Measuring Comprehensive Accessibility to Community Facilities for Elderly People based on Characteristics of Activity Spaces

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ABSTRACT
This paper explores the heterogeneity of elderly people’s (60 years and older) activity spaces and comprehensive accessibility to neighborhood facilities in various types of communities. The data is drawn from a trip survey conducted in 11 communities in Shanghai, China. Based on application programming interface, clustering heat map is used to identify various unique patterns of community-based activity spaces that are different in shape. By calibrating the distance decay function via regression analysis and considering the elderly people’s subjective needs, a modified potential model is applied to study the dissimilarities of the spatial distribution of facilities in different communities. The comparison shows that the surveyed communities can be divided into 3 types: planar-pattern, dotted-pattern, and dispersed-pattern. Pattern of elderly people’s activity spaces appear to be significantly related to the comprehensive accessibility to service facilities. We found that those communities with lower accessibility are linked with more extensive activity spaces and longer travel distance. This indicates that specific transportation service strategies towards different types of communities should be presented, which will be critical for older people’s quality of life in an aging society.

Keywords: Elderly people, Activity spaces, Community facilities, Comprehensive accessibility
1 INTRODUCTION

One of the rapid demographic changes in the 21st century is a significant increase in the number of elderly people. The city of Shanghai in China has stepped into an aging society. Up to the year 2013, the population of elderly people (aged 60 and over) in Shanghai was 3.87 million, accounting for 27% of the city’s registered population. Projections suggested that 40% of the population would be 60 or over by 2030 (1).

Elderly people will experience great changes in time-use pattern and activity spaces after their retirement. But the changes could be quite different in various countries (2). In western nations, elderly people depend heavily on automobile and they will select driving as the preferred mode of travel, which results in longer travel distance (3). While in developing countries like China, seniors tend to travel shorter distance and travel by non-motorized modes (4). Their activity spaces are usually confined to limited area around the community. Communities then become the most suitable places for elderly residents’ daily life and activity. With the sustained development of aging society, elderly people are producing greater demand for leisure and social activities (5). But nowadays, distribution of facilities and transportation system services in communities still lack the essential concern for elderly people. The mismatches between built environment and the elderly’s needs are getting more severe. Elderly people have to increase travel distance to satisfy their specific needs or lower down their travel rates due to the unfriendly communities, even though they initially expect to seek more social interaction. Therefore, community transportation systems that meet the accessibility needs of elderly people are crucial for their daily activity engagement and enhance of quality of life.

This study intends to compare elderly people’s activity spaces and comprehensive accessibility to facilities in different types of communities. More specifically, we aim to present pertinence transportation service strategies towards various residential communities in the context of aging society. For this purpose, the investigated communities are categorized into 3 types based on the unique patterns of the elderly’s activity spaces that are different in shape. The activity patterns are expressed through clustering heat maps, which are created by Google Map Application Programming Interface (API) using data from a trip survey conducted in 11 communities in Shanghai, China. To explore the difference between various communities, we first conduct a quantitative analysis in which travel distance and distance decay function are jointly analyzed. Later on, we identify the elderly respondents’ most and least favored facilities by using the stated preference data. Considering the elderly people’s subjective needs, a modified potential model is constructed to measure the spatial distribution of facilities, so as to explore the underlying relationship between accessibility and activity spaces.

The next section describes previous studies on elderly people’s travel behavior and accessibility measurement. After that, along with the data used for this research, the methods used to quantify activity spaces and measure accessibility are presented. Empirical results are shown and discussed in Section 5. The final section then concludes with the summary of findings and future tasks.

