 subspaces

Correlation analysis between the AUZ data and density of all staying activities (DSA) help to understand the effects of usable zone (Fig. 5.31).

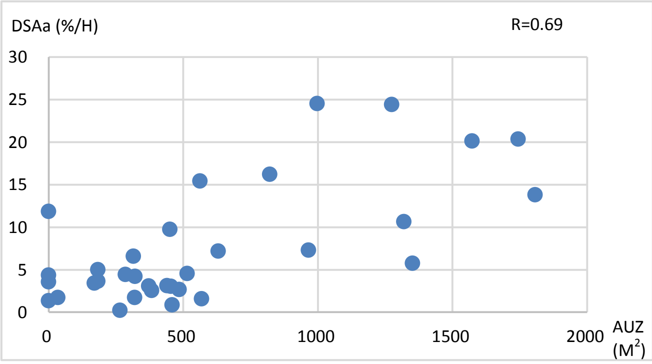


Figure 5.31 Influence of usable zone on all staying activities

Fig. 5.31 indicates that the area of usable zone proposed is fairly well correlated with density of staying activities. It shows that enough space which permit people get together and communicate for a while can support staying activities.

5.4.2 Spatial width to length ratio

Discussion of the area of subspaces is not enough. For instance, even if two different subspaces have the same area, some staying activities may vary due to the shape of a space. In common sense if two-dimensional shape is closer to circle, more people supposed to gather and more integrated. I, therefore, used spatial width to length ratio (WLR) of a rectangle proposed in Section 5.2.1 to explain spatial integration. Spatial width to length ratio (WLR) in the plan is closer to 1, means higher integration. With the data of WLR in Fig. 5.32, we can analyze its effects on all staying activities (Fig. 5.33).

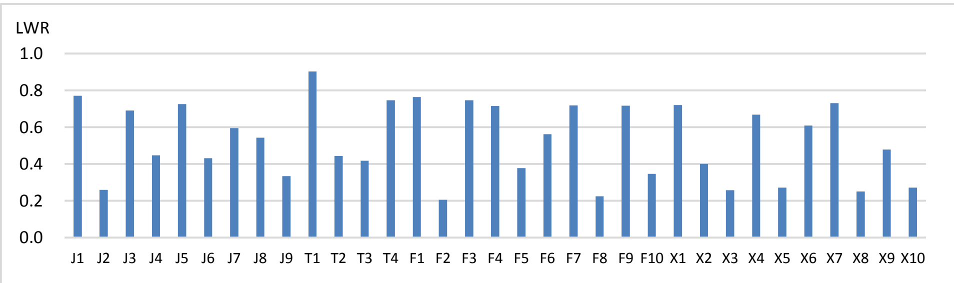


Figure 5.32 Spatial width to length ratio (WLR) data of 33 subspaces

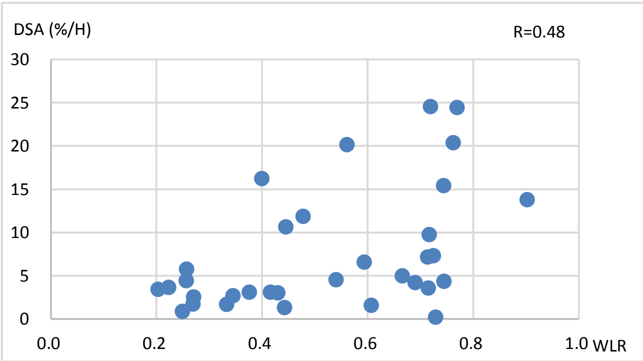


Figure 5.33 Influence of spatial width to length ratio on all staying activities

Fig. 5.33 indicates that the shape of subspace effects on density of staying activities fairly. The width to length ratio may be significant variable to all staying activities.

5.5 Summary

Until now I extracted three variables of accessibility (VAS, PAS and VIS) in subspace scale; four variables of facilities including: SC, PO, EEC, and SAC based on the rules for choosing that each variable is strongly correlated with all staying activities but uncorrelated with other items; and two variables of spatial configuration, including area of usable zone (AUZ), and spatial width to length ratio (WLR). The influence of each variable on all staying activities were discussed, and I found such variables as VAS, PAS, PO, AUZ, and WLR well correlate with staying activities while other variables as VIS, SAC, SC, and EEC show limited correlation. These results help extract influential variables to build a comprehensive model for staying activities.

CHAPTER 6 Explanatory Models for Staying Activities in Outdoor Spaces

6.1 Introduction

The long-term goal of this paper is to promote social interactions among neighbors. As staying activities potentially contribute to social interactions, it is useful to explore the significance of selected factors for staying activities. Multiple regression analysis was used to develop explanatory models for staying activities to show the influences of significant factors. There are three parts of this chapter. At first, the general model for all staying activities was discussed. Considering the needs of different age may change, the variation of influential factors according to age groups was discussed then. Moreover, from the view of contribution to social interaction, the quality of different staying activities is different. Therefore, the variation of influential factors according to different staying activities was discussed for coping with different needs of staying activities.

6.2 Explanatory Model for All Staying Activities

The relationships between selected physical variables and all staying activities were discussed separately in Chapter 4 and 5. The eleven physical variables have been grouped into subcategories of three main factors: accessibility, facilities and spatial configuration (Table 6.1). Linear regressions were conducted to build models for all staying activities. Variables of physical factors were treated as independent variables (IVs), while the densities of all staying activities were treated as dependent variables (DVs). The quantitative data of these IVs or DVs for each subspace are summarized.

Table 6.1 Variable of all staying activities and physical variables

	Factors		Variables	Explanation	Operational Definition	Location
Dependent variables (DVs)	Density of all staying activities (DSA)		DSA_A	Density of all staying activities	$DSA_n=\Sigma(P_n/P)$ P: Community population; P_n: Number of users of all staying activities per hour in subspace N.	Chapter 3 Section 3.4
Independent variables (IVs)	Accessibility	Community level	SVSD	Spatial Visual Step Depth: Visiual step depth from all community entrances of a subspace using the space syntax (VGA) method	$SVSD=\sum_{1}^{m}(\sum_{1}^{n}VSD_n\times W_n)/m$ m: Number of analysis points inside a subspace; n: Number of community entrances; VSD_n: Visiual step depth of an analysis point from entrance N; W_n: Weight of significance of entrance N.	Chapter 4 Section 4.2
			AD	Accumulative Distance: Accumulative distance of shortest routes from every building	$AD_n=\sum D_n$ AD_n: Accumulative distance of subspace N; D_n: Shortest distance from a building to subspace N (m).	Chapter 4 Section 4.3
		Subspace level	VAS	Visual Accessibility of a Subspace: How easy a subspace can be seen or found by people	VAS=Lo×EOD Lo: Total length of openings (m); EOD: Evenness of openings' distribution. (Sources: Section 5.2.1)	Chapter 5 Section 5.2.1
			PAS	Physical Accessibility of a Subspace: How easy a subspace can be approached by people	PAS=N×EED N: Number of entrances of a subspace; EED: Evenness of entrances' distribution. (Sources: Section 5.2.2)	Chapter 5 Section 5.2.2
			VIS	Vehicle Intervention Score: Evaluation of different conditions of vehicle roads connected to a subspace	Intervention of vehicle roads: 0(None), 1(adjoin), 2(go through)	Chapter 5 Section 5.2.3
	Facilities		SC	Seating Capacity: How many people can sit simultaneously	SC=N+Ls/0.6 N: Number of individual seating furniture; Ls: Length of continuous benches.	Chapter 5 Section 5.3.1
			PO	Playing Object: Number of playable physical elements, including play equipment, climbable rockery, etc.	Evaluated by environment datasheets	Chapter 5 Section 5.3.2
			EEC	Exercise Equipment Capacity: How many people can use items simultaneously	Evaluated by environment datasheets	Chapter 5 Section 5.3.3
			SAC	Shops and Activity Centers: Number of shops and activity centers whose entrances face to the subspace	Evaluated by environment datasheets	Chapter 5 Section 5.3.4
	Spatial configuration		AUZ	Area of Usable Zone: Paved ground with wider than three meters	Evaluated by site maps (m^2)	Chapter 5 Section 5.4.1
			WLR	Width to Length Ratio: Spatial width to length ratio	WLR=W/L W: Shorter side of a rectangle; L: Longer side of a rectangle. (Sources: Appendix)	Chapter 5 Section 5.4.2

Table 6.2 Quantitative data of selected eleven variables for each subspace

	Accessibility					Facilities				Spatial configuration	
	Accessibility in community scale		Accessibility in subspace scale								
	SVSD	AD	VAS	PAS	VIS	SC	PO	EEC	SAC	AUZ	WLR
J1	2.0	3615	269.4	25.2	0	20	1	7	0	1274	0.77
J2	2.38	4279	190.5	16	0	48	0	0	0	1351	0.26
J3	2.25	4287	167.7	16	0	16	0	0	0	321	0.69
J4	2.42	5077	298.2	30.4	0	32	1	0	0	1319	0.45
J5	2.38	4093	227.7	30.4	0	12	0	0	0	965	0.73
J6	2.98	5576	104.4	6.6	0	12	1	0	0	454	0.43
J7	2.86	5460	248.7	12	2	6	0	2	0	315	0.59
J8	4.23	5871	180.9	14.5	2	12	1	0	1	514	0.54
J9	2.5	6010	44.4	4	0	0	0	0	0	34	0.33
T1	2.58	7323	372	30.4	1	42	1	16	1	1807	0.9
T2	4.0	9443	120	7.6	2	0	0	0	0	0	0.44
T3	3.11	13639	14.9	2.4	1	15	0	0	0	372	0.42
T4	2.46	13299	316.2	16	2	2	0	0	1	0	0.75
F1	2.35	6179	210.9	20.4	0	12	0	0	1	1744	0.76
F2	2.45	5817	293.7	7.5	0	2	0	0	0	170	0.2
F3	2.9	7582	171.3	20.4	0	6	1	0	0	562	0.74
F4	2.95	6334	324.6	10.8	0	12	0	7	0	630	0.71
F5	3.1	6538	268.8	30.4	0	8	0	3	0	440	0.38
F6	1.73	4716	240.3	25.2	0	22	1	0	1	1573	0.56
F7	3.55	6405	156.6	10.8	0	8	0	6	0	450	0.72
F8	3.6	5421	47.5	4	0	1	0	0	0	183	0.22
F9	2.45	6046	343.2	26.4	0	18	0	0	0	0	0.72
F10	2.45	5664	257.1	7.5	0	10	0	0	0	485	0.35
X1	2.31	5973	348	20.4	0	16	2	0	0	997	0.72
X2	2.85	5462	444	20.4	1	110	0	0	0	821	0.4
X3	2.58	6760	240	18.6	0	8	0	0	0	285	0.26
X4	4.55	9176	142.5	16	0	12	0	0	0	183	0.67
X5	4.53	8274	71.4	4	1	4	0	0	0	320	0.27
X6	4.46	9720	62.8	13	0	16	0	0	0	568	0.61
X7	4.53	8339	139.2	3	1	8	0	0	0	265	0.73
X8	2.83	7181	137.7	7.5	0	9	1	0	0	459	0.25
X9	1.77	7939	154.2	12	2	0	0	0	1	0	0.48
X10	4.55	5970	117.6	6.6	1	12	0	0	0	383	0.27

The data of 11 variables for each of 33 subspaces were calculated using investigated data of physical environment (Table 6.2). At first, the results of bivariate correlation analysis discussed in Chapter 4 and 5 are summarized in Table 6.3. However, high correlations do not mean influential effects. A general consideration to choose IVs is that they are not highly correlated with each other in correlations. Table 6.4 shows the correlation coefficients among IVs. Notably the correlation coefficients between VAS and PAS, as well as PAS and AUZ are quite high (0.68 and 0.60 respectively), therefore we removed PAS from candidate variables for linear regression.

The general consideration to choose significant IVs is that regression is best when the IV is strongly correlated with DVs (Tabachnick and Fidell, 2014). Therefore, the coefficient of determination (R^2) was used to sort variables for all staying activities. Individual IV's were tested by IBM SPSS Regression at the beginning, and the best R^2 was selected. Then we gradually added other variables into the regression one by one. Every time a new IV was added, the IV that results in the best regression was chosen.

