A GIS-Based Assessment of Spatial Accessibility to County Hospitals: A Case Study of Dancheng County, China

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Abstract. The aim of this study was to investigate Chinese rural people's accessibility to healthcare. GIS techniques and the gravity-based model were combined to calculate the measure of accessibility to county hospitals in Dancheng County. The result demonstrates that when travel friction coefficient is 1.0, the highest accessibility is found in the county seat and declines outward to other settlements. The residents in the east and southeast part of the county have worse accessibility to county hospitals. To improve rural people's accessibility to health services, the paper suggests that the local government should build a county-level hospital in the east part of the county and increase road class to reduce travel time. The suggestions can be applied to other counties in rural China. Finally, bus routes and timetables should be considered in a future study of measuring rural people's access to services in the county seat.

Keywords: spatial accessibility, health services, GIS; gravity model, Dancheng County, China.

1 Introduction

Spatial accessibility is a key research issue in geography, referring to the level of convenience allowing people to undertake the activities such as work, shopping, and recreation at one location from a given place [1]. The spatial distribution of services is often not optimal and thus needs careful planning and allocation to match people's demands. Otherwise, some people would be marginalized to obtain these services. Therefore, access to services, especially public ones, is also a social justice issue [1]. This is particularly true in rural areas [2]. According to Khan [3], access can be classified into four categories: potential spatial access, potential aspatial access, revealed spatial access, and revealed aspatial access. This study focuses on measuring potential spatial accessibility in rural health care services.

Primary care is the most important form of healthcare to maintain population health because it is relatively cheap. Furthermore, if primary care is evenly distributed, it can effectively prevent disease progression on a large scale [4]. In

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addition, developments in Geographical Information Systems (GIS) have made it possible to calculate measures of physical accessibility such as distance or time in a more automated and sophisticated manner than was previously practical [5]. Based on GIS techniques, many researchers have investigated accessibility to primary healthcare services. Brabyn and Gower [6] used minimum travel distance (time) to the closet service provider to measure accessibility to general medical practitioners in New Zealand. Luo and Wang [7] adopted GIS techniques to implement spatial accessibility measures to define physician shortage areas in Illinois. Using GIS techniques, Lovett et al. examined accessibility to GP surgeries in South Norfolk by public and private transport [5]. Improving the effectiveness of the two-step floating catchment area method, McGrail and Humphreys measured spatial accessibility to primary care in rural areas [8]. Based on analysis of recent developments in GIS and spatial analysis, Guagliardo [4] summarized the major questions concerning geographic accessibility of primary care. In China, however, little research has focused on spatial accessibility to primary healthcare services, especially in rural areas.

In China, heath services within a county can be classified into three levels: village, township, and county. The hospitals at the county level, especially the people's hospital of the county, have better equipment and more skilled staff. Therefore, the hospitals at the county level can perform routine operations and treat the more serious diseases that the village clinics and township hospitals cannot treat. Thus, accessibility to the hospitals at county level is important to the residents in rural China. Furthermore, the Chinese government has been improving rural roads since 2006. Five years have elapsed, it was thus thought appropriate to assess accessibility based on the improved rural road network and find the problem of accessibility that still faced by the Chinese rural people. To achieve this objective, an investigation of accessibility to health care services at county level was undertaken for the Dancheng County, which is a typical rural county in China.

Dancheng County is located at Henan Province, central China (Fig. 1). The county covers an area of 1489 km^2 and had a population of approximately 1.29 million in 2008. Since 2006, the road systems in Dancheng County have been improved. As a result, each administrative village has had access to paved roads (Fig. 1). In Dancheng, the roads can be classified into three levels: village and township, county, and provincial. However, these roads have the similar speed (approximately 35-40 km^2/h), according to the data provided by the local roads authority and our empirical test. Thus, we use travel distance rather than travel time in this study to measure accessibility.

2 Data

2.1 Population of Each Settlement

In this study, Dancheng was classified into 489 settlements, which include one county seat and 488 villages. The population of each settlement in 2008 was provided by the Statistics Bureau of Dancheng County.

2.2 The Number of Doctors in the Hospitals at County Level

The number of doctors in the health services at county level was extracted from the Annual Statistics Manual of Dancheng County. The county had seven hospitals at the county level in 2008, and the total number of doctors working in these agencies was 590.