2 LITERATURE REVIEW

Research has shown that elderly people spend most of their time at home with estimates of around 19.5 hours on average per day (6), though engagement of outdoor environments may produce various benefits for older people through participation in physical activity (7). Studies conducted over the past 15-20 years have shown that seniors tend to make fewer outdoor activities and travel shorter distance (2, 8). The most common forms of mobility among older people are driving and walking (9). However, the cultural and economic dissimilarities between developing and
developed countries may lead to different travel behavior. Greater automobile dependency among the elderly is witnessed in the United States, Europe and Australia (10). Individuals become more accustomed to driving, while public transport is not a frequently used mode for the elderly in many western nations, especially in the USA (3). This can be attributable to a number of reasons such as a greater amount of disposable income, a more active and healthier older population, and an increasing number of older people with driver’s licenses (11). In addition to this, elderly people tend to fulfill all activity needs in the most efficient manner, reinforcing the attractiveness of driving and the unattractiveness of public transport (12). While in developing countries like China, the majority of elderly people prefer living in communities to relocating to institutions as they age (13). Municipal governments have made series of policies to improve the availability and accessibility of service facilities for the elderly living in communities (14). As a result, elderly people have the psychological effect of accessing by proximity. Most of the outdoor activity locates within the distance range of 0.5-1 km. Activity intensity weakens rapidly with the increase of distance (15). Thus, walking and non-motorized modes undoubtedly become the most favorable choices for the elderly (2).

Compared to the previous studies that have shed lights on the elderly’s mobility needs and travel behavior, limited researches have focused on the activity spaces of elderly people. An activity space is the area through which a person travels during their day, representing the spatial component of an individual’s time-space prism (16). Elderly people’s activity spaces tend to center around their communities, and expand to cover the range of other facilities they visit to pursue various needs (17). They interact less frequently with areas that are farther afield (18). Activity spaces are closely related to transportation research as they frame the travel decisions made by residents. Smaller activity spaces indicate more uses of walking and bicycles, while larger ones are correlated with higher shares of motor vehicles (19). However, there is substantial disagreement about how activity spaces should be measured. Two-dimensional methods attempt to fit one or more shapes around a set of activity locations. Minimum convex hulls and ellipse-based representations are the most common and simple two-dimensional ways to represent an activity space (20, 21), as they clearly demarcate areas that are inside or outside the activity space. Instead of providing a discrete boundary around the places, density-based methods map the space onto a smooth grid of values, with more activity-rich areas taking a higher value (22). They report the probability that each area will be the site of an activity. Different methods may have different results (23), and methods used rely on the fineness of detail in the source data. Providing a complete record of an individual’s movement, travel diaries have generally been the primary data source for activity space estimation, but they are costly and difficult to collect (24). In contrast, social media data like twitter data is an inexpensive and valuable complementary source because of the ease of data collection using Twitter’s APIs (25). Though twitter users are clearly not a representative sample of the residents (26), social media data can provide a much longer record of individuals’ travel for heterogeneity analysis in activity-based modeling and simulation (17).

Plenty of studies have found highly significant impacts of diverse built-environment factors on travel behavior and activity spaces in the past few decades (27, 28). Researchers defined built environment characteristics as density, diversity, design and so on (29, 30). Among those factors, accessibility has drawn lots of attention because it determines the basic spatial settings for human activities. In general, accessibility can be defined as the ease of reaching valued destinations (31). Elderly people living in communities are found to be especially susceptible to the accessibility to service facilities (32, 33), because of their declining physical functioning and availability of transportation (34). Promoting accessibility is an effective strategy for elderly population to have more community oriented activities (35), which typically involve shorter travel distances and more
usage of non-motorized modes. A large number of measures of accessibility have been proposed since 1959 (36). The existing operational accessibility measures can be distinguished into 3 categories. The nearest opportunity measurements assume that individuals may only choose the nearest facilities (37), which have been considered unrealistic (38), as they ignore the size and service level of the facilities. To overcome this limitation, contour measures, also known as cumulative opportunity measure, count the number of opportunities within each contour (39-41). However, these methods assume that all the opportunities within the distance threshold are equally accessible, which is questionable with respect to spatial barriers or the perception of distances. In order to address the problem, gravity measures have been proposed, based on the social equivalent of Newton’s law of gravity (42). The gravity model includes two basic components: attractiveness of a location and travel cost. This has become more recently a popular measure (37, 43, 44), for its advantage of flexibility and consistency.

