Measuring Urban Facility Spatial Accessibility in Beijing Using Gaussian 2SFCA Method

Yanli Fu[1], Changfeng Jing*[,1] , Mingyi Du[1]

[1] School of Geomatics and Urban Spatial Information, Beijing University of Civil Engineering and Architecture,100044 Beijing, China
*Email: jingcf@bucea.edu.cn

Abstract

Spatial accessibility to public service facilities is critical for allocating the limited resources to the most needed places. In view of the previous literatures usually about the domains of health care and green space, only a few of studies on public service facilities and specific parameter setting with explicit and scientific basis, like search radius, so there is a pressing need to determine the parameters referred in the method and to apply an appropriate approach to the accessibility calculation. Considering that the Gaussian two-step floating catchment area (2SFCA) is simple and straightforward to implement, mature as well, it is employed in the study with the combination of Geographic Information Systems. After calculating accessibility with the Gaussian 2SFCA method, GIS can be effectively utilized to carry out analysis of spatial accessibility to public service facilities. Then, a comparison of the results from the Gaussian 2SFCA method and Gravity Model respectively is executed. The results show that there are some similar points and differentia between the above two methods, and the results are influenced by the parameters involved in the method.

Keywords: Spatial Accessibility, The Gaussian 2SFCA, Garbage Building, GIS.

1. Introduction

Public service facility takes a crucial role in identifying shortage areas and allocating limited resources to the scarcities, in order to ensure social equity. Although social policies and projects, intend to provide equal access for all, in the final evaluation, fairness of the public service facility distribution is normally described by accessibility (Radke and Mu, 2000).

Walter G.Hansen in 1959 first put forward the concept accessibility, defined as the potential of opportunities for interaction (Hansen, 1959). Then, different scholars give accessibility different classifications on the basis of their various understanding about accessibility. Among the different sorting methods, Khan et.al. classified accessibility according to two dichotomous dimensions—— potential & revealed, spatial & non-spatial, into four kinds——potential spatial accessibility, potential non-spatial accessibility, revealed spatial accessibility and revealed non-spatial accessibility (Khan, 1992). Spatial accessibility emphasizes the importance of spatial separation between demand and supply as a barrier or a facilitator, while non-spatial accessibility highlights nongeographic barriers or facilitators, such as demographic and socioeconomic variables (Pill, 1984). In this paper, much attention to potential spatial accessibility has been paid, which signifies the probability of utilizing the given public service facility (accessibility below referred to potential spatial accessibility). It has been applied in a wide range of domains, including accessibility to primary health care services (Delamater, 2013; Jamtsho and Corner et al., 2015), maternal health services (Vadrevu, 2016), urban public facilities (Dadashpoor and Rostami et al., 2016), social programs (Radke and Mu, 2000), job (Wang and Tang, 2013), urban green space (LI and Yang et al., 2016) and so on. In a word, accessibility is one of vital indices to weigh the reasonability of public service facility.

Based on the aforementioned application, it is clear to find that the previous researches are extensive, and they are principally concentrated on health care and green space. However, there are a few studies on environmental public service facility in small-scale city, and some specific parameter in many researches to assess accessibility is set by experience, which is too subjective. Focused on the above issue, this paper tends to take urban small-area as instance to calculate accessibility aiming at public service facilities (like garbage buildings in this paper) under the support of a kind of mature appraisal method, and we analysis the result with the combination of the selected model and the parameters we set in this study.

2. Methodology

This study focuses on the Xicheng District of Beijing in China, which is a small-scale city region with approximately 50 km^2. It has a population of about 1,243,000 people in accordance with census 2000. The Xicheng District located in the Beijing central city west, is divided into 15 sub-districts as the study unit. In light of terrain, the elevation variation is relatively small.

The data used in the study case includes graphic data and attribute data. Graphic data includes population, remote sensing image and garbage building data, and attribute data involves in population and polygon garbage building data. The case study is conducted within ESRI ArcGIS 10.2 software.

The 2SFCA with Gaussian function to reflect distance decay effect is implemented in the following two steps:

Step 1: Calculate supply catchments—— for each provider (garbage building)(j) , assume or determine a spatial distance d_0 as the spatial catchment area, calculate the number of the demanders for each demand point (k) within the catchment area, assign weight and sum up based on the Gaussian function, thus obtain the number of the demanders at the supply location (j), then the area of garbage building (j) divide the total number of potential demanders (population), finally, the supply and demand ratio R_j shown in formula (1) is computed.

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\leq d_0\}} G(d_{kj}, d_0) P_k} \quad (1)$$

Where d_{kj} is the distance between population (k) and garbage building (j); a given spatial distance for supply location is marked as d_0; P_k denotes the quantity of population at location (k) whose centroid falls into catchment (j) (namely, up to $d_{kj} \leq d_0$); S_j is total supply, representing a measure of the availability of supply at location (j) to all demanders P_k (k=1,2,3,⋯⋯); $G(d_{kj}, d_0)$ is Gaussian equation as distance decay function, which is a smooth decay with increasing distance and can be formulated as formula (2) (Dai, 2010):

$$G(d_{kj}, d_0) = \begin{cases} \frac{e^{-\frac{1}{2}\times\left(\frac{d_{kj}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1-e^{-\frac{1}{2}}}, & d_{kj} \le d_0 \\ 0, & d_{kj} > d_0 \end{cases} \quad (2)$$

The parameters in the formula (2) are the same with formula (1).