Table 6.3 Bivariate correlations between selected variables and density of all staying activities

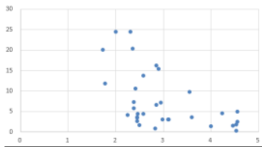
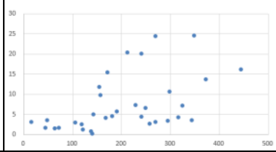
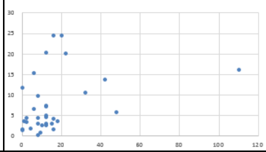
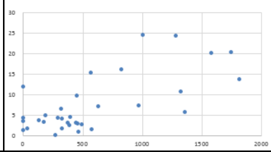
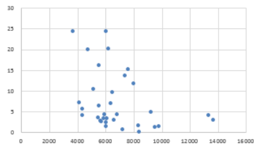
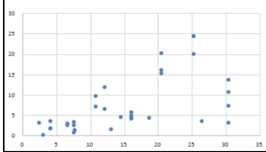
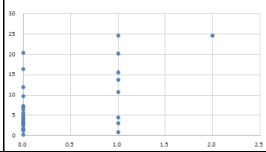
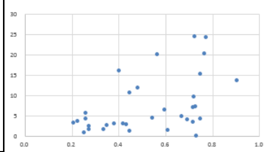
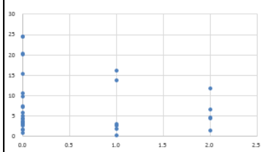
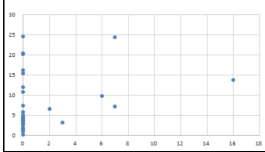
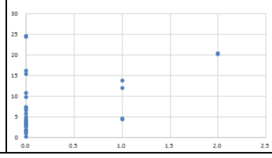
Accessibility		Facilities	Spatial configuration
Accessibility in community scale	Accessibility in subspace scale		
SVSD (R=-0.52) 	VAS (R=0.49) 	SC (R=0.35) 	AUZ (R=0.69) 
AD (R=-0.33) 	PAS (R=0.59) 	PO (R=0.56) 	WLR (R=0.48) 
	VIS (R=-0.15) 	EEC (R=0.29) 	
		SAC (R=0.44) 	

Table 6.4 Correlations between Independent Variables

	IVs										
	SVSD	AD	VAS	PAS	VIS	SC	PO	EEC	SAC	AUZ	WLR
SVSD		.36	.50	-.47	.24	-.16	-.25	-.11	-.31	-.38	-.13
AD			-.30	-.34	.45	-.24	-.23	-.09	.05	-.39	.07
VAS				.68	-.02	.52	.24	.36	.16	.39	.34
PAS					-.24	.36	.39	.31	.26	.60	.48
VIS						-.03	-.14	.00	.23	-.31	.04
SC							.09	.16	.00	.47	.02
PO								.19	.17	.46	.24
EEC									.10	.42	.46
SAC										.45	.31
AUZ											.33

Figure 6.1 presents the change of R^2 for all staying activities in the process, suggesting that four significant IVs (AUZ, SVSD, WLR, and PO) are proper combination of IVs because R^2 does not increase significantly after PO, even when new IVs are added into the model. With these four IVs, we conducted a standard multiple regression (Table 6.5).

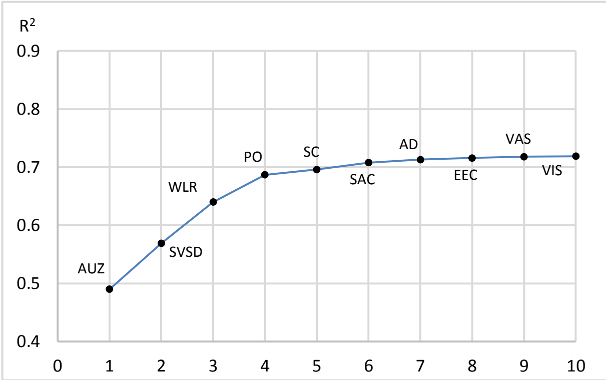


Figure 6.1 Change of R^2 value with different size of independent variables

Results of evaluation of assumptions led to transformation of the variables to reduce skewness, reduce the number of outliers, and improve the normality, linearity, and homoscedasticity of residuals. The four were fairly well correlated with all staying activities without transformation. They were not transformed. No cases had missing data were found, N=33.

Table 6.5 displays the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semipartial correlations (sr^2), R^2, and adjusted R^2.

Table 6.5 Standard multiple regression of selected IVs on density of all staying activities

IVs	DSA_A (DV)	AUZ	SVSD	WLR	PO	B	β	sr^2 (Unique)
AUZ	.69					0.005^{**}	0.39	0.10
SVSD	-.52	-.38				-2.2^{*}	-0.28	0.064
WLR	.48	-.33	-.13			8.6^{*}	0.25	0.056
PO	.56	.46	-.25	.24		3.4^{*}	0.26	0.051
					Intercept=5.7			
Means	7.55	578	2.99	0.52	0.30			$R^2=.68^{a}$
Standard deviations	6.97	519	0.86	0.20	0.53		Adjusted R^2	$R^2=.63$ $R=.82^{***}$

***$p<.001$, **$p<.01$, *$p<.05$
a. Unique variability =.22; shared variability = .46, 95% confidence limits from .52 to .83

The significance level for R is found with F(4,28)=14.54, $p<.001$, with R^2 at .68 and 95% confidence limits from .52 to .83. The adjusted R^2 value of .63 indicates that more than 60% of the variability in density of all staying activities (DSA_A) is predicted by area of usable zone (AUZ), spatial visual step depth (SVSD), spatial width to length ratio (WLR), and playing object (PO).

The first three IVs (AUZ, SVSD, and WLR) in combination contributed another .46 in shared variability. Altogether, 68% (63% adjusted) of the variability in density of all staying activities was predicted by knowing scores on the total four IVs. The size and direction of the relationships suggest that more people to do staying activities are associated with an increase in area of usable zone (AUZ), a reduction of spatial visual step depth (SVSD), and an increase in spatial width to length ratio (WLR), and more playing object (PO). Among those four, however, area of usable zone is much more important, and spatial visual step depth is the next.

Although the bivariate correlation between density of all staying activities (DSA_A) and playing object (PO) was statistically different from zero, r=.56, F(1,31)=14.4, *p*<.05, playing object did not contribute significantly to regression for the reason that it includes zero as possible vale of 95% confidence interval for B. Apparently, the relationship between the density of all staying activities and playing object is mediated by the relationships between area of usable zone, spatial visual step depth, spatial width to length ratio, and density of staying activities. The result can be predicted by the explanatory model as below:

$$DAS_A = f(AUZ, SVSD, WLR, PO)$$
$$= 5.7 + 0.005AUZ - 2.2SVSD + 8.6WLR + 3.4PO$$

Where DAS_A: Density of all staying activities;

AUZ: Area of usable zone;

SVSD: Spatial visual step depth;

WLR: Spatial width to length ratio;

PO: Playing object.

As expected the area of usable zone (AUZ) can be considered as most significant variable for all staying activities with the smallest *p* value, and biggest squared semi-partial correlations (sr^2). Notably another variable of spatial configuration, WLR also contribute significantly to all staying activities, which implies that spatial configuration is the most influential factor to all staying activities. In addition, SVSD and PO have the next significance, which suggests that accessibility and facilities may mediate statistically significant differences for all staying activities.

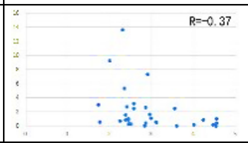
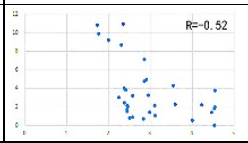
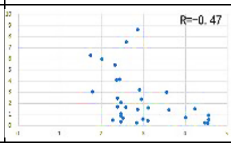
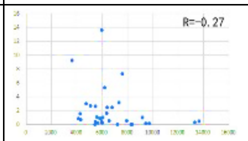
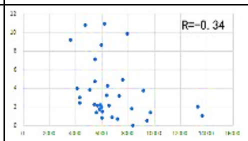
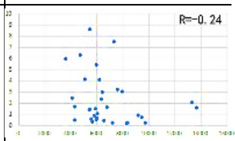
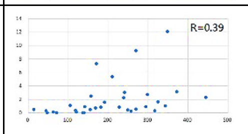
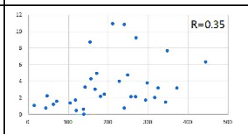
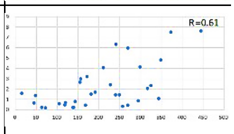
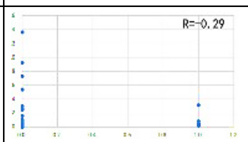
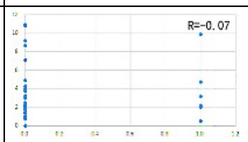
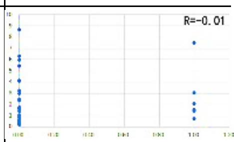
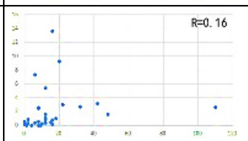
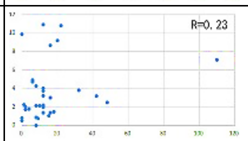
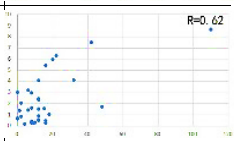
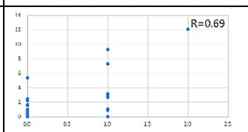
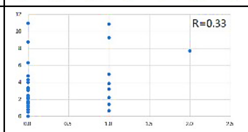
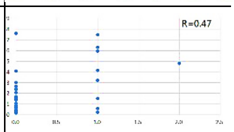
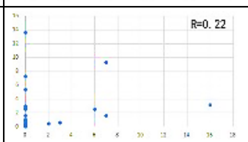
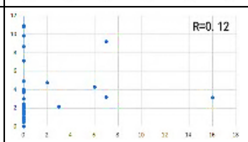
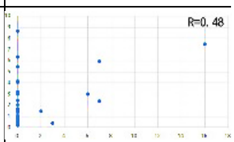
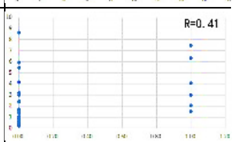
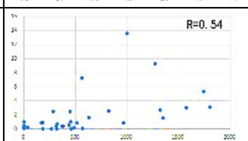
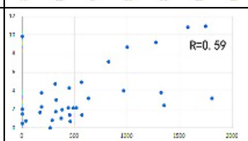
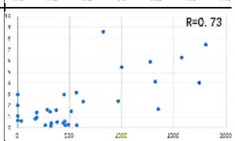
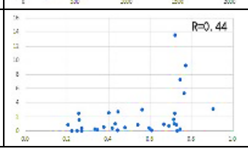
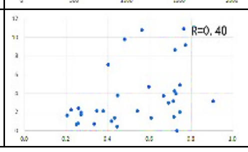
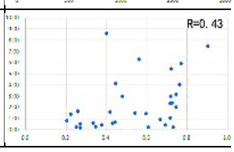
6.3 Variation of Influential Factors in Terms of Age Group

The model of all staying activities can show the most influential variables of physical environment for all people. But influential variables may vary in terms of age group. Basically I divided all the people who did the staying activities into 3 groups: children (0~20 years), adult (21~60 years), and elderly (60~ years) according to the activity observation sheets (Fig. 2.6). I then calculated the density of staying activities (DSA) of different age groups like Table 6.6. As examined in previous section, PAS was removed from physical variables. Finally we did the correlation analysis between rest ten variables and DSA of different age groups (Table 6.7) as the first step of building models for different age groups.

Table 6.6 Definition of DSA for different age groups

Explanation	Operational Definition	
Density of children's staying activities (DSAc)	DSAc=Σ(P_n/P) P_n: Number of users of children's staying activities per hour in subspace N.	P: Community population
Density of adults' staying activities (DSAa)	DSAa=Σ(P_n/P) P_n: Number of users of adults' staying activities per hour in subspace N.	
Density of elderly's staying activities (DSAe)	DSAe=Σ(P_n/P) P_n: Number of users of elderly's staying activities per hour in subspace N.	

Table 6.7 Bivariate correlations between selected IVs and DSA of different age groups

Factors		Variables	Children's DSA	Adults' DSA	Elderly's DSA
Accessibility	Community accessibility	SVSD			
		AD			
	Spatial accessibility	VAS			
		VIS			
Facilities		SC			
		PO			
		EEC			
		SAC			
Spatial configuration		AUZ			
		WLR			

The correlation coefficients (Rs) in Table 6.7 are used to identify the significant IVs for each age group. Then I sort the ten IVs in descending order of the absolute Rs with DSA of different age groups (Table 6.8).