Although these “classical” accessibility measurements are very useful, they present some limitations. By ignoring the subjective needs of individuals, they only provide an “objective-dimensional” biased view of accessibility. In particular, this paper adopts a composite measure approach in which we take into account the elderly people’s subjective needs. Additionally, the majority of “activity spaces–accessibility” studies have predominantly been conducted in western nations, while little is known about the situation in developing countries like China. With data collected from the city of Shanghai, this paper investigates in depth the differences between various types of communities, so as to improve the quality of elderly’s life in an aging society.

3 DATA COLLECTION

The data used in this study were collected from a residential travel survey that was conducted in 11 residential communities in Shanghai from December 2014 to May 2015 (Figure 1). To ensure the representativeness and typicality of respondents, we took into account geographic feature, housing type and social economic background when selecting communities for survey, covering residential communities with various locations, income levels and occupations. The selected communities occupy an area of around 1 km², with a population from 10 to 20 thousand (data from the 2010 National Population Census). A questionnaire survey was designed and carried out to capture the following information: demographic characteristics, residents’ willingness for travel activities and daily travel information. Target respondents were elderly people aged 60 and above, who were selected randomly through an on-street survey. Totally 701 questionnaires were collected and 664 ones were valid, with the valid rate of 94.8%, which met the need of this study. Among those there were 354 male respondents and 309 female respondents, representing 53.4% and 46.6% of valid questionnaires respectively. The majority of respondents were elderly people aged 60-69, with 26.9% of respondents aged 60-64 and 18.5% aged 65-69.

Given that elderly people’s perceptions for travel distance are relatively vague in the traditional method of questionnaire survey and their responses are easily biased, this study adopted API data from Google Map to calibrate the actual travel distances of elderly people. Google Map contains the actual walking networks, which can provide the actual walking time and walking distance. The calculation of elderly people’s travel distance was finished through Direction API of Google Map, which contains a set of walking retrieval interfaces provided in the form of HTTP, and returns to retrieval data of XML or JSON format. The walking distances acquired from Google Map interfaces can be accurate to 1 meter.
FIGURE 1 The spatial distribution of surveyed communities

4 METHODS

Three steps of analysis were taken to understand comprehensive accessibility for the elderly to community facilities. The first step aimed to categorize the surveyed communities into different types based on the elderly’s activity spaces. In this study, clustering heat maps of elderly people’s activity spaces were presented through secondary development of Google Map API with JavaScript. Next, by calibrating the distance decay function via regression analysis and identifying the elderly people’s subjective needs, a modified potential model was developed to measure the accessibility at a community level. Finally, based on the assessment results, specific transportation service strategies towards different types of communities were presented.

4.1 Defining Activity Space

Methods like travel distance and layer structure have been developed to study elderly’s activity spaces. Though layer structure can be used to analyze the spatial attenuation regularities and fluctuation of daily activities, it can hardly reflect the actual consistency between elderly’s activity patterns and the distribution of facilities within communities. Instead, this paper depicted activity spaces by clustering heat map, which would be used as a criterion of community classification.

Heat map is a popular method in the visualization of spatial data, as it directly reflects the distribution of individual’s activity points. We calculated the elderly’s activity heat map using a three-step approach. The first step was batch geocoding. Addresses of activity destinations were resolved to coordinate via HTTP interface of Google Map. Java was used to issue requests and analyze XML data, so as to perform conversion between addresses and coordinate. In the second step, we realized the activity spots clustering. Since that geographic tag data contains coordinate and activity locations information (name, type and scale), we had to create cluster by longitude and latitude. In the process of clustering, activity frequency of the elderly was included as a weight to respect their subjective needs. Lastly, grayscale images and colorization were put forward. Color graduated circles that center on cluster centers with a radius of cluster radius were drawn, and we colorized each pixel using values in the color palette.
4.2 Measuring Accessibility