Step 2: Calculate demand catchments—— for each demand point (i), d_0 as the catchment size, search all supply locations (j) within the catchment area of demand point (i), and determine the spatial accessibility by summing up the supply and demand ratio R_j weighted with Gaussian function G, Then, the spatial accessibility A_i^F at demand point (i) is calculated as below:

$$A_i^F = \sum_{j\in\{d_{ij}\le d_0\}} G(d_{ij}, d_0)\, R_j \quad (3)$$

A larger volume of accessibility value A_i^F indicates a better spatial accessibility to demanders at supply location.

Spatial accessibility of the Gaussian 2SFCA is an index, relying on search radius. Namely, search radius is the key to selecting a rational spatial distance threshold d_0. The catchment size delimits how far geographically services are delivering public service facilities to people, and determines how far population are affordable to access the services. Actually, it can be determined from the following two respects: ① according to demanders' actual willing to suffer the facilities of transportation distance; ② in terms of the related policy and planning goals (Tao and Cheng, 2016). In this paper, catchment size is defined based on related technical code.

In the initial, population grid data, divided into 160m ×160m unit, require registration to cater for the existent Xicheng District map because of different coordinates. When collecting garbage by human way, the appropriate service radius is within 0.4km and not more than 1.0km according to *Technical code for transfer station of municipal solid waste CJJ 47-2006.* Hence, the search radius d_0 in this paper is defined as 0.4km.

Specific steps are as follows: ① Buffer analysis and Erase Point, two editing tools in ArcToolbox, are utilized to differentiate the population datum within catchment area and outside. ② In view of gentle elevation variation in the study area, we apply point distance tool to calculate the straight-line distance between the supply and the demand as d_{kj} in formula (2), then, $G(d_{kj}, d_0)$ is obtained. Furthermore, straight-line distance is highly correlated with street network distance, so it can be approximately substituted (Phibbs and Luft, 1995; Salze and Banos et al., 2011). ③ Garbage building accessibility A_i^F is calculated in the Field Calculate tool. ④ Finally, graduated colors classifies the accessibility values into 6 categories with Natural Breaks. In order to observe the difference between the Gaussian 2SFCA and Gravity Model, a comparison of the two results are made.

3. Conclusions

This paper employs Gaussian 2SFCA method and Gravity Model（shown in Figure2）, respectively, with population and garbage buildings to assess urban public service facility accessibility. The results show that: ① Accessibility from the two methods has the similar trend —— concentric pattern of accessibility near garbage buildings. ② Gravity Model reveals an obvious hierarchy structure, while

Gaussian 2SFCA method is closely associated with the layout of garbage buildings. ③ The Gaussian 2SFCA demonstrates more details than Gravity Model. ④The accessibility of Gaussian 2SFCA method is closely related with population distribution, whereas Gravity Model has some relations, but the relation is not too strong.

4. References

Dadashpoor, H. and F. Rostami, et al. 2016. "Is inequality in the distribution of urban facilities inequitable? Exploring a method for identifying spatial inequity in an Iranian city." *Cities*. 52, pp.159-172.

Dai, D. 2010. "Black residential segregation, disparities in spatial access to health care facilities, and late-stage breast cancer diagnosis in metropolitan Detroit." *Health & Place*. 16(5), pp.1038-1052.

Delamater, P. L. 2013. "Spatial accessibility in suboptimally configured health care systems: a modified two-step floating catchment area (M2SFCA) metric." *Health & Place*. 24(6), pp.30-43.

Hansen, W. G. 1959. "How Accessibility Shapes Land Use." *Journal of the American Planning Association.* 25(2), pp.73-76.

Jamtsho, S. and R. Corner, et al. 2015. "Spatio-Temporal Analysis of Spatial Accessibility to Primary Health Care in Bhutan." *ISPRS International Journal of Geo-Information.* 4(3), pp.1584-1604.

Khan, A. A. 1992. "An Integrated Approach to Measuring Potential Spatial Access to Health Care Services." *Socio-Economic Planning Sciences*. 26(4), pp.275-287.

LI, M. and L. Yang, et al. 2016. "Improved Gaussian based 2-step floating catchment area method: A case study of green space accessibility in Shanghai." *Progress in Geography.* 35(8), pp.990-996.

Phibbs, C. S. and H. S. Luft. 1995. "Correlation of travel time on roads versus straight line distance." *Medical Care Research and Review: formerly Medical Care Review*. 52(4), pp.532-542.

Pill, R. 1984. "Accessibility and Utilization: Geographical Perspectives on Health Care Delivery." *Journal of the Royal College of General Practitioners*. 34(265), pp. 452.

Radke, J. and L. Mu. 2000. "Spatial Decompositions, Modeling and Mapping Service Regions to Predict Access to Social Programs." *Geographic Information Sciences*.6(2), pp.105-112.

Salze, P. and A. Banos, et al. 2011. "Estimating spatial accessibility to facilities on the regional scale: an extended commuting-based interaction potential model." *International Journal of Health Geographics*. 10(1), pp.1-16.

Tao, Z. and Y. Cheng. 2016. "Research progress of the two-step floating catchment area method and extensions." *Progress in Geography*. 35(5), pp.589-599.

Vadrevu, L. 2016. "Measuring spatial equity and access to maternal health services using enhanced two step floating catchment area method (E2SFCA) – a case study of the Indian Sundarbans." *International Journal for Equity in Health*. 15(1), pp.87.

Wang, F. and Q. Tang. 2013. "Planning toward Equal Accessibility to Services: A Quadratic Programming Approach." *Environment and Planning B: Planning and Design*. 40(2), pp.195-212.