The characteristics of leisure activities and the built environment influences in large-scale social housing communities in China: the case study of Shanghai and Nanjing

Lingling Zhang and Zihao Wu
School of Architecture, Soochow University, Suzhou, China

ABSTRACT
In large-scale residential communities for social housing in China where low-income groups gather, public green space is the most dominant public leisure space for residents. Therefore, researches on the characteristics of leisure activities in these communities and the built environment factors that exert an impact on leisure activities would provide an important theoretical basis for future reform of the public space of large-scale social housing communities in China. The study uses the method of behavioral mapping to obtain the data of the residents' leisure activities in two typical large-scale social housing communities in Nanjing and Shanghai. This study employs methods such as syntactic modeling and site investigation to collect data of environmental factors. This study processes them with the multi-factor linear regression model to explore the “environment-behavior” relationship. The results indicate that the leisure activities of middle and low-income groups in large-scale communities follow a certain pattern in terms of the changes in time axis, sex ratio, location, willingness to socialize. Integrating the impacts of spatial structure and site elements with three groups of variables – spatial configuration, planning conditions and site elements – can explain approximately 70% of the leisure activities distribution.

1. Introduction
1.1. Background
In 2007, China’s State Council issued the important document of Several Opinions on Solving the Difficulties of Urban Low-income Families (GF [2007] No. 24). Since then, large-scale social housing construction has been carried out in major cities all over the country. During the 12th Five-Year Plan period (2010–2015), the state planned to build 36 million social housing units. In big cities, these houses are mainly supplied in the form of centralized newly construction entities. Taking Shanghai as an example, Shanghai Housing Construction Plan (-2008–2012) pointed out that 4 million square meters of social housing, such as low-rent housing and affordable housing, would be newly constructed per year, reaching 20 million square meters in five years, accounting for about 20% of the total volume of newly built houses in the corresponding period. As for these huge social housing construction plans, Shanghai, Nanjing, Chongqing and many other big cities take newly built large-scale communities in the suburbs as coping strategies (Zhang...
These large-scale communities will determine the resident modality of ten-million middle and low-income families in the recent decade or two, and in the meanwhile shape the morphology of the outer suburbs of these big cities in China.

Since 2011, the large-scale social housing communities in major cities have been taking shape and residents have begun to move in. These communities are located in the outer suburbs, with texture isolated from the city (Yingjie 2010), and with houses of the similar exterior designs (Yuhong and Yong 2008). The size of such a community is large, usually more than 50 hectares (Zhang 2017), containing a dozen or even dozens of residential quarters. The residents in the community are mostly people of middle and low income with low rates of vehicle ownership (Zhenyu and Zhang Lingling 2011), who are less likely to go to the city center for daily leisure activities. Therefore, the public green space within the community plays a dominant role in facilitating the residents in carrying out their daily leisure activities, especially for those retired and unemployed residents without work commuting. Improving the public green space environment of these large-scale communities is a direct channel to enhance the quality of public leisure lifestyle of residents. Exploring the characteristics of public lifestyle and leisure activities of residents and their “Environment-Behavior” relationship provides an essential theoretical basis for the public green space reform of these communities in the future.

1.2. Literature review

Existing researches on community public space around the world are mostly related to the physical (Tsai et al. 2019) and mental (Wood et al. 2017) health of residents, while behavior itself as one of the medium affecting psychology is rarely discussed (Houlden et al. 2018). When it comes to specific behaviors of residents, recreational walking is the main focus of the research (Lu 2018). Researches on the leisure activities with the feature of social gathering are still limited. In China, recreational walking (Park et al. 2016) only accounts for a small percentage in residents’ community lifestyle, and leisure activities featured with consumption, such as drinking coffee, are also very limited. A big part of the community lifestyle and physical exercise still take the form of gathering leisure activities in the free public space in the community. Consequently, in China, compared with the research on recreational walking that on gathering leisure activities can provide a more comprehensive overview of the characteristics of residents’ public lifestyle in the community.

In different disciplines such as medicine and landscape architecture, as to the public green space in community, most discussions are about the influences of natural or semi-natural afforested environment on people’s physical and psychological conditions (Tsai et al. 2019), but not that much about the artificial environment (San Juan, Subiza-Perez, and Vozmediano 2017). The residential density of Chinese communities is high and the public green space is mostly artificial. For now, it is of little significance to discuss the influence of afforested factors, such as vegetation type and greening configuration on residents in China. There is a widespread lack of green space in low-income communities around the world (Astell-Burt et al. 2014; Wen et al. 2013), which may be more serious in China. Therefore, we should not only focus on the greening itself but also on the overall environment when it comes to discuss the usage pattern and environmental relevance of public green space in low-income communities in today’s China.