Table 6.8 Variables sorted by size of R value in different age groups

No.	Children		Adult		Elderly	
1	PO	0.69	SAC	0.60	AUZ	0.73
2	AUZ	0.45	AUZ	0.59	SC	0.62
3	WLR	0.44	SVSD	-0.52	VAS	0.61
4	VAS	0.39	WLR	0.40	EEC	0.48
5	SVSD	-0.37	VAS	0.35	SVSD	-0.47
6	VIS	-0.29	AD	-0.34	PO	0.47
7	AD	-0.27	PO	0.33	SAC	0.44
8	EEC	0.22	SC	0.23	WLR	0.43
9	SC	0.16	EEC	0.12	AD	-0.24
10	SAC	0.13	VIS	-0.07	VIS	-0.01

Similar with all staying activities, individual IV was tested by coefficient of determination (R^2). The first one is the IV with highest correlation coefficient in Table 6.8. After the first one, the rest IVs were tested by IBM SPSS Regression, and the best R^2 was selected. I did repeatedly for several times by phasing dawn the least significant variables one by one, the trend of R square is shown in Fig. 6.2.

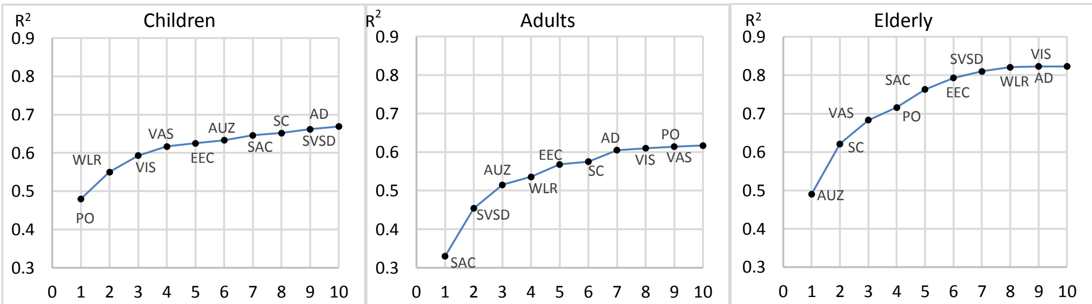


Figure 6.2 Change of R^2 value with different size of IVs according to age groups

Optimum size of influential variables assumed to be proper for building regression models. Fig. 6.2 suggests that four IVs (PO, WLR, VIS, and VAS) can be used to build the model of children's staying activities; seven IVs (SAC, SVSD, AUZ, WLR, EEC, SC, and AD) may help to build the model of adults' staying activities; and eight IVs (AUZ, SC, VAS, PO, SAC, EEC, SVSD, and WLR) can be used to describe the elderly's staying activities.

Statistical regression analysis will be used to elaborate those IVs' effects on staying activities in different age groups, and the models will be built after tested the variables. In addition, on the way to build the models for staying activities in different age groups, we had to adjust the range of *p* value. I fixed 0.1 as the maximum *p* value in this paper.

6.3.1 Children's Staying Activities

6.3.1.1 Explanatory model for children's staying activities

First, four IVs (PO, WLR, VIS, and VAS) assumed to be proper to build the model for children's staying activities. Density of children's staying activities was calculated as mentioned in Table 6.6. Standard multiple regression analysis was conducted with these four IVs, Table 6.9 shows the selected output of the result.

Table 6.9 Selected output of standard multiple regression analysis of density of children's staying activities (DSAc) with PO, WLR, VIS, and VAS

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	-1.336	.983		-1.359	.185
	PO	2.918	.648	.554	4.505	.000
	WLR	3.580	1.722	.262	2.079	.047
	VIS	-.810	.435	-.219	-1.864	.073
	VAS	.004	.003	.158	1.259	.218

a. Dependent Variable: DSAc

The result shows that VAS is not so significant to children's staying activities with *p*>.2. Therefore, VAS is excluded from this model. Standard multiple regression analysis is conducted again with rest three IVs (PO, WLR, and VIS). Table 6.10 presents the result with the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semi-partial correlations (sr_i^2), R^2, and adjusted R^2.

Table 6.10 Standard multiple regression of selected IVs on DSAc

Variables	DSAc (DV)	PO	WLR	VIS	B	β	sr^2 (unique)
PO	.69				3.1^{***}	0.58	0.31
WLR	.44	.24			4.2^{**}	0.31	0.09
VIS	-.29	-.15	.04		-0.82^{*}	-0.22	0.048
				Intercept=-.87			
Means	1.89	0.30	0.52	0.49			R^2=.60[a]
Standard deviations	2.79	0.53	0.20	0.76			Adjusted R^2 R^2=.56 $R=.78^{***}$

$^{***}p<.001$, $^{**}p<.05$, $^{*}p<.1$

a. Unique variability =.40; shared variability = .20, 95% confidence limits from .42 to .79.

The significance level for R is found with F(3,29)=14.55, *p*<.001, with R^2 at .60 and 95% confidence limits from .42 to .49. The adjusted R^2 value of .56 indicates that more than 55% of the variability in density of children's staying activities (DSA) is predicted by playing objects (PO), spatial width to length ratio (WLR), and vehicle intervention score (VIS).

The first two IVs (PO, and WLR) in combination contributed another .20 in shared variability. Altogether, 60% (56% adjusted) of the variability in density of children's staying activities was predicted by knowing scores on these three IVs.

The size and direction of the relationships suggest that more children to do staying activities are decided by physical characteristics of more playing object (PO), higher spatial width to length ratio (WLR) , and less vehicle intervention (VIS). Among those three, however, playing object is much more important, then spatial width to length ratio. The statistical model for children's staying activities, which can be summarized as below:

$$DASc = f(PO, WLR, VIS) \quad = -0.87+3.1PO+4.2WLR-0.82VIS$$

Where DASc: Density of children's staying activities;
PO: Playing object;
WLR: Spatial width to length ratio;
VIS: Vehicle intervention score.

This model is adapted as best one for children's staying activities at this stage. The significant IVs present differently in the model of children's staying activities. Playing object (PO) is most significant variable for children's staying activities with the smallest *p* value, and biggest squared semi-partial correlations (sr^2). Interestingly a variable of spatial configuration, WLR also contribute significantly, and the vehicle intervention negatively influence children's staying activities.

6.3.1.2 Implications of the model

The explanatory model indicated the magnitude of the effects of influential variables. Suggestions about environment design for children can be summarized as following:

(1) As PO contributed most to the regression, the playing objects such as play equipment and playable elements should be considered firstly for attracting children. I found that the subspaces only with play equipment usually are not active like the spaces with different types of playing objects in children's activities. Adding diversity of playing object is supposed to be helpful to encourage children do different staying activities on the ground. The reason may be that playing object (PO) provides affordance for most children's activities such as climbing, sliding etc.

(2) Spatial width to length ratio is the next need of children's staying activities. High spatial width to length ratio suggested that the shape of subspaces is more integrated. The reason may be that children usually like to gather/play together in an integrated subspace, which provides affordance for group activities or multiple activities such as playing football, playing games etc.

(3) Notably although vehicle intervention is the last significant variable, it negatively effects on children's staying activities. The reason may be that parents usually do not permit their children to stay near vehicle roads with consideration of safety, the subspaces with high vehicle intervention may be excluded first.

6.3.2 Adults' Staying Activities

6.3.2.1 Explanatory model for adults' staying activities

At the beginning of this section, I proposed that seven IVs – shop/activity center (SAC), spatial visual step depth (SVSD), area of usable zone (AUZ), spatial width to length ratio (WLR), exercise equipment capacity (EEC), seating capacity (SC), and accessibility from residential buildings (AD)– may help to build the model for adults' staying activities. On the other hand, density of adults' staying activities (IV) was calculated as mentioned in Table 6.6.

At first, I input all these IVs into standard multiple regression (Table 6.11). The combination of IVs needs to be modified by excluding IVs with more than 0.1 p value. At the first the least significant variable (SC) with biggest p value was excluded, the standard regression was conducted again to examine the rest IVs (Table 6.12). However, there are still several IVs with more than 0.1 p value. Thus, I excluded the next insignificant IV (EEC, p=0.180), and did the standard regression again (Table 6.13). I did the similar analysis by excluding insignificant IV (AUZ, p=0.313), all the IVs' p value were less than 0.1. Therefore, the rest four IVs (SAC, SVSD, WLR, and AD) are supposed to be the best combination to explain adults' staying activities. Then I conducted standard multiple regression with these four variables, Table 6.14 presents the result with the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semi-partial correlations (sr_i^2), R^2, and adjusted R^2.

Table 6.11 Selected output of standard multiple regression analysis of density of adults' staying activities (DSAa) with SAC, SVSD, AUZ, WLR, EEC, SC, and AD

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.979	2.582		1.928	.066
	SAC	2.047	.822	.386	2.491	.020
	SVSD	-.857	.545	-.246	-1.573	.129
	AUZ	.001	.001	.184	.913	.371
	WLR	4.470	2.235	-.307	2.000	.057
	EEC	-.162	.136	-.181	-1.194	.244
	SC	.015	.025	.099	.578	.568
	AD	.000	.000	-.235	-1.570	.129

a. Dependent Variable: DSAa

Table 6.12 Selected output of standard multiple regression analysis of density of adults' staying activities (DSAa) with SAC, SVSD, AUZ, WLR, EEC, and AD

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
2	(Constant)	4.525	2.001		2.261	.032
	SAC	1.932	.768	.364	2.571	.018
	SVSD	-.777	.470	-.223	-1.654	.110
	AUZ	.001	.001	.184	1.460	.156
	WLR	4.123	2.035	.283	2.026	.053
	EEC	-.175	.127	-.196	-1.378	.180
	AD	.000	.000	-.223	-1.566	.129

a. Dependent Variable: DSAa

Table 6.13 Selected output of standard multiple regression analysis of density of adults' staying activities (DSAa) with SAC, SVSD, AUZ, WLR, and AD

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
3	(Constant)	5.205	1.971		2.641	.014
	SAC	2.136	.766	.403	2.790	.010
	SVSD	-.788	.478	-.227	-1.651	.110
	AUZ	.001	.001	.163	1.027	.313
	WLR	3.039	1.908	.208	1.593	.123
	AD	.000	.000	-.232	-1.606	.120

a. Dependent Variable: DSAa

Table 6.14 Standard multiple regression of selected IVs on DASa

Variables	DSAa (DV)	SAC	AD	WLR	SVSD	B	β	sr^2 (unique)
SAC	.60					2.5^{**}	.46	0.18
AD	-.34	.05				$.0002^{*}$	-.30	0.073
WLR	.40	.30	.08			3.6^{*}	.25	0.055
SVSD	-.52	-.31	.36	-.13		$-.84^{*}$	-.24	0.045
					Intercept=6.1			
Means	3.46	0.240	6772	0.525	2.99			R^2=.60[a]
Standard deviations	2.97	0.561	2291	0.204	0.855		Adjusted R^2	R^2=.55
								$R=.78^{***}$

***p<.001, **p<.01, *p<.1

a. Unique variability =.31; shared variability = .29, 95% confidence limits from .42 to .78

The significance level for R is found with $F(4,28)=10.62$, $p<.001$, with R^2 at .60 and 95% confidence limits from .42 to .78. The adjusted R^2 value of .55 indicates that about 55% of the variability in density of adults' staying activities (DSAa) is predicted by shop/activity center (SAC), accumulative distance (AD), spatial width to length ratio (WLR), and spatial visual step depth (SVSD).

The first three IVs (SAC, AD, and WLR) in combination contributed another .29 in shared variability. Altogether, 60% (55% adjusted) of the variability in density of adults' staying activities was predicted by knowing scores on total four IVs. The size and direction of the relationships suggest that more adults to do staying activities are decided by physical environment of subspace with more shop/activity center (SAC), further accumulative distance (AD), higher spatial width to length ratio (WLR) and worse spatial visual step depth (SVSD). Among those four variables, however, shop/activity center is much more important. The model can be summarized as below:

DASa= f (SAC, SVSD)

$$=6.1+2.5SAC+0.0002AD+3.6WLR-0.84SVSD$$

Where DASa: Density of adults' staying activities;

SAC: Shop/activity center;

AD: Accumulative distance;

WLR: Spatial width to length ratio;

SVSD: Spatial visual step depth.

This model was adapted as best one for adults' staying activities. This model can predict about 60% density of adults' staying activities in newly developed residential communities in China. The significant IVs present differently in the model of adults' staying activities. Shop/activity center (SAC) is most significant variable with the smallest p value, and biggest squared semi-partial correlations (sr^2). Interestingly, accumulative distance (AD) affects positively on adults' staying activities. However, its influence is limited, which may because that residents are familiar with their little communities, the distance does not matter much.