To evaluate the accessibility to community facilities for elderly people comprehensively, we require a method that can simultaneously consider activity spaces and individual’s subjective needs. The method that seems most promising for this purpose is potential model. The potential model is one of the most classic gravity-based or spatial interaction models, which are based on social physics and assume some analogies between social and physical phenomena (37). The concept of potential refers to the fact that the influence between two places is inversely proportional to the distance between them (44). A general formulation of potential model can then be written as:

\[ A_i = \sum_{j=1}^{n} A_{ij} = \sum_{j=1}^{n} \frac{M_j}{D_{ij}} \]  

(1)

Where \( A_i \) is the potential at point \( i \), \( M_j \) is the facility scale of point \( j \), \( D_{ij} \) is the distance (or time) between \( i \) and \( j \). This paper provided the following improvements when evaluating accessibility with potential model: (1) introducing elderly’s subjective needs as an index when characterizing the service capabilities of community facilities; (2) proposing an impedance travel (or distance decay) function for travel between \( i \) and \( j \); and (3) considering the influence of community population. The modified model is written as:

\[ A'_i = \sum_{j=1}^{n} A'_{ij} = \sum_{j=1}^{n} \frac{K_j M_j}{f(D_{ij}) V_i} \]  

(2)

Where \( A'_i \) is the comprehensive accessibility for community \( i \), \( K_j \) represents the index of elderly’s subjective needs for facility \( j \), which will be characterized by the importance (weight) evaluation scores rated by elderly respondents. And \( M'_j \), represented by construction area in this paper, is the service quality of facility \( j \). \( n \) refers to the number of facilities that located within the scope of community \( i \). \( V_i \) is the resident population of community \( i \), and \( f(D_{ij}) \) is a distance decay function, which can be regarded as “frictional effect of space”.

4.2.1 Calibrating Distance Decay Function

Three necessary steps were taken to specify travel impedance: (1) selecting distance metric \( D_{ij} \); (2) establishing distance decay function \( f(D_{ij}) \); and (3) calculating the parameters of this function. Many different definitions of distance measurement have been used, including Euclidean distance, Manhattan distance, network distance or time cost (37). Considering that elderly people’s perceptions for travel distance and travel time are relatively vague, the distance metric data we obtained from questionnaire may be easily biased. We therefore decided to use the actual street network distances that were acquired from Google Map API as the distance metric. In order to define distance decay function, we sought to find a linear relationship between trip length and activity intensity. For this purpose, different forms of functions were tested, among which negative exponential \( f(D_{ij}) = \exp(-\alpha \cdot D_{ij}) \) and inverse power \( f(D_{ij}) = D_{ij}^{-\gamma} \) are the most favorable. We applied these functions to available data on trip lengths for elderly’s daily activities, and it turned out that negative exponential provided the best fit. Therefore, the relationship between distance and volume of interactions is defined as:

\[ P_l = \alpha \cdot e^{-\beta \cdot D_{ij}} \]  

(3)

Where \( P_l \) is the probability for interaction at distance \( D_{ij} \), \( \alpha \) is the constant term, and \( \beta \) is a distance exponent to be determined. The higher the value of \( \beta \), the faster activity intensity decays as travel distance increases. Once the type of function was determined, the last step was calculating
the associated parameters (i.e. $\alpha$ and $\beta$) that would produce the best fit to the observed data. In this study, the calibration was done by performing linear regression with log-transformed data.