When it comes to specific research variables, environmental psychology focuses more on the influence of single spatial element on behavior, including accessibility (Giles-Corti et al. 2005), site area, distance, age, health condition (Schipperijn, Stigsdotter, Randrup, Troelsen, et al. 2010), visual threshold (Zhengying and Dongfeng 2016), attraction and facility function (Yiyong and Weibin 2015; Yiyong and Tao 2016), etc. Meanwhile, urban planning pays more attention to the impact of urban spatial structure on the fairness and accessibility of public facilities (Shan et al. 2015), and then to discuss the travel behavior at a macro-scale. The existing research shows that both spatial structure and site elements can affect human behavior, but no research has ever integrated those two aspects. In terms of research methods, although GIS, GPS, big data and the other research technologies (Chang and Xiaoming 2016) have developed continuously, behavioral observation at micro-behavior level still remains the most effective method, including behavioral mapping, trace investigation, etc. (Gehl and Gemzoe 2003; Xiaoling 2013). Hence, this research adopts behavioral observation method to collect behavioral data, and obtained the environmental data from two aspects: spatial structure and site elements. The research focuses on leisure activities and the built environment influences in low-income communities in China and its objects are two large-scale social housing communities in Shanghai and Nanjing.

2. Methods

2.1. Study sites

Before 2018, residential communities’ development usually followed the principle of hierarchical gated
community (Yin and Zhenyu 2009) including three-level “Community-Residential Quarter-Group” in China (Figure 1). The public green space for leisure activities in these communities can be classified into four types: green space in residential quarters, green space in community park, commercial affiliated plaza and street recreational space. Compared with the continuous public space system in western countries, which is composed of streets, squares and small parks, the biggest difference is our non-contiguous structure, and the space is divided into two parts: inside and outside residential quarters, which are both the important daily leisure space for residents. Although the planning cycle and construction period of large-scale social housing communities are relatively short, the general planning principles and control methods are the same as those of ordinary communities in China, and the road network structure, public facilities layout and community structure are mostly similar to those of common large-scale communities too. Therefore, the public space system in those large-scale residential communities for social housing still follows the characteristics of non-contiguous structure which divided into two parts inside and outside residential quarters.

Both Shanghai and Nanjing are Chinese megacities, and their socio-economic levels are similar. They can reflect the situation of large urban communities in China’s economically developed regions to a certain extent. Both places are located in the Yangtze River Delta with hot summers and cold winters, and have similar climatic characteristics and cultural habits. Selecting communities in these two places for comparison study can better explore and analyze the different use of public green space brought about by the differences in community planning modes under the premise of similar other conditions. After the samples were screened and compared, Heshahangcheng in Shanghai and Daishan New Town in Nanjing were selected as the research samples. Heshahangcheng and Daishan New Town are large, well-developed communities. Both have a relatively long tenant retention with the typical characteristics of large-scale social housing community, which have large site area and located in the outer suburbs of the city, which means isolated texture from the city. These two samples are typical representing cases, which makes them suitable for research study. However, these two samples are different in their planning mode. From the perspective of planning mode, Heshahangcheng in Shanghai and Daishan New Town in Nanjing represent the large-scale communities of “thousand-person index” mode and “neighborhood center” mode, respectively, covering the two main community planning modes in China. In the past 20 years, the large-scale community planning of many cities in China, represented by Shanghai, has followed the Code for Planning and Design of Urban Residential Areas (GB50180-93, 2002): Residential public facilities are

![Figure 1. Illustration of three-level hierarchical-gated community in China.](image-url)
configured according to three levels pattern of “Community-Residential quarter-Group”. Various facilities are provided at all levels according to the corresponding area per thousand people. The location of the facilities is determined by the service radius, so generally, it is evenly spread out (Figure 2, left). This planning mode is called “thousand-person index” mode. Some other cities, such as Nanjing, Suzhou, and Shenzhen, have adopted the “neighborhood center” mode derived from Singapore, emphasizing the centralized layout of major public facilities in communities to form community centers. The public facilities of this type of community have the characteristics of centripetal arrangement (Figure 2, right).

Daishan New Town is located in the southwestern end of Nanjing, near Xishan Bridge, Yuhuatai District. It is about 20 kilometers away from the city center and 3 kilometers away from the nearest

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1In China, most government statistics are not publicly available and data access channels are limited. Community-level demographic data is even more difficult to obtain. Therefore, the team chose the method of combining both recording the number of houses with lights on at night and consulting relevant staff of the neighborhood committee to confirm the data and estimate the occupancy rate. The occupancy rate of Nanjing Daishan New Town is about 42%, and that of Shanghai Heshahangcheng is about 43%. The data may be skewed to a certain extent.
2.2. Built environmental data acquisition