6.3.2.2 Implications of the model

The explanatory model indicated the magnitude of the effects of influential variables. Suggestions about environment design for adults can be summarized as following:

(1) As SAC contributed most to the regression, the shop/activity center (SAC) should be considered firstly for attracting adults. The reason may be that shop/activity center (SAC) provides affordance for most adults' staying activities.

(2) Accumulative distance (AD) affect significantly. Interestingly it affects positively on adults' staying activities, which means further subspaces are more attractive to adults. In fact, further subspaces usually near the center part of the communities with diverse physical characteristics, which can support different adults' staying activities.

(3) Spatial width to length ratio (WLR) need to be considered for adults' staying activities. High WLR means high integration of subspace, which may hold more adults to gather together.

(4) The spatial visual step depth (SVSD) should be examined, which suggests that subspaces more close to community entrances could attract more adults staying there. This result implies that shops/activity centers close to community entrances may be more popular and well used by adults.

6.3.3 Elderly's Staying Activities

6.3.3.1 Explanatory model for elderly's staying activities

As mentioned before, eight IVs (AUZ, SC, VAS, PO, SAC, EEC, SVSD, and WLR) can be used to describe the elderly's staying activities. Beside, density of elderly's staying activities (IV) was calculated in Table 6.6. Then I put all the eight IVs into standard multiple regression (Table 6.15).

Similar with adults' staying activities, I examined IVs by excluding insignificant variables one by one. Eventually five variables were selected which include seating capacity (SC), playing object (PO), shop/activity center (SAC), exercise equipment capacity (EEC) and spatial visual step depth (SVSD).

Table 6.15 Selected output of standard multiple regression analysis of density of elderly's staying activities (DSAe) with AUZ, SC, VAS, PO, SAC, EEC, SVSD, and WLR

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.155	1.176		.982	.336
	AUZ	0.000	.001	.054	.384	.704
	SC	0.053	.013	.499	4.131	.000
	VAS	.000	.003	.016	.125	.901
	PO	.943	.400	.232	2.356	.027
	SAC	.968	.396	.252	2.443	.022
	EEC	.144	.067	.222	2.119	.045
	SVSD	-.474	.269	-.188	-1.764	.091
	WLR	1.409	1.099	.133	1.282	.212

a. Dependent Variable: DSAe

With these five variables, standard multiple regression analysis was conducted to build the model. Table 6.16 presents the output of the result. The significance level for R is found with F(5,27)=24.057, *p*<.001, with R^2 at .82 and 95% confidence limits from .72 to .91. The adjusted R^2 value of .78 indicates that about 78% of the variability in density of elderly's staying activities (DSAe) is predicted by seating capacity (SC), exercise equipment capacity (EEC), shop/activity center (SAC), playing object (PO), and spatial visual step depth (SVSD).

Table 6.16 Standard multiple regression of selected IVs on DSAe

Variables	DSAe (DV)	SC	EEC	SAC	PO	SVSD	B	β	sr^2 (unique)
SC	.62						$.055^{***}$	.52	0.26
EEC	.48	.16					$.19^{**}$	.30	0.082
SAC	.44	.00	.10				1.2^{**}	.30	0.082
PO	.47	.09	.19	.17			1.1^{**}	.27	0.064
SVSD	-.47	-.16	-.11	-.31	-.25		-.50	-.20	0.033
							Intercept=2.0		
Means	2.20	15.5	1.2	0.24	0.30	3.0			R^2=.82[a]
Standard deviations	2.15	20.2	3.3	0.56	0.53	0.85		Adjusted R^2	R^2=.78 R=$.90^{***}$

***p<.001, **p<.01

a. Unique variability =.34; shared variability = .48, 95% confidence limits from .72 to .91

The first four IVs (SC, EEC, SAC, and PO) in combination contributed another .34 in shared variability. Altogether, 82% (78% adjusted) of the variability in density of elderly's staying activities was predicted by knowing scores on total IVs. The size and direction of the relationships suggest that more elderly to do staying activities are associated with an increase in seating capacity (SC), playing object (PO), shop/activity center (SAC), exercise equipment (EEC), and a reduction of spatial visual step depth (SVSD). Among those five, however, seating capacity is much more important for elderly. The model for elderly people can be summarized as below:

DASe= f (SC, EEC, SAC, PO, SVSD)

=2.0+0.055SC+0.19EEC+1.2SAC+1.1PO-0.5SVSD

Where DASe: Density of elderly's staying activities;

SC: Seating capacity;

EEC: Exercise equipment capacity;

SAC: Shop/activity center;

PO: Playing object;

SVSD: Spatial visual step depth.

This model was adapted as best one for elderly's staying activities, which can predict more than 75% density of elderly's staying activities in newly developed residential communities in China. This model can fairly well describe the elderly's staying activities. The significant IVs present differently in the model of elderly's staying activities. Seating capacity (SC) is most significant variable with the smallest p value, and biggest squared semi-partial correlations (sr^2). Exercise equipment capacity (EEC) and shop/activity center (SAC) have almost the same magnitude of significance next to SC. Notably playing object (PO) also contribute significantly to elderly's staying activities. The least significant variable is spatial visual step depth (SVSD).

6.3.3.2 Implications of the model

The explanatory model indicated the magnitude of the effects of influential variables. Suggestions about environment design for elderly people can be summarized as following:

(1) As SC contributed most to the regression, seating capacity (SC) should be considered firstly to meet elderly's needs of staying activities. The reason may be that elderly people like seating if they decide to stay in a subspace.

(2) Except SVSD, all the other influential variables belong to "facilities", which implies that "facilities" is the dominant factor to elderly's staying activities. The reason may be that facilities provide affordance to most elderly's staying activities, which implies that elderly usually do activities using facilities or outdoor furniture in China.

(3) The spatial visual step depth (SVSD) should be examined for elderly people. SVSD is associated with number of passengers, which suggests that subspaces more close to community entrances could attract more people staying there. This may be the same for more elderly people staying the subspaces.

6.4 Variation of Influential Factors in Terms of Activity Category

Assessments on the different activity categories can indicate different activity needs. Basically I divided staying activities into 2 main groups (three categories): occasional stoppings (less than 1 minute), and longtime staying (1 or more than 1 minute) which includes sedentary activities and vigorous activities (Table 3.2). I then calculated the density of staying activities (DSA) of different activity categories as described in Table 6.17. As mentioned, PAS was removed from physical variables. Finally we did the correlation analysis between rest ten variables and DSA of different activity categories (Table 6.18).

Table 6.17 Definition of DSA for different activity categories

<table>
<tr><th colspan="2">Explanation</th><th colspan="3">Operational Definition</th></tr>
<tr><td colspan="2">Density of occasional stoppings (DSAo)</td><td colspan="2">DSAo=Σ(P_n/P)
P_n: Number of users of occasional stoppings per hour in subspace N.</td><td rowspan="3">P: Community population</td></tr>
<tr><td rowspan="2">Density of longtime staying (DSA_L)</td><td>Density of sedentary activities (DSAs)</td><td>DSAs=Σ(Pn/P)
P_n: Number of users of sedentary activities per hour in subspace N.</td><td rowspan="2">DSA_L =DSAs+DSAv</td></tr>
<tr><td>Density of vigorous activities (DSAv)</td><td>DSAv=Σ(P_n/P)
P_n: Number of users of vigorous activities per hour in subspace N.</td></tr>
</table>

Table 6.18 Bivariate correlation coefficients between IVs and DSA of different activity categories

Factors		Variables	Occasional stoppings	Longtime staying	Sedentary activities	Vigorous activities
Accessibility	Community accessibility	SVSD	-.49	-.49	-.51	-.43
		AD	-.35	-.29	-.24	-.31
	Spatial accessibility	VAS	.35	.51	.53	.44
		VIS	.01	-.21	-.10	-.30
Facilities		SC	.25	.36	.43	.26
		PO	.23	.66	.54	.70
		EEC	.25	.28	.17	.37
		SAC	.49	.38	.47	.28
Spatial configuration		AUZ	.56	.69	.63	.69
		WLR	.38	.47	.40	.51

Table 6.19 Variables sorted by size of R value in different activity categories

No.	Occasional stoppings		Longtime staying		Sedentary activities		Vigorous activities	
1	AUZ	0.56	AUZ	0.69	AUZ	0.63	PO	0.70
2	SAC	-0.49	PO	0.66	PO	0.54	AUZ	0.69
3	SVSD	0.49	VAS	0.51	VAS	0.53	WLR	0.51
4	WLR	0.38	SVSD	-0.49	SVSD	-0.51	VAS	0.44
5	AD	-0.35	WLR	0.47	SAC	0.47	SVSD	-0.43
6	VAS	0.35	SAC	0.38	SC	0.43	EEC	0.37
7	EEC	0.25	SC	0.36	WLR	0.40	AD	-0.31
8	SC	0.25	AD	-0.29	AD	-0.24	VIS	-0.30
9	PO	0.23	EEC	0.28	EEC	0.17	SAC	0.28
10	VIS	0.01	VIS	-0.21	VIS	-0.10	SC	0.26

The correlation coefficients (Rs) in Table 6.18 are used to identify the significance of IVs to specific activity categories. I sort the ten IVs in descending order of the absolute Rs with DSA of different activity categories (Table 6.19). Similar with all staying activities, individual IV was tested by coefficient of determination (R^2). The first one is the IV with highest correlation coefficient in Table 6.19. After the first one, the rest IVs were tested by IBM SPSS Regression, and the best R^2 was selected. I did repeatedly for several times by phasing dawn the least significant variables one by one, the trend of R square is shown in Fig. 6.3.

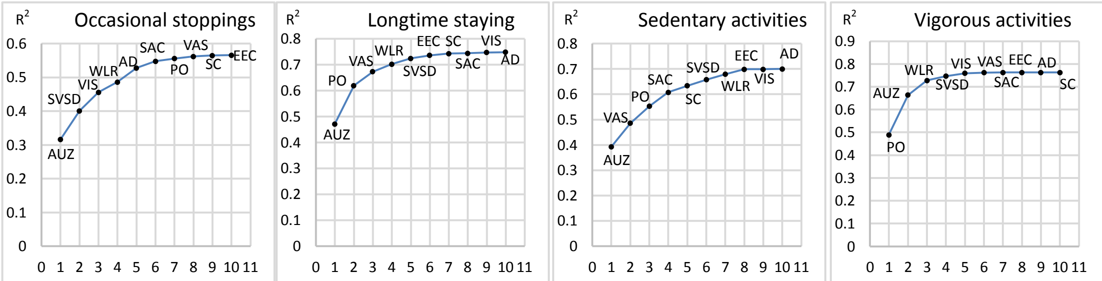


Figure 6.3 Change of R^2 value with different size of IVs according to activity categories

Optimum size of influential variables assumed to be proper for building regression models. Fig. 6.3 suggests that six IVs (AUZ, SVSD, VIS, WLR, AD, and SAC) may be used to build the model of occasional stoppings; seven IVs (AUZ, PO, VAS, WLR, SVSD, EEC, and SC) may be used to build the model of longtime staying; eight IVs (AUZ, VAS, PO, SAC, SC, SVSD, WLR, and EEC) may help to build the model of sedentary activities; and five IVs (PO, AUZ, WLR, SVSD, and VIS) may be used to describe the vigorous activities.

Statistical regression analysis will be used to elaborate those IVs' effects on staying activities in different activity categories, and the models will be built after tested the variables. Similarly I fixed 0.1 as the maximum p value in this paper.

6.4.1 Occasional stoppings

6.4.1.1 Explanatory model for occasional stoppings

Occasional stoppings refer to activities that users stop in the subspace for a short time (less than 1 minute) (Section 3.4.1). I presume that occasional stoppings depend on physical environment not so much like longtime staying. From the view of social interaction, the significance of occasional stoppings may be not high because communication chances and communication quality may be less than longtime staying limited by time.

I separated occasional stoppings from other staying activities, and density of occasional stoppings is calculated to analyze the environmental effects (Table 6.17). As examined before, six IVs (AUZ, SVSD, VIS, WLR, AD, and SAC) assumed to be helpful to build the model for occasional stoppings. Standard multiple regression analysis was conducted with these six IVs, Table 6.20 presents the selected output of standard regression.