4.2.2 Activity needs for elderly people

Activity needs for elderly people were defined using the following indicators: importance degree and activity frequency, which have gained little attention in previous accessibility studies. The importance degree of a certain type of facility was measured by the stated importance. Elderly respondents were asked to rate certain facilities on a scale 1-5, where: 1 = Not at all important to 5 = Most important. The importance degree index was then calculated using:

$$K_i = \frac{\sum_m k_{ij}}{m \times 5}$$  \hspace{1cm} (4)

Where $k_{ij}$ is the importance value of surveyed facility $i$ evaluated by the elderly respondent $j$, $m$ is the number of elderly respondents, and 5 is the highest importance scale. The importance degree of different facilities was converted into weights while using the modified potential model above. Besides, we also took into account the activity frequency of elderly people when considering their subjective needs.

5 EMPIRICAL RESULTS

5.1 Classification based on Activity Spaces

Activity spaces of elderly residents were created by the heat map module of Google Map API, each with a unique shape and coverage (Figure 2). The zone with an intense red color indicates the area included the most in elderly’s activity spaces. We can see that the majority of seniors’ habitual activities concentrate around their home locations. Daily activities basically obey the rules of distance decay, which means that activity intensity for elderly people decreases with travel distance increasing. However, heterogeneity between different neighborhoods exists in the study sample. According to the aggregated pattern of activity spaces, the 11 studied communities are categorized into the following three types by graphical comparison: planar-pattern, dotted-pattern, and dispersed-pattern. We classified five of the communities (Laoshan, Zhongfu, Shiquan, Dong’an, and Panyu) as planar pattern, four (Gongkang, Heping, Pengpu, and Yinxing) as dotted pattern, and the other two (Lizi and Lvbo) as dispersed pattern.

In planar-pattern communities, the activity spaces of elderly people have a wide distribution surrounding the neighborhoods, with a relatively homogeneous shape. These communities are well equipped with multitude service facilities within a radius of acceptable walking distance for the elderly. Therefore, diversified preferences are well catered, making these communities exhibit the most concentrated habitual activity spaces. For dotted-pattern communities, activity spaces are confined to a restricted area, and the highest activity space density occurs in limited locations around the community. Though the activity spaces for elderly people do not extend far away from the neighborhood, only three to four specific locations are heavily visited. This suggests that travel distance is unfair to those who live in the same community, due to the limited activity choices. Unlike the two types mentioned above, elderly residents living in dispersed-pattern communities show opposite activity patterns. They seem to have the most extensive but least intense activity spaces, with daily activity destinations being less concentrated around home locations and extending deeper into other places. This can be explained by the fact that these communities are short of attractive and competitive facilities within the neighborhood, so that elderly residents have to conduct their habitual activities either downtown or in the city center, which usually occurs in newly developed suburban areas in China.
Moreover, certain differences can be identified between the cumulative frequencies of travel distance of elderly residents living in the three types of communities (Figure 3). Elderly people who live in planar-pattern communities have the most intense activity space within a modest spatial coverage, which can be attributed to the proximity of their home and service facilities. Their activity patterns are of great concentration and convergence, with over 50% of daily activities performed within 1 km of home. And many of their local activity spaces stop expanding at the distance of 2 km. The second class (dotted-pattern) communities show a less intense activity space. This is reasonable because daily activity locations are only focused on a few sites. Elderly people who live near the attractive facilities experience a shorter distance, while that for the others may be longer to some extent. Though about 50% of daily activities are similarly performed within
1 km, the 85th percentile of travel distance increases to 2.5 km because of a considerable percentage of medium-distance travel. In contrast, the distance distribution of dispersed-pattern communities has a unique pattern. The fundamental difference lies in the percentage of long-distance travel. In this type of communities, elderly people have to increase their travel distance to satisfy their own needs. Some of their daily activities are performed 5 km or more from home, which is likely caused by the lack of appropriate facilities within the neighborhood.

5.2 Comprehensive Accessibility Evaluation

The process of evaluation was divided into two parts. The first part was to figure out the index of elderly’s subjective needs and the distance decay exponent. The second part was to join these indices with the modified potential model to calculate the comprehensive accessibility for each community, using Google Direction API and ArcGIS.