Through the literature reviews in different fields, it can be seen that the spatial structure and site elements will affect the leisure activities of the community, but the current researches with single-variables analysis have lower explanatory power (Yiyong and Weibin 2015; Yiyong and Tao 2016). According to China’s planning procedures in the past, only the community road network and the approximate location of the main public green space would be determined during the community planning stage, and the design of the specific site and facility configuration wouldn’t be taken into account. So, these two kinds of variables can be considered independent of each other. Combining the two types of variables may be able to obtain a better explanatory mode. After in-depth expert consultation and pre-investigation, the variables that the research eventually introduced to describe the plot environment includes spatial structure and site elements two aspects, divided into three variable groups of spatial configuration, planning conditions and site elements, with a total of 15 variables (Figure 4. Variable hierarchical relationship, Table 1: Variable Definition and Statistic Information). The spatial structure variables are further divided into spatial configuration variables that represent the impact of the road network topology and planning condition variables that represent the impact of the condition and location of public facilities.

After consultation with experts in the field of space syntax, NAIN (Normalized Angular Integration) and NACH (Normalized Angular Choice) are finally adopted as the spatial configuration variables to quantify the road network topological value of the location of the public green space (Shengqiang and Yang 2019). NAIN is the standardized value of integration, which measures the potential of the road where the plot is located to become the destination. The better the value is, the better accessibility it represents. NACH is the standardized value of Choice, which measures the frequency with which the road on the plot is chosen as the shortest path between any two points. The better the value is, the higher the traverse frequency it represents, which reflects the advantage of being the shortest path. The purpose of standardization is to compare different road network systems of different scales and complexity (Hillier, Yang, and Turner 2012). NAIN and NACH are intended to measure the “natural” impacts the community road network layout have on the distribution of leisure activities.

Planning conditions including business coefficient, distance from food market, distance from school, public transit coefficient, road width and sidewalk width usually are the environmental factors determined in the planning phase. Different from the

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Based on Delphi Method, the research team consulted 5 experts in 3 fields: two experts in the field of planning, including one expert in the field of relationship between community crime and community environment, and the other in the field of TOD efficiency around community rail transit stations. Both are experts who study the relationship between community environment and behavior from different perspectives. Another expert in the field of space syntax, focusing on the quantitative methods of road network topological relationships and its relevance to behavior. Two experts in the field of environmental behavior, one is an expert in community leisure behavior, and the other is an expert on the relationship between soundscape and behavior. Through multiple rounds of anonymous feedback and consultations, the research finally introduce 15 environmental variables of 3 groups into the model.

Figure 4. Variable hierarchical relationship.

Youfangqiao subway station. The total site area of the community is 223 hectares, containing 17 residential quarters, with an average occupancy time-span of about 10 years. Heshahangcheng is located in Hangtou Town, Pudong New Area, at the southeastern end of Shanghai. It is about 22 kilometers away from the city center and 2 kilometers away from the nearest subway station. The site area of the community within the scope of the study is 164 hectares, including 13 residential quarters. The average occupancy time-span of each quarter is about 8 years, and the average occupancy rate of both community is close to half. The location, code and activity volume of public green space in the two communities are shown in Figure 3. More specifically, Shanghai community includes 26 plots while Nanjing community includes 28 plots. In total, there are 54 plots, which means the following data analysis includes 54 sets of data.
Table 1. Variable definition and statistic information.