The combination of IVs needs to be modified by excluding IVs with more than 0.1 p value. At the first the least significant variable (SAC) with biggest p value was excluded, the standard regression was conducted again to examine the rest IVs (Table 6.21). However, there are still several IVs with more than 0.1 p value. Thus, I did the same analysis by excluding insignificant

IVs one by one until all the IVs' p value became less than 0.1. Eventually, three IVs left (AUZ, SVSD, and VIS) are supposed to be the best combination to explain occasional stoppings. Then I conducted standard multiple regression with these three variables, Table 6.22 presents the result with the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semi-partial correlations (sr_i^2), R^2, and adjusted R^2.

Table 6.20 Selected output of standard multiple regression analysis of density of occasional stoppings (DSAo) with AUZ, SVSD, VIS, WLR, AD, and SAC

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	4.579	1.693		2.704	.012
	AUZ	.001	.001	.268	1.446	.160
	SVSD	-.667	.414	-.248	-1.612	.119
	VIS	.690	.496	.227	1.390	.176
	WLR	2.474	1.633	.220	1.516	.142
	AD	.000	.000	-.285	-1.733	.095
	SAC	.760	.712	.186	1.067	.296

a. Dependent Variable: DSAo

Table 6.21 Selected output of standard multiple regression analysis of density of occasional stoppings (DSAo) with AUZ, SVSD, VIS, WLR, and AD

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
2	(Constant)	4.494	1.696		2.651	.013
	AUZ	.002	.001	.363	2.230	.034
	SVSD	-.793	.398	-.295	-1.992	.057
	VIS	.898	.457	.295	1.965	.060
	WLR	2.630	1.630	.234	1.613	.118
	AD	.000	.000	-.253	-1.561	.130

a. Dependent Variable: DSAo

Table 6.22 Standard multiple regression of selected IVs on DSAo

Variables	DSAo (DV)	AUZ	SVSD	VIS	B	β	sr^2 (unique)
AUZ	.56				0.002^{***}	.50	0.20
SVSD	-.49	-.38			$-.94^{**}$	-.35	0.10
VIS	.01	-.31	.24		$.76^{**}$	.25	0.055
					Intercept=4.3		
Means	3.15	578	2.99	0.485			R^2=.46[a]
Standard deviations	2.30	519	0.855	0.755		Adjusted R^2	R^2=.40 $R=.68^{***}$

***p<.001, **p<.01

a. Unique variability =.30; shared variability = .16, 95% confidence limits from .24 to .68

Results of evaluation led to transformation of the variables to reduce skewness, reduce the number of outliers, and improve the normality, linearity, and homoscedasticity of residuals. The significance level for R is found with F(3,29)=8.09, *p*<.01, with R^2 at .46 and 95% confidence limits from .24 to .68. The adjusted R^2 value of .40 indicates that about 40% of the variability in density of occasional stoppings (DSAo) is predicted by area of usable zone (AUZ), spatial visual step depth (SVSD), and vehicle intervention score (VIS).

The first two IVs (AUZ, and SVSD) in combination contributed another .16 in shared variability. Altogether, 46% (40% adjusted) of the variability in density of occasional stop was predicted by knowing score on total three IVs. The size and direction of the relationships suggest that occasional stoppings likely occur in a subspace with larger area of usable zone (AUZ), worse spatial visual step depth (SVSD), and may be moderated by vehicle intervention. The results suggest a model for occasional stoppings, which can be summarized as below:

$$DASo = f(AUZ, SVSD, VIS)$$
$$= 4.3 + 0.002AUZ - 0.94SVSD + 0.76VIS$$

Where DASo: Density of occasional stoppings;
AUZ: Area of usable zone;
SVSD: Spatial visual step depth;
VIS: Vehicle intervention score.

For occasional stoppings, the adjusted R^2 value indicates that nearly 46% of the variability in density of occasional stoppings (DSAo) can be predicted by the regression model. The area of usable zone (AUZ) is the most significant variable to occasional stoppings. Further, an increase in occasional stoppings may associated with a reduction of the spatial visual step depth (SVSD), and an increase in vehicle intervention score (VIS).

6.4.1.2 Implications of the model

The explanatory model indicated the magnitude of the effects of influential variables. Suggestions about environment design for occasional stoppings can be summarized as following:

(1) As AUZ contributed most to the regression, area of usable zone (AUZ) should be considered firstly to meet occasional stoppings, which may due to that it support stoppings by wider space.

(2) Spatial visual step depth (SVSD) contribute negatively to occasional stoppings, which indicates that a reduction of distance from community entrances associate with number of passengers, may increase chances of occasional stoppings such as brief meetings or stoppings.

(3) Interestingly, although vehicle intervention affect negatively on children's staying activities, it is positively associated with occasional stopping. The reason may be that vehicle intervention increases more interruption during passengers passing by, which may result in brief stoppings.

6.4.2 Longtime staying

As mentioned before, longtime staying (LSA) refers to staying activities which spend relatively more time in a subspace (usually >1minutes), which supposed to contribute more to social interactions. From the view of social interaction, the quality of longtime staying is good because it creates much more chances for communication.

I separated users of longtime staying from occasional stoppings, and density of longtime staying is calculated to analyze the environmental effects (Table 6.17). As examined before, seven IVs (AUZ, PO, VAS, WLR, SVSD, EEC, and SC) assumed to be helpful to build the model for longtime staying. Standard multiple regression analysis was conducted with these seven IVs, Table 6.23 presents the selected output of standard regression.

The combination of IVs needs to be modified by excluding IVs with more than 0.1 p value. At the first the least significant variable (VAS) with biggest p value was excluded, the standard regression was conducted again to examine the rest IVs (Table 6.24). However, there are still several IVs with more than 0.1 p value. Thus, I did the same analysis by excluding insignificant IVs one by one until all the IVs' p value became less than 0.1. Eventually, four IVs (AUZ, PO, WLR, and SVSD) are supposed to be the best combination to explain longtime staying. Then I conducted standard multiple regression with these four variables, Table 6.25 presents the result with the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semi-partial correlations (sr_i^2), R^2, and adjusted R^2.

Table 6.23 Selected output of standard multiple regression analysis of density of longtime staying (DSA_L) with AUZ, PO, VAS, WLR, SVSD, EEC, and SC

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.013	3.415		-.004	.997
	AUZ	.003	.002	.303	1.996	.057
	PO	3.864	1.149	.396	3.362	.002
	VAS	.004	.008	.090	.584	.564
	WLR	7.022	3.123	.277	2.248	.034
	SVSD	-1.121	.774	-.185	-1.449	.160
	EEC	-.189	.194	-.121	-.973	.340
	SC	.030	.036	.116	.816	.422

a. Dependent Variable: DSA_L

Results of evaluation led to transformation of the variables to reduce skewness, reduce the number of outliers, and improve the normality, linearity, and homoscedasticity of residuals. The significance level for R is found with $F(4,28)=17.33$, $p<.001$, with R^2 at .71 and 95% confidence limits from .57 to .85. The adjusted R^2 value of .67 indicates that nearly 67% of the variability in density of stay (DSA_L) is predicted by area of usable zone (AUZ), playing object (PO), spatial width to length ratio (WLR) and spatial visual step depth (SVSD).

Table 6.24 Selected output of standard multiple regression analysis of density of longtime staying (DSA_L) with AUZ, PO, WLR, SVSD, EEC, and SC

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
2	(Constant)	1.153	2.736		.421	.677
	AUZ	.003	.001	.283	1.940	.063
	PO	3.947	1.126	.404	3.507	.002
	WLR	7.565	2.944	.299	2.570	.016
	SVSD	-1.349	.659	-.223	-2.046	.051
	EEC	-.162	.186	-.104	-.870	.392
	SC	.041	.030	.162	1.387	.177

a. Dependent Variable: DSA_L

Table 6.25 Standard multiple regression of selected IVs on DSA_L

Variables	DSA_L (DV)	AUZ	PO	WLR	SVSD	B	β	sr^2 (unique)
AUZ	.69					$.003^{**}$	.343	0.08
PO	.66	.46				3.8^{**}	.386	0.11
WLR	.47	.33	.24			6.1^{*}	.239	0.05
SVSD	-.49	-.38	-.25	-.13		-1.4^{*}	-.226	0.04
						Intercept=2.2		
Means	4.36	578	0.30	0.525	2.99			R^2=.71[a]
Standard deviations	5.17	519	0.529	0.204	0.855		Adjusted R^2	R^2=.67 R=.84***

***p<.001, **p<.01, *p<.05

a. Unique variability =.24; shared variability = .47, 95% confidence limits from .57 to .85

The first three IVs (AUZ, PO, and WLR) in combination contributed another .47 in shared variability. Altogether, 67% (64% adjusted) of the variability in density of longtime staying was predicted by knowing score on total four IVs. The size and direction of the relationships suggest that longtime staying likely occurs in a subspace with more playing object, larger area of usable zone, higher spatial width to length ratio, and lower spatial visual step depth. The results suggest a model for longtime staying, which can be summarized as below:

$$DAS_L = f(PO, AUZ, WLR, SVSD)$$

$$= -2.2 + 3.77PO + 0.003AUZ + 6.1WLR - 1.4SVSD$$

Where DAS_L: Density of longtime staying;

PO: Playing object;

AUZ: Area of usable zone;

WLR: Spatial width to length ratio;

SVSD: Spatial visual step depth.

This model just can predict about 67% density of longtime staying in newly developed residential communities in China. The result can fairly well explain the activities. The playing objects (PO) contribute most to longtime staying, and area of usable zone (AUZ) as well as spatial width to length ratio (WLR) are significant to the regression. Moreover, spatial visual step depth (SVSD) mediated the regression. Notably, both the variables of spatial configuration (AUZ and WLR) play an important role in regression. In combination, spatial configuration can be seen as the most significant factor to longtime staying.

However, the influential variables may vary according to different categories of longtime staying (sedentary activities and vigorous activities). The variations will be discussed in the following sections.

6.4.2.1 Sedentary activities

6.4.2.1.1 Explanatory model for sedentary activities

Sedentary activities refer to such activities as sitting, standing that users remain in a subspace more than 1 minute without locomotion (Section 3.4.1). I calculated users of sedentary activities separately (Table 6.17). Eight IVs (AUZ, VAS, PO, SAC, SC, SVSD, WLR, and EEC) supposed to be influential to sedentary activities. Standard multiple regression analysis was conducted with these eight IVs, Table 6.26 presents the selected output of standard regression.

The combination of IVs needs to be modified by excluding IVs with more than 0.1 p value. At the first the least significant variable (VAS) with biggest p value was excluded, the standard regression was conducted again to examine the rest IVs (Table 6.27). However, there are still several IVs with more than 0.1 p value. Thus, I did the same analysis by excluding insignificant IVs one by one until all the IVs' p value became less than 0.1. Eventually, four IVs (PO, SAC, SC, and SVSD) are supposed to be the best combination to explain sedentary activities. Then I conducted standard multiple regression with these four variables, Table 6.28 presents the result with the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semi-partial correlations (sr_i^2), R^2, and adjusted R^2.

Table 6.26 Selected output of standard multiple regression analysis of density of sedentary activities (DSAs) with AUZ, VAS, PO, SAC, SC, SVSD, WLR, and EEC

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.559	1.797		.311	.758
	AUZ	.001	.001	.121	.645	.525
	VAS	.002	.004	.103	.608	.549
	PO	1.493	.611	.321	2.443	.022
	SAC	1.031	.605	.235	1.704	.101
	SC	.034	.020	.279	1.729	.097
	SVSD	-.594	.411	-.206	-1.447	.161
	WLR	2.697	1.680	.223	1.606	.121
	EEC	-.129	.104	-.174	-1.239	.227

a. Dependent Variable: DSAs

Table 6.27 Selected output of standard multiple regression analysis of density of sedentary activities (DSAs) with AUZ, PO, SAC, SC, SVSD, WLR, and EEC

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.198	1.440		.832	.413
	AUZ	.000	.001	.097	.537	.596
	PO	1.541	.599	.331	2.574	.016
	SAC	1.043	.597	.237	1.745	.093
	SC	.041	.016	.332	2.488	.020
	SVSD	-.718	.352	-.249	-2.041	.052
	WLR	2.988	1.590	.247	1.880	.072
	EEC	-.114	.100	-.154	-1.142	.264

a. Dependent Variable: DSAs

Table 6.28 Standard multiple regression of selected IVs on DSAs

Variables	DSAs (DV)	PO	SAC	SC	SVSD	B	β	sr^2 (unique)
PO	.54					1.8^{**}	0.39	0.14
SAC	.47	.17				1.4^{**}	0.33	0.097
SC	.43	.09	.00			$.043^{**}$	0.35	0.12
SVSD	-.51	-.25	-.31	-.16		$-.74^{*}$	-.26	0.055
						Intercept=2.7		
Means	2.09	0.30	0.24	15.5	2.99			$R^2=.65^a$
Standard deviations	2.46	0.53	0.56	20.2	0.85		Adjusted R^2	$R^2=.60$ $R=.80^{***}$

***p<.001, **p<.01, *p<.05

a. Unique variability =.36; shared variability = .29, 95% confidence limits from .48 to .81

The significance level for R is found with F(4,28)=12.77, *p*<.001, with R^2 at .65 and 95% confidence limits from .48 to .81. The adjusted R^2 value of .60 indicates that about 60% of the variability in density of sedentary activities is predicted by playing object (PO), shop/activity center (SAC), seating capacity (SC), and spatial visual step depth (SVSD).