Community facilities may refer to viability of urban life such as police and fire protection, water supply, sanitation and waste disposal, or fixed urban services like parks, libraries and public health facilities. However, among those only four types of service facilities that are closely related to elderly people are considered in this study: fresh markets, shopping malls, recreational places, and medical facilities. Compared with shopping malls, elderly residents indicate that fresh markets are more important (Table 1), as markets provide them with more opportunities for social contacts and encounters with different social groups, which is good for their physical and mental health. Survey data show that elderly people go to fresh markets 5.1 times per week on average, much higher than that of shopping malls (2.4 times per week), showing that elderly people indeed prefer fresh markets from an activity frequency perspective. In addition, seniors are in need of better cultural and spiritual lives besides economic security. They enjoy making greater use of urban public spaces like parks and squares, which plays an important role in improving quality of life. As a result, recreational places also become the favorable facilities for elderly residents.

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Fresh Markets</th>
<th>Shopping Malls</th>
<th>Recreational Places</th>
<th>Medical Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Score</td>
<td>4.38</td>
<td>2.47</td>
<td>4.01</td>
<td>3.56</td>
</tr>
<tr>
<td>Importance Degree</td>
<td>0.88</td>
<td>0.49</td>
<td>0.80</td>
<td>0.71</td>
</tr>
</tbody>
</table>

In terms of distance decay exponent, we illustrated the probability for activity interaction by using the cumulated per cent of trips that were greater than a given distance. The distance decay exponent was calibrated respectively for each type of communities using the values of the parameters derived from the linear regression analyses (Figure 4). Note that the travel distance was considered based on actual street network and this paper did not take into account the network distance by specific mode (walking, bike, transit, or auto). Based on the survey data, over 80% of the elderly people living in communities travelled around by walking. As a result, consideration of a decay measure by travel mode was not necessary.

Results show that the distance decay effect of planar-pattern communities is the strongest, with the decay exponent equaling to 1.805. Dotted-pattern communities rank the second ($\beta_2 = 1.685$), while dispersed-pattern communities are found to have the poorest distance decay effect ($\beta_3 = 1.354$).
Based on these indices, we estimated potential values for each surveyed community. Because the main travel mode for elderly people is walking, the comprehensive accessibility was calculated based on local street network within 1 km buffer around communities, which was estimated by the walking mobility of elderly people (Figure 5).

**FIGURE 5 Map of accessibility to facilities surrounding surveyed communities**

Results reveal significant differences among various types of communities. Planer-pattern communities have more areas with good accessibility to public facilities. Dotted-pattern communities are in the middle, while dispersed-pattern ones again are found to have the poorest comprehensive accessibility. It is worth noting that the situation is more contrasted in the case of dotted-pattern communities, where comprehensive accessibility is unevenly distributed, which means that only a few locations gain excellent accessibilities while others not.

Based on these findings, we have good reasons to believe that corresponding relationship does exist between accessibility and activity spaces of elderly people. For example, sufficient service facilities at different levels are well located around communities like Zhongfu and Panyu, including neighborhood-level facilities (e.g. convenience stores and health stations) within 500 m
buffer, as well as large-scale commercial facilities within a radius of 1 km. Since the availability of facilities in and around these communities are relative higher, elder people need less time to reach the same number of service facilities, so that the activity spaces are distributed relatively equally around the neighborhood. In contrast, communities like Lizi and Lvbo have more areas with poor or very poor accessibility for elderly residents than other communities. The major issue with these communities is the inadequate provision of service facilities, both shopping as well as health caring or availability of recreational places around the neighborhood, which definitely shapes a dispersed activity space.

5.3 Specific Transportation Service Strategies

The dissimilarities of activity spaces and comprehensive accessibility among different types of communities indicate that the travel needs for elderly residents in various communities are heterogeneous. Presenting differential and specific transportation service strategies on a community level can reinforce the cooperation among activity spaces, distribution of service facilities, and transportation system.