| Variable | Definition and data acquisition method | Descriptive Statistics |
|----------|---------------------------------------|------------------------|
| I1 NAIN (R = 800 m) | NAIN compares the angular total depth with the mean value of the total depth of the city system to obtain a standardized integration value. It can be used to measure the potential of road where the plot is located to be the destination. Better value means better accessibility as the destination. | Minimum 0.64 | Maximum 1.33 | Average 1.00 | Standard Deviation 0.14 |
| I2 NACH (R = 1000 m) | NACH refers to the Choice based on the standardization of the angular distance, which can represent the spatial efficiency integrating the influence of Choice and Integration. Better value means higher frequency, which reflects the advantage of being the shortest path. | Minimum 0.59 | Maximum 1.36 | Average 1.12 | Standard Deviation 0.18 |
| L1 Business coefficient | Fuzzy evaluation of the commercial status of the street where the plot is located through site investigation. On the scale of 0–4, 0 means no business in nearby street and 4 means business bordering the plot. 1, 2, 3 are fuzzy evaluation of the prosperity level and commercial status of the street nearby. | Minimum 0.00 | Maximum 4.00 | Average 1.65 | Standard Deviation 1.29 |
| L2 Distance from food market | Walking distance from the plot to the nearest food market | Minimum 10.00 | Maximum 860.00 | Average 353.70 | Standard Deviation 211.41 |
| L3 Distance from school | Walking distance from the plot to the nearest school | Minimum 20.00 | Maximum 840.00 | Average 274.07 | Standard Deviation 174.62 |
| L4 Public transit coefficient | The number of bus routes in the streets where two steps topological radius from the plot | Minimum 0.00 | Maximum 7.00 | Average 2.69 | Standard Deviation 1.90 |
| L5 Road width | The maximum road width of the street where the plot is located | Minimum 3.00 | Maximum 48.00 | Average 19.57 | Standard Deviation 11.00 |
| L6 Sidewalk width | The maximum sidewalk width of the street where the plot is located | Minimum 3.00 | Maximum 15.00 | Average 6.61 | Standard Deviation 3.87 |
| S1 Site area | Area of the plot | Minimum 400.00 | Maximum 33000.00 | Average 6392.89 | Standard Deviation 4738.35 |
| S2 Hard paved area | Hard paved area suitable for activities in the plot | Minimum 190.00 | Maximum 8012.00 | Average 2340.69 | Standard Deviation 1788.70 |
| S3 Greening rate | The ratio of the green coverage area to the site area in the plot, including turf, shrub coverage and canopy coverage | Minimum 0.05 | Maximum 0.80 | Average 0.40 | Standard Deviation 0.21 |
| S4 Enclosing degree | The proportion of enclosing degree of the plot, the value of four sides enclosing is 1 and the value of open land is 0; there are buildings and structures within in a range of 30 m be regarded as enclosing | Minimum 0.00 | Maximum 1.00 | Average 0.49 | Standard Deviation 0.23 |
| S5 Number of rest facilities | The number of rest facilities in the plot by site investigation, including formal seats and informal seat, such as the edge of parterres suitable for sitting | Minimum 0.00 | Maximum 94.00 | Average 18.85 | Standard Deviation 19.77 |
| S6 Number of fitness facilities | The number of fitness facilities in the plot by site investigation | Minimum 0.00 | Maximum 21.00 | Average 6.35 | Standard Deviation 6.38 |
| S7 Number of games facilities | The number of games facilities in the plot by site investigation | Minimum 0.00 | Maximum 4.00 | Average 0.39 | Standard Deviation 0.68 |

1) Spatial Configuration variables are marked as I, Planning Conditions variables are marked as L, and Site Elements variables are marked as S; 2) This research uses the data of NAIN (Normalised Angular Integration) and NACH (Normalised Angular Choice) collected in 14 cases whose searching radius ranges from 400 m-3000 m as independent variables and uses leisure activity data as dependent variable to determine the optimal searching radius for I1 and I2. According to the result, the best variable appears in the following cases: the NAIN value when searching radius is 800 m: P = 0.000, R = 0.669, the NACH value when searching radius is 1000 m: P = 0.029, R = 0.412. Thus, these two sets of data are used as spatial configuration data in statistics analysis and modeling; 3) When the plot sits adjacent to two roads or more, the variables I1, I2, L5 and L6 are determined according to the principle of optimal P value. That is to say to conduct analysis with variables in different cases of road number and activities data, then use the appropriate data in the model when P value is optimal. The result shows that I1 and I2 should take form of the maximum volume; same applies to L5 and L6; 4) S5 rest facilitate refers to makeshift resting place (an informal seat). This research defines a small-sized round or square landscape pond as one seat and each edge of a large-sized landscape pond as one seat.

The natural impact of spatial configuration, public transit coefficient, road width and sidewalk width can be seen as the achievable “artificial” impact that the planning phrase can determine (Sun, Jusheng, and Donghui 2017; Mehta 2007; Yong and Xinghua 2014). Business coefficient explores whether commercial atmosphere around the plot would affect leisure activities distribution (Park et al. 2016). Distance from food market and distance from school explores if the necessary activities, such as grocery shopping and going to school would affect leisure activities. These variables are considered to have effects on walking behavior in the research of the walk-ability (Yong and Xinghua 2014) in the community. However, whether these variables have effects on leisure behaviors or not remains unknown.

The variable set of site elements that describes the characteristics of the site itself includes 7 variables: site area (Yiyong and Weibin 2015; Yiyong and Tao 2016), hard paved area (Giles-Corti, Broomhall, Knuiman, et al. 2016).
2005; Giles-Corti, Donovan, and Holman 1996), greening rate (Astell-Burt et al. 2014), enclosing degree (Leiqing, Ning, and Chengyu 2013), site facilities (include rest facilities, fitness facilities, games facilities) (Yiyong and Weibin 2015; Yiyong and Tao 2016; Yong and Xinghua 2014; Leiqing and Kang 2014; Zhang et al. 2019, etc.). These are crucial factors that have been proved to have impacts on leisure activities in the pertinent researches in Architecture, Environmental Psychology, and Public Health. However, whether these factors will have impacts on the leisure activities of middle and low-income group in large-scale social housing community has yet to be proven.