The first three IVs (PO, SAC, and SC) in combination contributed another .29 in shared variability. Altogether, 65% (60% adjusted) of the variability in density of sedentary activities was predicted by knowing scores on the total four IVs. The size and direction of the relationships suggest that an increase in sedentary activities in a subspace associated with an increase in playing object (PO), shop/activity center (SAC), seating capacity (SC), and spatial visual step depth (SVSD). Compared with model for longtime staying, the area of usable zone is not important to sedentary activities. Playing object still affects significantly on sedentary activities. The model can be summarized as following formula:

DASs= f (PO, SAC, SC, SVSD)

=2.7+1.8PO+1.4SAC+0.043SC-0.74SVSD

Where DASs: Density of sedentary activities;

PO: Playing object;

SAC: Shop/activity center;

SC: Seating capacity;

SVSD: Spatial visual step depth.

This model was adapted as best one for sedentary activities. The results shown in Table 6.28 clearly indicate that playing object (PO) and seating capacity (SC) are most influential variables to sedentary activities. This result may be well understood as the playing objects may increase the chance of sedentary activities like watching, standing etc. and seating capacity may increase chance of sedentary activities like seating. Furthermore, spatial visual step depth (SVSD) is negatively associated with sedentary activities, which means that the number of passengers have significant effects. Interestingly, except spatial visual step depth (SVSD) the rest three IV belong to "facilities", which implies that "facilities" is the most significant factor to sedentary activities.

6.4.2.1.2 Implications of the model

The explanatory model indicated the magnitude of the effects of influential variables. Suggestions about environment design for sedentary activities can be summarized as following:

(1) The dominant factor is "facilities", in which playing object (PO) and seating capacity (SC) are crucial ones. It implies that the settings of playing objects and seats should be considered firstly for sedentary activities. The reason may be that playing objects can attract children playing or adults watching by, seats can provide affordance for seating.

(2) Shop/activity center (SAC) is less important to sedentary activities, but also quite significant. It provide a place to gather people for its functional reason.

(3) Spatial visual step depth (SVSD), which is associated with number of passengers, is statistically significant. The shorter SVSD lead to more passengers that will create great chance for sedentary activities.

6.4.2.2 Vigorous activities

6.4.2.2.1 Explanatory model for vigorous activities

Vigorous activities refer to such activities as exercise, playing football that users remain in a subspace more than 1 minute with locomotion (Section 3.4.1). It can be considered to contribute significantly to social interactions. I separated users of vigorous activities from other staying activities, and density of vigorous activities is calculated as described in Table 6.17.

As examined before, five IVs (PO, AUZ, WLR, SVSD, and VIS) assumed to be influential to vigorous activities. Standard multiple regression analysis was conducted with these six IVs, Table 6.29 presents the selected output of standard regression.

The combination of IVs needs to be modified by excluding IVs with more than 0.1 p value. At the first the least significant variable (SAC) with biggest p value was excluded, the standard regression was conducted again to examine the rest IVs (Table 6.21). However, there is still an IV with more than 0.1 p value. Thus, I did the same analysis by excluding the insignificant IVs one by one until all the IVs' p value became less than 0.1. Eventually, three IVs left (PO, AUZ, and WLR) are supposed to be the best combination to explain vigorous activities. Then I conducted standard multiple regression with these three variables, Table 6.31 presents the result with the correlations between the variables, the unstandardized regression coefficients (B) and intercept, the standardized regression coefficients (β), the semi-partial correlations (sr_i^2), R^2, and adjusted R^2.

Table 6.29 Selected output of standard multiple regression analysis of density of vigorous activities (DSAv) with PO, AUZ, WLR, SVSD, and VIS

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.063	1.376		-.046	.942
	PO	2.359	.582	.436	4.057	.000
	AUZ	.002	.001	.311	2.603	.015
	WLR	4.035	1.430	.288	2.821	.009
	SVSD	-.448	.347	-.134	-1.290	.208
	VIS	-.441	.385	-.116	-1.146	.262

a. Dependent Variable: DSAv

Table 6.30 Selected output of standard multiple regression analysis of density of vigorous activities (DSAv) with PO, AUZ, WLR, and SVSD

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
2	(Constant)	-.087	1.383		-.063	.951
	PO	2.364	.585	.437	4.043	.000
	AUZ	.002	.001	.346	2.980	.006
	WLR	3.775	1.420	.269	2.659	.013
	SVSD	-.504	.346	-.151	-1.458	.156

a. Dependent Variable: DSAv

Table 6.31 Standard multiple regression of selected IVs on DSAv

Variables	DSAv (DV)	PO	AUZ	WLR	B	β	sr^2 (unique)
PO	.70				2.4***	.45	0.16
AUZ	.69	.46			.002**	.40	0.12
WLR	.51	.24	.33		3.8**	.27	0.064
					Intercept=-1.8		
Means	2.21	0.30	578	0.52			R^2=.73[a]
Standard deviations	2.86	0.53	519	0.20		Adjusted R^2	R^2=.70 R=.85***

***p<.001, **p<.01
a. Unique variability =.28; shared variability = .45, 95% confidence limits from .59 to .87

The result shows that this model is feasible to interpret vigorous activities. The significance level for R is found with F(3,29)=25.85, $p<.001$, with R^2 at .73 and 95% confidence limits from .59 to .87. The adjusted R^2 value of .70 indicates that about 70% of the variability in density of vigorous activities is predicted by playing object (PO), area of usable zone (AUZ), and spatial width to length ratio (WLR).

The first two IVs (PO, and AUZ) in combination contributed another .45 in shared variability. Altogether, 73% (70% adjusted) of the variability in density of vigorous activities was predicted by knowing scores on the total four IVs. The size and direction of the relationships suggest that vigorous activities likely occur in a subspace with more playing objects, bigger area of usable zone and higher spatial width to length ratio. Among those three, however, playing object (PO) is most significant variable. The model can be summarized as below:

DASv= f (PO, AUZ, WLR)

=-1.8+2.4PO+0.002AUZ+3.8WLR

Where DASv: Density of vigorous activities;

PO: Playing object;

AUZ: Area of usable zone;

WLR: Spatial width to length ratio.

This model was adapted as best one for vigorous activities. This model can predict about 70% density of vigorous activities in newly developed residential communities in China. Table 6.31 reveals that PO contributes most significantly to vigorous activities. However, the combination of two variables of spatial configuration (AUZ and WLR) almost has the same significance with their high sr^2, which implies that facilities and spatial configuration are both significant to vigorous activities.

6.4.2.2.2 Implications of the model

The explanatory model indicated the magnitude of the effects of influential variables. Suggestions about environment design for vigorous activities can be summarized as following:

(1) Similar with model for longtime staying, vigorous activities are associated with playing objects (PO), area of square space (AUZ), and spatial width to length ratio (WLR). The reason may be that playing objects (PO) provides affordance to such vigorous activities as sliding, climbing, or playing; bigger area of usable zone (AUZ) and higher spatial width to length ratio (WLR) provide wide space for such vigorous activities as group games, football playing.

(2) Unlike model for longtime staying, spatial visual step depth (SVSD) does not show significance to vigorous activities. The reason may be that residents are familiar with subspaces in their small communities, which make accessibility insignificant to residents' choice of vigorous staying.

(3) Notably both the two variables of spatial configuration affect significantly on vigorous activities, which implies that "spatial configuration" is the most important factor.

6.5 Interpretation of All the Results

Our findings suggest that the physical characteristics of community are related to the density of different staying activities (DSA). Variables of the physical environment are related to staying activities, but the magnitude of the effect differs significantly by activity category. Table 6.32 generally summarized all the models proposed, which give us several hints.

Table 6.32 Standard multiple regression of selected IVs on DSA in different activity categories

Physical environment factors / variables		All staying activities		Children's staying		Adults' staying		Elderly's staying		Occasional stoppings		Longtime staying		Sedentary activities		Vigorous activities	
		B	*p*	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*
Community-level accessibility	SVSD	-2.2	.026			-.84	.087	-.50	.035	-.94	.026	-1.4	.049	-.74	.045		
	AD					.0002	.031										
Subspace-level accessibility	VAS																
	VIS			-.82	.073					.76	.098						
Facilities	SC							.055	<.001					.043	.005		
	PO	3.4	.046	3.1	<.001			1.1	.005			3.8	.002	1.8	.003	2.4	<.001
	EEC							.19	.002								
	SAC					2.5	.002	1.2	.002					1.4	.01		
Spatial configuration	AUZ	.005	.007							.002	.003	.003	.01			.002	.001
	WLR	8.6	.036	4.2	.016	3.6	.06					6.1	.035			3.8	.014
Adjusted R^2		.63		.56		.55				.40		.67		.60		.70	
Intercept coefficient		5.7		-.87		6.1				4.3		2.2		2.7		-1.8	

I consider that magnitude of the effect differs significantly among activity categories may due to the needs of specific staying activities. For instances, children's staying activities such as sliding, climbing usually associate with playing equipment or playable objects, that is the reason why playing object (PO) is quite significant to children's staying activities. Similarly, elderly's staying activities such as sitting or exercising is associated with seats or exercise equipment. Therefore, it is necessary to elaborate the needs of activities.

First, I found some similarities among different activity categories. The similar models assume to have similar property or high coincidence in contents, whose needs can be elaborate as one. The models of all staying activities and longtime staying have the same influential variables with a little change in significance of some IVs. However, playing object (PO) is the most significant IV for longtime staying, whereas the area of usable zone (AUZ) is the one for all staying activities. Because all staying activities include two parts (occasional stoppings and longtime staying), and AUZ is quite important to occasional stoppings due to its affordance of space, therefore AUZ became more significant than PO in all staying activities. Moreover, there is similarity between elderly's model and sedentary activities. It is easy to understand the high association because of that elderly people is the main participants of sedentary activities. While exercise equipment capacity (EEC) does not show its influence in the model of sedentary activities. The reason should be that exercise equipment associate with such staying activities as exercising which does not belong to sedentary activities.

Second, the different significance of physical factors reveals specific needs of staying activities. Spatial configuration is the most influential factor for all staying activities, occasional stoppings and vigorous activities, but it is not for different age groups or sedentary activities. This suggests that the size and shape of the space provide significant affordance to occasional stoppings and vigorous activities, but not for others. The great significance of accessibility just can be found in occasional stoppings and adults' model, especially there is no variable of accessibility works in vigorous activities, which implies that accessibility is not influential for longtime staying (sedentary activities and vigorous activities) or elderly/children's staying activities. The reason may be that residents are familiar with subspaces in their small communities, which make accessibility insignificant to most residents' choice of longtime staying. Facilities are important for all age groups, and longtime staying (including its subcategories), but totally not for occasional stoppings, which suggests that the affordance of facilities do not support occasional stoppings. Whereas, sedentary activities like sitting and vigorous activities like sliding are associated with the affordance of such facilities as seating furniture and playing object. At last but not the least important, playing object (PO) is significant both to children and elderly people. One of considerable reasons is that elderly people usually accompany with grandchildren to the place with installation of playing object. They always stand or seat nearby to watch grandchildren playing. Therefore seating furniture and playing object can be installed as a set of facility to attract children and elderly people.

6.6 Summary

This chapter introduced models for staying activities to explain the significance of physical factors/variables. Our findings suggest that the physical characteristics of community are related to the density of different staying activities (DSA).