For planar-pattern communities where comprehensive accessibility is satisfying, the main strategy should aim at encouraging walking among the elderly by pedestrian friendly design, as the travel distances in these communities are relatively shorter. Walking is an important source of outdoor physical activity among elderly people. Factors such as the presence of pavements, well-maintained walking surfaces, shelter, and greenbelts should be considered, so as to strengthen the links between markets and urban public places, which are considered the most important facilities for the elderly. In addition, barrier-free access facilities are perceived as being attractive for walking, because travel safety and convenience may be a prerequisite of daily physical activity levels among elder residents. Secondly, there are two main possible strategies for dotted-pattern communities whose accessibility is from poor to average. The first way is to add specialized and flexible shuttle bus service to link locations visited most, aiming to provide convenient transit services for the elderly. Second, considering that highest activity space density occurs in limited locations in these communities, the recommendation is to add pedestrian doorways to reduce the unfairness for people living in different domestic blocks. Lastly, in dispersed-pattern communities that have the most areas with poor or very poor comprehensive accessibility, it is hard for elder people to access to service faculties by walking or non-motorized modes due to the long travel distance. Therefore, strategies need to focus on enhancing the level of public transport services, based on the elderly’s activity spaces. Specifically, common problems like high transport fare, boarding constraints, and long waiting time at bus stops are in need of immediate improvement.

To summarize, the specific transportation service strategies on a community level for different types of communities are shown in Table 2, to aid the development of traffic policies aimed at maintaining the functional status and health of the elderly.

### TABLE 2 Specific Transportation Service Strategies for Different Types of Communities

<table>
<thead>
<tr>
<th>Type</th>
<th>Activity Spaces</th>
<th>Accessibility to Facilities</th>
<th>Transportation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar</td>
<td>Intense activity spaces; Concentration and convergence; Intensity decreases rapidly.</td>
<td>Good; Multitude activity choices; Proximity to facilities.</td>
<td>Pedestrian friendly design; Linking various facilities; Barrier-free access.</td>
</tr>
<tr>
<td>Dotted</td>
<td>Restricted area, limited locations; Merely focused on a few sites; Unfairness of travel distance.</td>
<td>Medium; Unevenly distributed; Basically satisfy the needs.</td>
<td>Flexible shuttle bus service; Adding pedestrian doorways</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Most extensive; Extend far away from home; Long travel distance.</td>
<td>Poor; Inadequate service facilities Constrain activity spaces.</td>
<td>Enhancing the level of public transport services.</td>
</tr>
</tbody>
</table>
6 CONCLUSIONS

Activity needs of the elderly and accessibility measurement have received extensive attention in an aging society. However, studies in developing countries are limited. Using data from Shanghai China, the main purpose of this paper was to introduce a classification methodology of residential communities by demonstrating activity spaces, as well as to propose some improvement to the accessibility measure. A modified potential model that overcomes some of the limitations of more simple accessibility indices was applied. Comparison analysis showed that elderly people behaved differently in activity spaces and travel distances due to the distinction of accessibility. Seniors living in high-accessibility communities were found to have shorter travel distance with intense and convergent activity spaces, while those in low-accessibility communities would have to travel far away from home. These findings are able to point clearly what type of transportation service strategies are needed to improve the overall public service and in particular the way it can be tailored to the needs of the elderly, so as to provide relevant information to policy-makers in the field of community planning.

However, some limitations were found from this study. Even though the three groups of communities were identified by different patterns of activity spaces, they may be actually differentiated by socioeconomic status and location of residence. More statistical analysis are needed to explore the impacts of demographic characteristics and built environment, as they could have significant impacts on elderly people’s activity spaces. Therefore, a quantitative method should be developed in future studies, to provide further insights on the links between activity spaces and accessibility for the elderly among different socioeconomic groups, as they are likely to have distinct needs, levels of mobility and attitudes towards various facilities and services.

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