2.3. Behavioral data acquisition

In the study, two methods are used to obtain leisure activities data: behavioral mapping and questionnaire. The record of leisure activities location is narrowed down to the plot, reflected by the plot code, and the activities location within the plot is not recorded in detail. We conducted two pre-surveys in Dec. 2017 and Apr. 2018, respectively, in Daishan New Town in Nanjing, determined the road connectivity, gateway condition, site internal condition, activity overview and questionnaire content. The official investigations were conducted on

### Table

| A. Sex | Overall | Nanjing | Shanghai |
|--------|---------|---------|----------|
| Male   | 42%     | 13%     | 31%      |
| Female | 58%     | 26%     | 51%      |

| B. Age | Overall | Nanjing | Shanghai |
|--------|---------|---------|----------|
| Children | 22% | 8% | 14% | 19% |
| Youth & Middle-aged | 34% | 27% | 16% | 16% |
| The Elderly | 44% | 17% | 18% | 32% |

| C. Job | Overall | Nanjing | Shanghai |
|--------|---------|---------|----------|
| Working | 39% | 10% | 29% | 10% |
| Retired | 34% | 9% | 20% | 31% |

| D. Education Level | Overall | Nanjing | Shanghai |
|---------------------|---------|---------|----------|
| No schooling | 5% | 2% | 4% | 11% |
| Primary-school | 15% | 5% | 2% | 10% |
| Middle-school | 49% | 13% | 31% | 40% |
| Bachelor | 29% | 4% | 25% | 23% |
| Master & Doctor | 2% | 3% | 1% | 1% |

| E. Average Monthly Household Income | Overall | Nanjing | Shanghai |
|-------------------------------------|---------|---------|----------|
| 0-1k | 4% | 1% | 3% | 11% |
| 1k-3k | 19% | 21% | 6% | 14% | 14% |
| 3k-5k | 34% | 36% | 11% | 25% | 25% |
| 5k-10k | 28% | 5% | 22% | 22% |
| 10k-30k | 13% | 10% | 3% | 13% |
| 30k+ | 2% | 2% | 1% | 2% |

Figure 5. Demographic characteristics of the survey and characteristic of leisure activities distribution inside and outside residential quarters in Nanjing and Shanghai.
May 27, May 28, June 3 and June 4 in 2018, including two workdays and two weekends. The presurvey of Heshahangcheng in Shanghai was launched on May 18 and 19 in 2019, and the formal survey was on June 2 and June 5 of the same year.

The detailed investigation arrangements in a single day are as follows: 1) The researcher counted the number of facilities in each plot, including rest facilities, fitness facilities, game facilities, etc.; 2) From 7:00 a.m. to 9:00 p.m., we selected 10 minutes per hour to count the number of people for on-site activities, recording them separately by children, young and middle-aged people, and the elderly, and briefly recorded the contents of their staying activities; 3) We issued questionnaires randomly for the rest of the time.

877 questionnaires were distributed to all plots in Nanjing, and 867 valid questionnaires were collected, recording 16,836 person-time in all. A total of 447 questionnaires were distributed to all plots in Shanghai, and 435 valid questionnaires were collected, with 9573 person-time recorded. Because this research mainly focuses on the relationship between public green space variables and leisure activities, we choose to conduct the research at late spring and early summer which is quite suitable for outdoor activities. The relatively larger size of sample was conducive to statistical analysis, and the impact of climate differences on leisure behavior was out of discussion.

3. Results

3.1. Behavioral data results

3.1.1. The features of population structure and the cross-analysis of location

The overall data of Daishan New Town in Nanjing and Heshahangcheng in Shanghai (hereinafter referred to as “Nanjing” and “Shanghai”) are relatively consistent, which indicates that the public leisure activities of residents followed a certain distribution pattern in large-scale residential communities for social housing (Figure 5).

The overall proportion of men and women in Shanghai is 44.5% for men and 55.4% for women, while men account for 39% and women 61% in Nanjing. The data of the two community samples shows that there are more women than men in leisure activities, and the sex ratio of Shanghai data is rather balanced while the percentage of women clearly surpasses men in Nanjing data. In the cross-analysis of sex and activity location, it can be found that compared with men, women prefer to take activities within the residential quarter, which is consistent in both two samples.

The proportion of the elderly in Shanghai is significantly higher than that in Nanjing. In the cross-analysis of age and location, the volume of children’s activities within the quarter is much higher than that outside the quarter, and the two community samples show the same pattern. Due to certain discrepancy in data, whether the elderly prefer to have activities within the quarter reaches no final conclusion.

In terms of occupation, the proportion of retirees in Shanghai is remarkably higher than that in Nanjing. As to the education level in the two samples, most participants received an education degree of junior or senior high school. Ranking second is the group who received a university degree. When it comes to the whole income level, Shanghai is slightly higher than that in Nanjing, and in both samples, the level of 3000–5000 Yuan accounts for the vast majority, showing the same distribution pattern. There is no obvious regularity in the relevance between location choice and occupation, education level and income.