The model of all staying activities suggested spatial configuration is the most significant factor to all people and other variables such as spatial visual step depth (SVSD) and playing objects (PO) also contribute significantly to all staying activities. After discussed the general one, the variation of influential factors in different age groups or activity categories were discussed to meet different needs of people or activity. The model for children's staying activities suggested that playing object (PO) is the most influential variable to children's staying activities, implying "facilities" is significant. Spatial width to length ratio (WLR) is the next significant IV, and the vehicle intervention (VIS) contributes next to WLR. "Facilities" is also the most significant IV to other people especially for elderly people. Shop/activity center (SAC) is recommended for adults, and all the "facilities" should be considered for elderly people. Accessibility contributes lots for people, especially for adults or occasional stoppings, which associate with number of passengers. Spatial configuration almost contributes significantly to every kind of staying activities except elderly's and sedentary activities, which are similar with each other. It implies that the shape or capacity of space is not important to elderly people.

In summary, we found relevant variables of the physical environment for different staying activities. The results provide basic knowledge on the design of residential communities to promote staying activities.

CHAPTER 7 Conclusions

7.1 General summary

This paper looked at the issue of China that the social interactions among neighbors in newly developed residential communities decreased drastically. An intensive field survey was conducted to gather empirical evidence to analyze relevant factors of the physical environment on outdoor activities which potentially contribute to social interactions.

Chapter 1 introduced the background of this research and placed this research as one part of community health development. The decrease of social interactions in newly developed communities was stated as an important issue in China, and elucidating relevant factors of the physical environment objectively to build statistical models for outdoor activities were settled as objectives of this research. After gave a general browse on the previous researches, the procedure of this research was introduced generally using framework graphic.

Chapter 2 introduced the method of an intensive field survey. Proper communities were chosen based on a pilot survey with clear criteria, the outdoor space was divided into subspaces through a preliminary survey. A systematical observation method conducted synthesized conventional observation tools such as behavioral mapping and SOPARC. The qualitative and quantitative data gathered movements of people and their attributes under specific spaces.

Chapter 3 described the results of field survey. 7668 user's activity data were grouped into two categories (passing activities and staying activities), and visualized on to activity maps preserved in Auto CAD files. The numerical and spatial data in the PC memory can be used to extract the statistical and spatial information of physical environment and observed activities. In the end, the significance of staying activities was highlighted. Variation of staying activities in terms of time (morning and afternoon, weekdays and weekends) and variation in terms of activity category were examined. Although there are no consistent similarities of staying activities in terms of time, the variation of different staying activities present potential connections with physical environment, which implies some potential physical variables for latter analysis.

Chapter 4 analyzed the influences of accessibility in community scale. Space syntax method was used to explain accessibility from the community entrances. The results show that space syntax method could fairly well describe passing activities, and staying activities. Moreover, a variable of accessibility from residential buildings (AD) was proposed to examine its influences on staying activities. Although the results show that AD is not well correlated with staying activities, it may fairly well explain staying activities in the comparatively well used subspaces

(DSA≧11%/H).

Chapter 5 explored the influences of spatial physical characteristics on staying activities which are considered to contribute to social interactions. Three variables of accessibility (visual accessibility -VAS, physical accessibility - PAS and vehicle intervention score - VIS) in subspace scale level were proposed, four variables of facilities (seating capacity - SC, playing object - PO, exercise equipment capacity - EEC, and shop/activity center - SAC) were proposed based on the rules that each variable is strongly correlated with all staying activities but uncorrelated with other ones. At last, two variables of spatial configuration, including area of usable zone (AUZ), and spatial width to length ratio (WLR) were extracted to describe the spatial character. The influences of each variable on staying activities were discussed. PAS, PO, AUZ, and WLR could well describe staying activities while other variables as VAS, SAC, VIS, SC, and EEC showed limited correlation. These results are used to understand comprehensive models for staying activities.

Chapter 6 built multiple regression models for staying activities with hierarchy of significant variables by using multiple regression analysis. The model for all staying activities suggested that the area of usable zone (AUZ) is the most significant variable, and other variables such as spatial visual step depth (SVSD), spatial width to length ratio (WLR), and playing object (PO) also contribute significantly to all staying activities. By contrast, the influential factors vary in terms of users' age and activity categories. For the variation of influential factors in terms of age group, there are three models proposed. The model for children's staying activities suggested that playing object (PO) become the most influential IV to children. Spatial width to length ratio (WLR) and the vehicle intervention (VIS) also need to be considered for children's staying activities. The model for adults' staying activities suggested shop/activity center (SAC) contribute most to the regression model. Accumulative distance (AD), spatial width to length ratio (WLR), and spatial visual step depth (SVSD) also significantly affect adults' staying activities. The model for elderly's staying activities suggested that seating capacity (SC), exercise equipment capacity (EEC), shop/activity center (SAC), playing object (PO), and spatial visual step depth (SVSD) influence elderly's staying activities significantly. The "facilities" is most significant factor for elderly people. For the variation of influential factors for different activity categories, there are four models discussed. The model for occasional stoppings suggested that area of usable zone (AUZ), spatial visual step depth (SVSD), and vehicle intervention score (VIS) can describe occasional stoppings well. The model for longtime staying suggested that area of usable zone (AUZ) is the most influential variable. Playing object (PO), spatial width to length ratio (WLR), and spatial visual step depth (SVSD) also effect significantly on longtime staying. Furthermore, the models for different longtime staying were discussed. The model for sedentary activities suggested that playing object (PO), shop/activity center (SAC), seating capacity (SC), and spatial visual step depth (SVSD) are statistically significant. The model for vigorous activities presented the significance of playing object (PO), area of usable zone (AUZ), and spatial width to length ratio (WLR).

7.2 Prospects of Future Research

On our route to explore the relationships between environmental factors and outdoor activities, we had to cope with different data. Although we explored models of staying activities for different age groups, and for different activities, the details of staying activities have not been explored, which lead to a considerable contribution to field research method in the future.

First, we developed a systematic observation method, which includes time arrangement consideration, simple and effective recording way, as well as systematic method of extracting useful data. This could be widely applicable for accumulating evidence-based activity data in a field survey.

Second, we proposed some physical measures which were found to relevant to people's activities: 1) the SVSD which stems from Visual Step Depth (VSD) in space syntax method, can explain visual depth (psychological distance) from multiple start points to a target point or a space, 2) area of usable zone (AUZ) which is defined by necessary ground surface and width of space for staying activities, was verified with its great effects.

In summary, we found relevant variables of the physical environment for different staying activities. On our premise that staying activities contribute to social interactions, the current results suggest that space design concerned with promoting staying activities may increase social interactions. Furthermore, community design targeted at promoting staying activities might be more effective if the design is tailored to a particular activity category. Therefore, our results can be a first step to create a guideline for community design for promoting social interactions between neighbors, and consequently create opportunities for accumulating evidence-based activity data to modify community design.

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LIST OF PUBLICATIONS

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1. Qing Yin, Ryuzo Ohno, Masashi Soeda, Study on Outdoor Activities in China's Residential Communities: Influence of Physical Characteristics on Staying Activities, *MERA Journal*, Vol.18 No.2, pp.1-10, Mar. 2016.

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1. Qing Yin, Ryuzo Ohno, How to Rebuild a Strong Social Network in New Communities of China? *Procedia Social and Behavioral Sciences*, Vol.170, pp.504-515, Jan. 2015.
2. Qing Yin, Ryuzo Ohno, Yiqian Yuan, Construction of Healthy Community in Newly Developed Residential Neighborhoods in China: A survey on social and physical activities in different types of housing in Tianjin, *Sustainable City Development and Social Housing Construction: The 10th China Urban Housing Conference*, pp.615-621, Jul. 2013.

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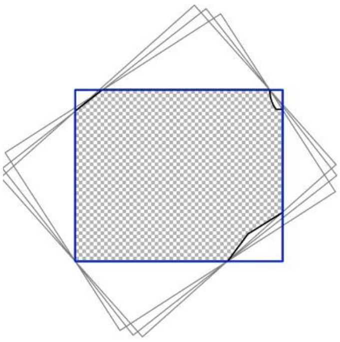
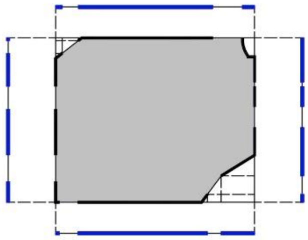
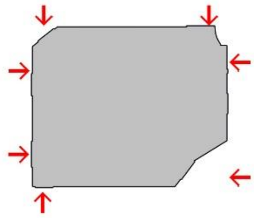
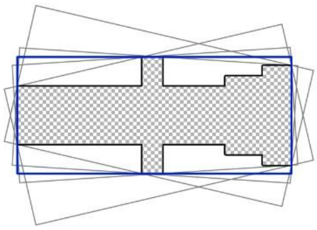
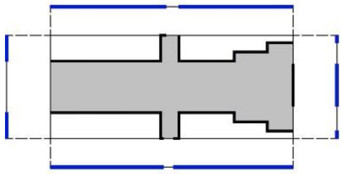
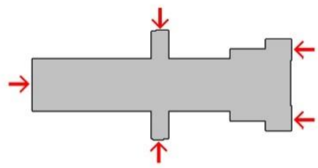
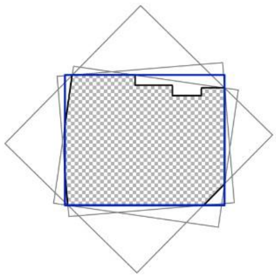
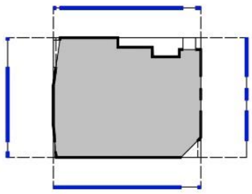
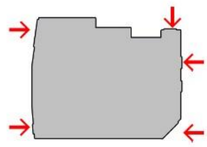
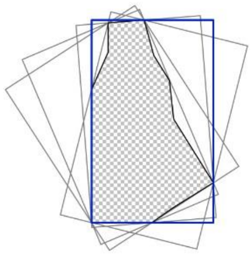
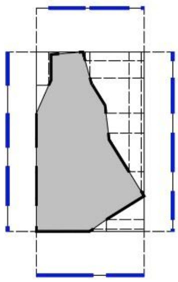
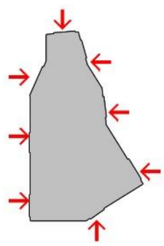
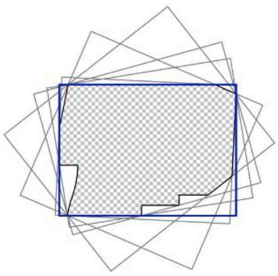
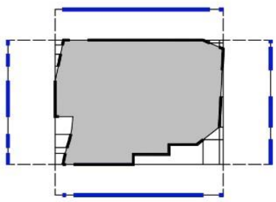
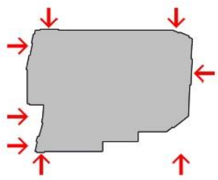
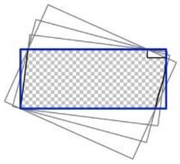
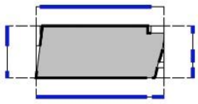
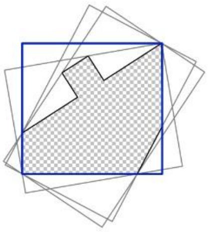
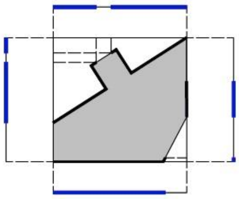
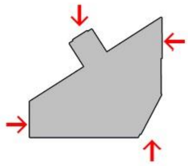
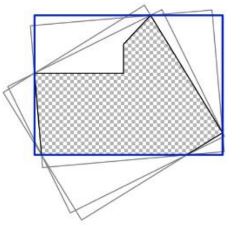
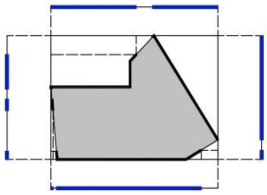
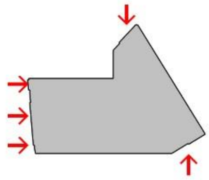
Appendixes