Figure 6. The variation of activity volume on the time axis in Shanghai (left) and Nanjing (right).

5Sporting include basketball, badminton, football, roller skating, fencing, table tennis, Taiji and other sports; outdoor playing with babies means the parents accompanying children who lack the ability of free activities to take activities; Playing refers to the activities of children who have independent ability of activities.
Through the questionnaire survey, we find that in Nanjing 28.7% of the people who carry out leisure activities within the residential quarter are from other neighborhoods, and that ratio in Shanghai is 13%. Thus, it can be speculated that the gated system of large-scale social housing communities will not completely block
activities, and the public green space in different residential quarters are shared to a certain degree.

3.1.2. Time axis and activity contents

The variation of activity volume in a day on the time axis (Figure 6) is basically the same in Shanghai and Nanjing, and the two peaks are 9-00–10:00 a.m. and 6:00–8:00 p.m. The difference is that activity volume still gradually increases in Nanjing after 6 p.m., but that in Shanghai reaches its peak from 6 p.m. to 7 p.m.

According to the data of activity contents, the night increase of the activity volume is for square dancing in Shanghai, while Nanjing night leisure activities show more diversity. Comparing the data of work-days and weekends in the two samples, we find the changing pattern of activity volume on the time axis is consistent with the overall trend, indicating that the activity pattern is quite stable.

There are 54 plots in the two sample communities and 30 types of activities are recorded. Ten kinds of activities, such as chatting, sitting, outdoor playing with babies, sporting and recreational walking, account for 90% of the total activity volume counted (Figure 7). Although there are some differences between the two samples in the specific frequency sorting, these 10 activities are the most predominant leisure activities in the two communities, accounting for 95% (Nanjing) and 86% (Shanghai) of the total volume, respectively. It can be inferred that these 10 kinds of activities are the main daily leisure activities among low and middle-income residents in China. Besides, the proportion of square dancing should be far higher than that shown at present, because what

![Figure 10. Scatter diagram for average activity volume of 54 plots. Original data(left), logarithm of the original data(right).](image)

Table 2. Multi-factor linear regression model and variables weight.

| Group                     | Branch                  | Variable               | Total Standardized Coefficient | Total Weight | Total Standardized Coefficient | Total Weight | Shanghai Standardized Coefficient | Shanghai Weight | Nanjing Standardized Coefficient | Nanjing Weight |
|---------------------------|-------------------------|------------------------|--------------------------------|--------------|--------------------------------|--------------|------------------------------------|-----------------|----------------------------------|----------------|
| Space Structure           | Spatial Configuration   | I1 NAIN                | 0.177*                         | 10.17%       | 0.471***                       | 28.49%       | 0.401**                            | 11.40%          |                                  |                 |
|                           | Planning Conditions (L) | I2 NACH                |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | L1 Business coefficient |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | L2 Distance from food market |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | L3 Distance from school |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | L4 Public transit      |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | coefficient            |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | L5 Road width          |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | L6 Sidewalk width      |                                |              |                                |              |                                    |                  |                                  |                 |
| Site Elements (S)         |                         | S1 Site area           |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | S2 Hard paved area     | 0.468***                       | 26.95%       | 0.184*                         | 11.13%       | 0.578***                           | 16.43%          |                                  |                 |
|                           |                         | S3 Greening rate       |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | S4 Enclosing degree    |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | S5 Number of rest      | 0.305***                       | 17.53%       | 0.669***                       | 40.47%       | -0.349**                           | 9.92%           |                                  |                 |
|                           |                         | facilities             |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | S6 Number of fitness   |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | facilities             |                                |              |                                |              |                                    |                  |                                  |                 |
|                           |                         | S7 Number of game      | 0.279***                       | 16.03%       |                                |              |                                    |                  | 0.496***                       | 14.10%         |
|                           |                         | facilities             |                                |              |                                |              |                                    |                  |                                  |                 |
| Regression Coefficient    | R²                      | 0.703                  |                                |              |                                |              |                                    |                  | 0.708                           |                 |
|                           | Adj. R²                 | 0.665                  |                                |              |                                |              |                                    |                  | 0.708                           |                 |

1) Overall model and Shanghai model adopt the method of Stepwise Regression, using probability of F-test(entry:0.1, removal: 0.2); Nanjing model adopts the method of Backward Elimination Regression, using probability of F-test (removal: 0.1); The values of the variables that have been eliminated will no longer be reflected in the table;

2) *represents P < 0.1, **represents P < 0.05, ***represents P<0.01;

3) Variable weight = the absolute value of the standardized coefficient/the sum of the absolute value of all standardized coefficients.
we recorded is the frequency of different activities, not the number of participants.

While square dancing is a group activity, and the actual number of participants in a single time far surpass other activities (Figure 8).

3.1.3. Willingness to socialize
In the questionnaire, we tested the willingness of residents to socialize in public space by enquiring their purposes of activities: “Having people to chat, play chess and play cards”. The data in Figure 9 shows that there is a significant negative correlation between willingness to socialize and education level, that is, the lower the education level is, the more willingness to socialize in public green space, which is a consistent pattern in Nanjing and Shanghai. This pattern has also been found in previous studies by the author (Lingling and Shaoliang 2018). There is a large discrepancy in the willingness to socialize of residents from different education levels in Shanghai, while there isn’t such a distinctive discrepancy shown in Nanjing.

3.2. Built environmental relevance
The “environment-behavior” relationship in regard to leisure activities and built environmental of public green space can be revealed through linear regression analysis of the collected data of behavioral factors and environmental factors.

3.2.1. Variable definition and statistical information
In data analysis, data of behavioral factors is set as the dependent variable, which is the mean value of the number of people recorded per hour in one day for each plot to minimize the influence of outliers. The original data of the dependent variable mostly shows a linear pattern. However, when increasing to a certain extent, it shows a tendency of exponential growth. This pattern can be observed in Shanghai data, Nanjing data and the total data. So the calculation result would be deviated to a certain extent if we just assume that it is the linear distribution. If we take the logarithm of the dependent variable, a relatively clear linear pattern can be observed in the scatter diagram (Figure 10). Thus, this linear regression analysis uses the natural logarithm of the behavioral data as the new dependent variable for modeling. Independent variables are divided into two groups: spatial structure and site elements. And spatial structure is further divided into spatial configuration and planning conditions (Figure 4). There are 15 environmental variables in total. Detailed information is listed in Table 1 in regard to variable definition, data acquisition method, and descriptive statistic information.

3.2.2. Multi-factor linear regression analysis
This research constructs a multi-factor linear regression model with the natural logarithm of the average hourly activity in Shanghai, Nanjing and total as dependent variables (Table 2). And this study uses SPSS for data modeling which adopts two different methods: Stepwise Regression and Backward Elimination Regression. Finally, three models are established based on the principle of optimal R-Squared. The VIF values corresponding to the variables in the three models are all less than 5, which means that there is no collinearity between the variables. Thus, these models can be considered valid. The R-squared of the total model is 0.703. The R-squared of the Shanghai model is 0.817 and for Nanjing model is 0.708. All the models can well explain the distribution of the leisure activities. This further enhances the proposed model which
integrates spatial structure and site elements is an effective way to quantify and evaluate community environment and it can better elucidate the “environment-behavior” relationship.

Generally speaking, the two groups of variables—spatial structure and site elements—carry roughly balanced and proportional influence in these three models, having between 40%-60% of the influence each (Figure 11). The calculation method of the variable weight in the model is the absolute value of the standardized coefficient divided by the sum of the absolute values of all standardized coefficients. The results of the similar research on leisure activities in large urban communities show that the coefficient of interpretation ($R^2$) of leisure activities with only site elements as variables is about 0.35 (Yiyong and Webin 2015; Yiyong and Tao 2016), which is consistent with the result of this study. In the total model and Nanjing model, the influence of planning conditions outweighs the influence of spatial configuration. This can be interpreted as under the influence of spatial structure, the distribution of various types of facilities has a greater influence than that of the road network in planning phase.

Differences and certain discrepancies exist between Nanjing sample and Shanghai sample. In the planning mode of the “thousand-person index”, the spatial structural impact of Shanghai community is relatively weaker due to the balanced distribution of facilities, and the NACH and the width of the sidewalk are the dominating factors when it comes to spatial structure impact. In the road topology network, the plots having higher Choice value (NACH) in the road network and located not adjacent to the main roads of the city are more likely to be chosen. On the other hand, the residents’ choice of activity location is obviously affected by the more complicated spatial structure factors in Nanjing community which adopts the mode of “neighborhood center”. Centralized facilities layout leads to the situation where NAIN would exert impact on activities distribution. In the meantime, the impact of public facilities (such as business facilities, food market and school) on leisure activities starts to show. Thus, the layout of public facilities determined in the planning stage will affect the leisure activities by exerting impact on the location and layout of different public green places. Centralized layout of public facilities will strengthen spatial structure’s influence on leisure activities in the public green space, conversely scattered layout of facilities will surely weaken that effect. It can be inferred that it is the difference between the two planning modes that brings about the difference in the valid variables of the spatial structure of the two community mathematical models.