Subspace	WLR related	VAS related	PAS related
J1			
J2			
J3			
J4			
J5			

J6			
J7			
J8			
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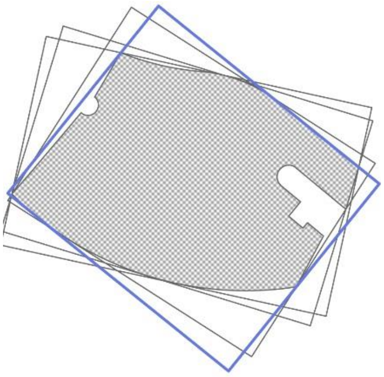
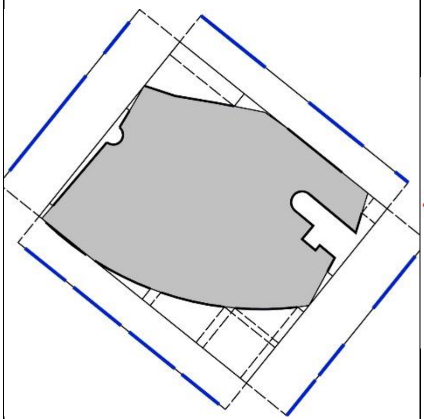
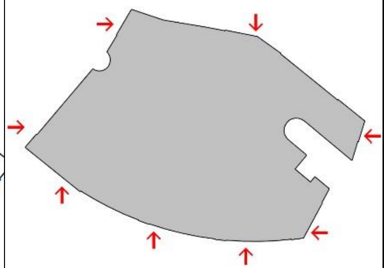
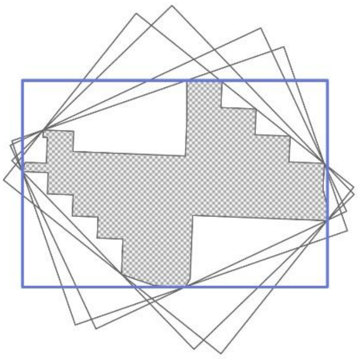
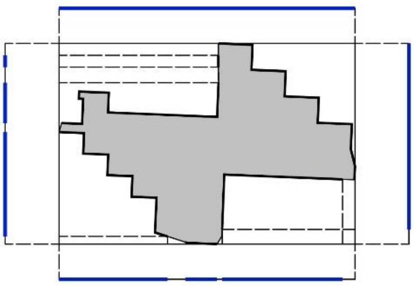
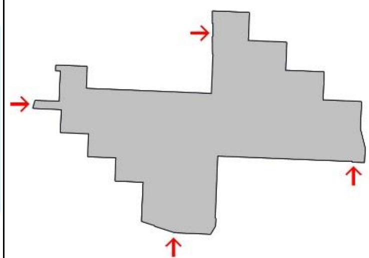
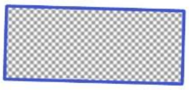
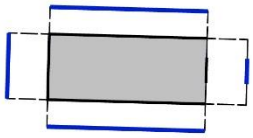
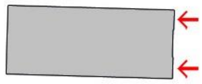
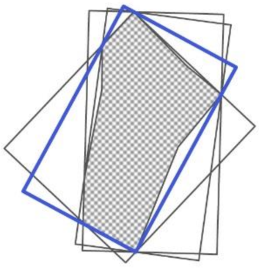
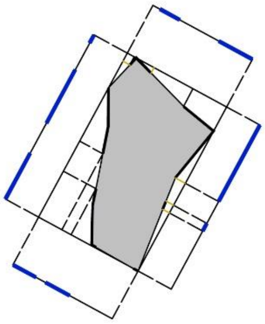
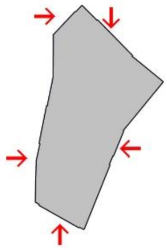
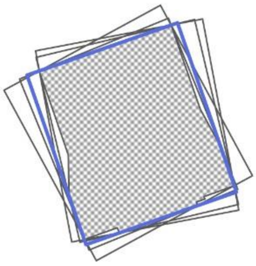
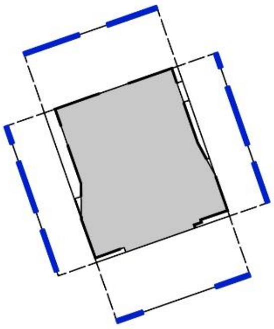
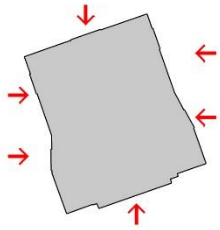
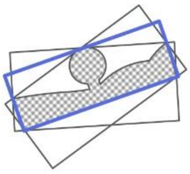
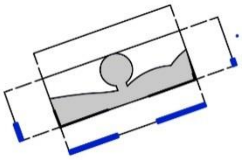
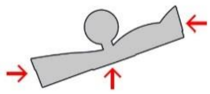
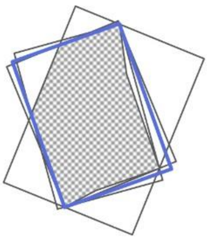
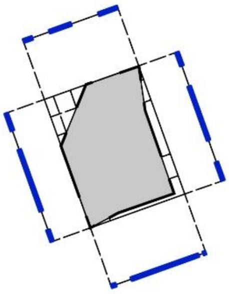
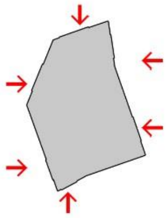
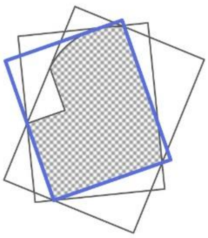
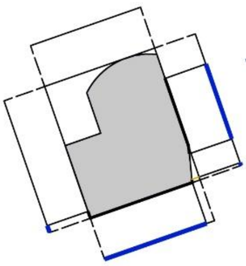
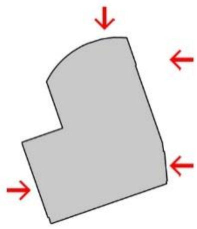
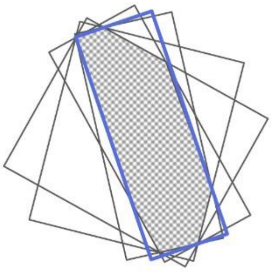
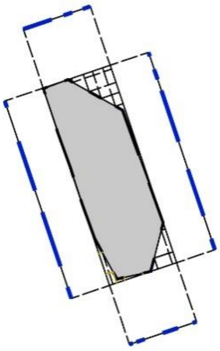
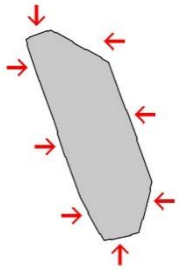
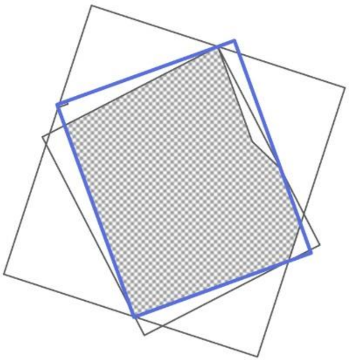
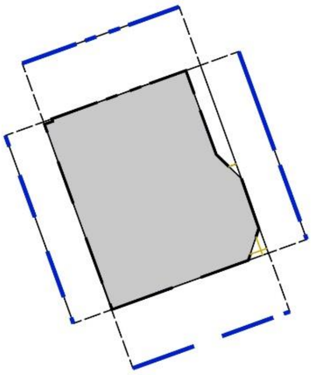
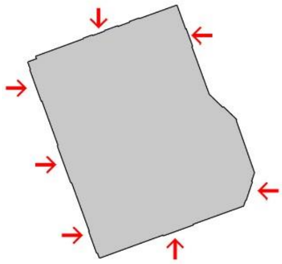
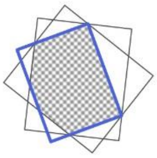
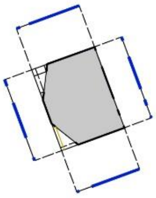
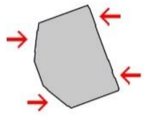
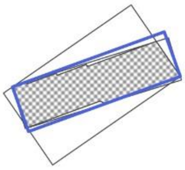
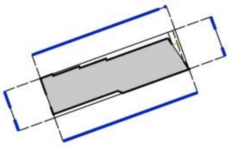
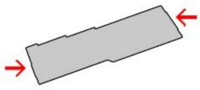
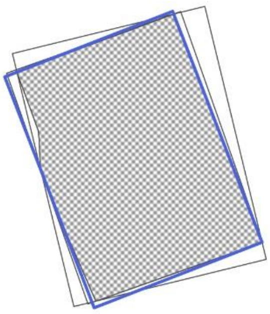
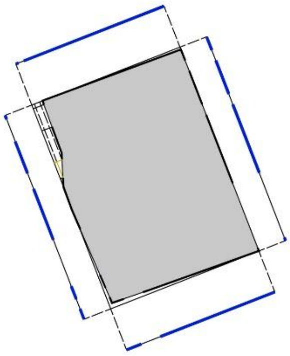
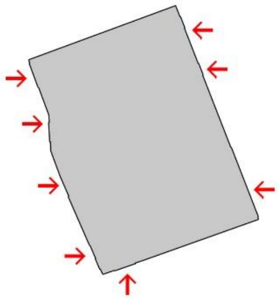
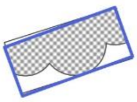
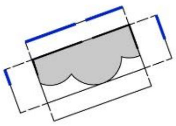
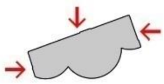
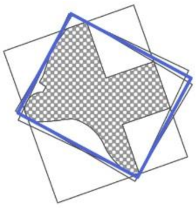
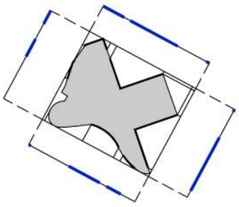
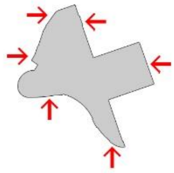
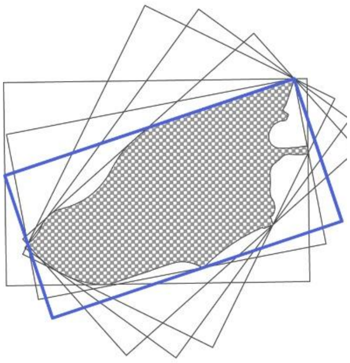
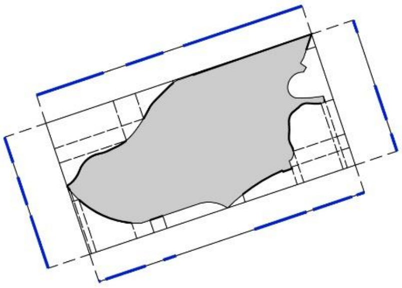
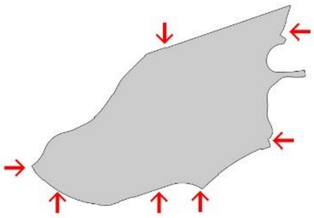
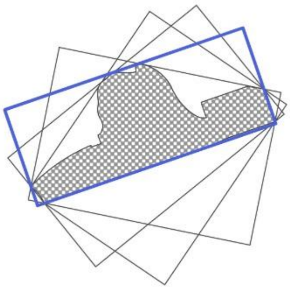
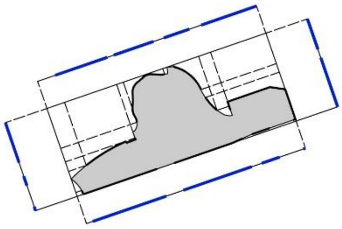
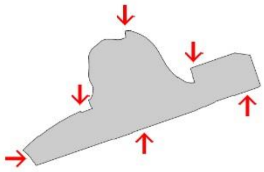
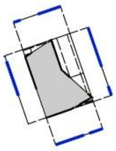
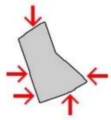
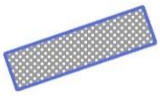
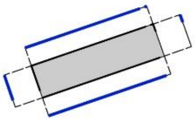
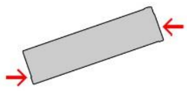
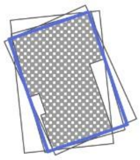
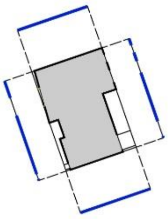
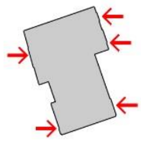
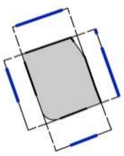
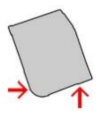
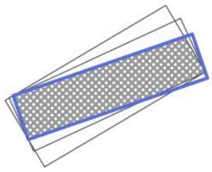
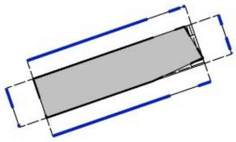
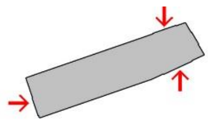
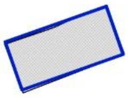
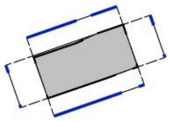
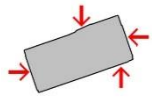
T1			
T2			

T3			
T4			
F1			
F2			
F3			
F4			

F5			
F6			
F7			
F8			
F9			
F10			

X1			
X2			
X3			
X4			
X5			
X6			
X7			

X8			
X9			
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