When it comes to specific impact of site elements, there’s clear sign of impact from site elements such as site area, hard paved area, rest facilities (seat number) and games facilities for children. In Shanghai sample, rest facilities (seat number) is the dominating factor of the distribution of activities, which mounts up to 40.47% of influence weight. On the other hand, Nanjing sample shows that site area, rest facilities and games facilities have roughly the same amount of impact. According to the statistical results of the site elements in the early stage survey, the site conditions of Nanjing are superior to that of Shanghai, and residents will be affected by more crossing factors when choosing the site. The conditions in Shanghai are limited, and its population proportion of the elderly is relatively larger. Sites that can provide more seats are obviously more popular. In general, the impact of the three site elements (hard paved area, rest facilities, and games facilities) on the distribution of leisure activities in large-scale social housing communities is relatively certain. The impact of certain indirect factors such as greening rate and enclosing degree has yet to be proven.

4. Discussion and conclusion

4.1. Preliminary Conclusion of leisure activity features of low-and middle-income residents in China

After studying the leisure activities of the two sample communities in the public green spaces, we can preliminarily draw the conclusion that the leisure activities of low- and middle-income groups in Chinese cities follow certain patterns in terms of time axis changes, gender ratio, location, and willingness to socialize: 1) 9:00~10:00 a.m. and 6:00~8:00 p.m. is the peak time for leisure activities in the community. 2) Men prefer to take activities in the community, while women and children are more likely to have activities within the quarter. 3) There are ten main types of leisure activities in the community: chatting, sitting, outdoor playing with babies, recreational walking, exercising, playing, walking dog, sporting, standing and square dancing. Square dancing is the most dominant leisure activities under limited conditions. 4) Residents of lower education level are more inclined to socialize when taking leisure activities in the public green space.

The public green space in the community is not only the space for leisure activities but also the place for public life. It is of more importance for low and middle-income residents than for the middle-upper class. The residents in large-scale social housing community show an obvious pattern in their activity time, location selection and activity contents, which can be a crucial theoretical basis in the future reform of large-scale communities. The target users of public green space inside the residential quarter are different from those outside the residential quarter, and more urban furniture and game facilities suitable for women and
children should be set at the green space inside the residential quarter.

4.2. Built environmental impact on leisure activities

In the large-scale social housing communities, leisure activities distribution can be mostly explained from the perspectives of the impact of spatial structure and site elements. The structural impact of the location of the public green space can be measured by structural variables, such as spatial configuration, numbers of bus routes and distance from the school. The site condition impact of the public green space can be measured by variables, such as the hard paved area, number of the rest facilities, and number of games facilities. The multi-factor linear regression model integrated of three variable groups (spatial configuration, planning conditions and site elements) can explain approximately 70% of the leisure activities distribution. Spatial structure and site elements have roughly the same impact on leisure activities. The “artificial” impact of the planning conditions outweighs the “natural” impact of spatial configuration (road network layout). The planning model of the community also affects the distribution of leisure activities. Centralized public facilities layout, such as “neighborhood center” model will strengthen the role of public facilities, such as business, school and food market in the use of public green space. Contrarily decentralized layout of facilities will weaken that effect.

To improve the public leisure life in large-scale social housing communities in China in a short period of time, the most effective way is to expand activity area, increase hard paved lots area and games facilities. We can increase the public green spaces by choosing highly choice value location with great accessibility, for example, where multiple residential quarter gateways converge in three-level hierarchical gated community. We can encourage more activities that are likely to boost socializing opportunities in public area outside the residential quarter such as profession training, etc. Meanwhile, we can also introduce elements that are favorable for the ladies inside the residential quarter, such as communal kitchens. Bettering the community public environment to improve the quality of the residents’ public leisure activities in large-scale social housing community is crucial to help the residents to enlarge their social network and accumulate their social capital. This enables the virtuous circle of the development of the community, therefore preventing the downfall.

4.3. Research limitations and prospects

The quantitative description method used in the research to measure built environment in the community has proved to be feasible. Combining the aspects of spatial structure and site elements to reveal the “Environment-behavior” relationship can add to its explanatory power. However, the research still has certain limitations that can be explored and optimized in the future: (1) Due to the limitations of research funds and work force resource, the community sample size is still rather small, and the coverage area is limited. Only the leisure activities of the low- and middle-income residents in the Yangtze River Delta, where the economy is relatively developed, are covered. The research conclusions are only applicable to this specific area. With regard to the northern and inland regions of China with large differences in climatic conditions and economic levels, whether the research conclusions are still applicable remains to be confirmed after further expansion of the research sample and research area. (2) The quantitative thinking of the study is feasible, but the established mathematical model is not stable enough. The valid variables in the same variable group of communities of different planning modes are quite different. This also requires more research samples in the future to obtain valid variables and models that are more stable. (3) The study found that “square dancing” is a very typical Chinese community leisure activity with a large number of participants and a wide range of influences. And there is no fixed places for this activities in a built environment. After obtaining more research samples, it will be a valuable direction to explore the conditions for the occurrence of “square dancing” and the impact mechanism of the built environment.

Acknowledgments

The authors would like to express their sincere gratitude for the support received from the National Natural Science Foundation (51708375) of China.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Natural Science Foundation of China (51708375).

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