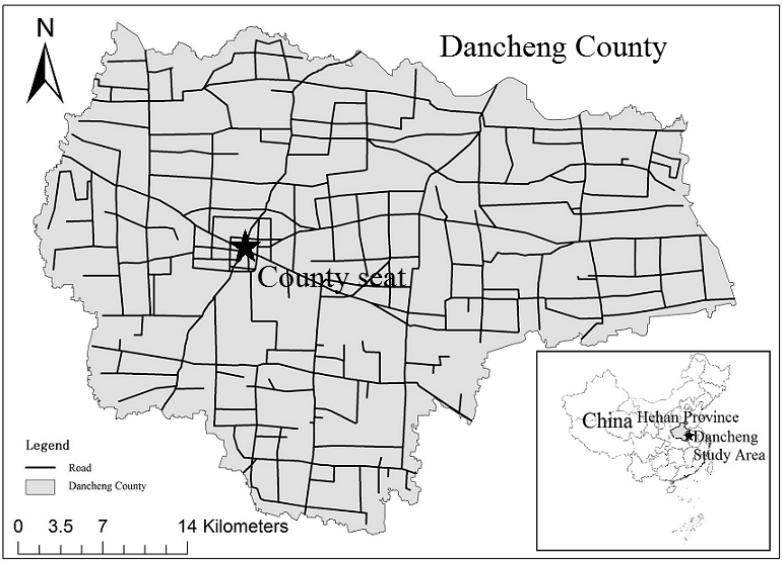

Fig. 1. The study area

2.3 Area Boundaries

The boundaries of the settlements were digitalized based on the land use map of Dancheng County, which was offered by the Land and Resources Bureau of Dancheng County.

2.4 Road Network

The road network in the study area was also digitalized based on the land use map of Dancheng County. The digitalized road network was checked by another map provided by the Civil Affairs Bureau of Dancheng County.

3 Methods

3.1 Gravity Model

Generally, researchers use the two-step floating catchment area method and the gravity method to measure spatial accessibility [1, 5, 6]. This study uses the gravity model for evaluating health care accessibility. The gravity-based accessibility measure at location *i* can be written as

$$A_i^G = \sum_{j=1}^{n} \frac{S_j d_{ij}^{-\beta}}{V_j}, \text{where} V_j = \sum_{k=1}^{m} D_k d_{kj}^{-\beta}. \quad (1)$$

In(1), A_i^G is the gravity-based index of accessibility, where n and m are the total numbers of supply and demand locations, respectively, S_j is the capacity of supply at location j, d_{ij} is the distance between i and j, V_j is the total demand at supply location j that falls within the catchment centered at i (i.e., $d_{ij} \le d_0$), D_k is the demand at location k that falls within the catchment (i.e., $d_{kj} \le d_0$) measured by population potential, d_{kj} is the distance between k and j, and β is the travel friction coefficient. A larger A_i^G implies better accessibility.

In this study, the location of health services at the county level was treated as one point. Thus, the above equation is rewritten as

$$A_i^G = \frac{S_j d_{ij}^{-\beta}}{V_j}, \text{where} V_j = \sum_{k=1}^{m} D_k d_{kj}^{-\beta}. \quad (2)$$

3.2 Calculating Journey Distance

After the data of 489 settlements were processed, a spatial layer of all these settlements was created. The attribute table of this layer contains the population data. A shapefile of centroids for all settlements was created by using the feature to point tool in ArcToolbox. Next, the x-y coordinates of the seven county-level hospitals was added. The x-y coordinate of the point of health services at the county level was obtained by averaging the x and y value of the seven hospitals. Next, the minimum travel distances from the cenroids of the settlement shapefiels to the point of health services was obtained by using the network analyst extension. These distances were exported to a table, which was joined to the shapefile of settlements. According to distances, the settlements were classified as six levels.

3.3 Measuring Accessibility by the Gravity Model

In this study, 20 km (approximately 30 minutes) was thought as to be an appropriate distance for the residents to travel to the county hospitals. We adopted this measure, according to other studies [1, 4] and our fieldwork. Based on the distance table, the distance $\le$ 20 km was selected. The new distance table only included those distances within the threshold of 20 km, and thus implements the selection conditions $i \in \{d_{ij} \le d_0\}$ and $k \in \{d_{ij} \le d_0\}$ in (2). Next, the table of distance was joined to the shapefile of centroids for all settlements and the shapefile of the health services at county level. The population potential of each settlements was obtained by computing the equation that population potential=population$\times$(1/distance) (assuming a travel friction coefficient β=1.0 here). Next, V_j was obtained by summarizing the population potential for the location of health services at county level. Finally, r was obtained by computing the equation that r =1000 $\times$ the number of doctors $\times$ (1/distance). Only one location is used in this study; thus, A_i^G = r. The table of r was

joined to the shapefile of settlements. According to r, the settlements are classified as six levels.

4 Results

4.1 Distance to County Hospitals

The minimum distance from the settlements to the health services at the county level was 1386.78 m, and the maximum distance was 45274.41m. As Table1 shows, the majority of settlements fall within the distance ranging from 5, 000 m to 30, 000 m.

Table 1. Settlement number within different catchments

Distance to county hospitals	Settlement number	Average distance
0 m - 5, 000 m	7	4, 114.56 m
5, 000 m - 10, 000m	48	7, 794.22 m
10, 000 m - 20, 000 m	199	15, 369.43 m
20, 000 m - 30, 000m	156	24, 315.22 m
30, 000 m - 40, 000m	67	34, 578.09 m
40, 000 m - 50, 000 m	12	41, 808.38 m

4.2 Accessibility Scores by the Gravity Model

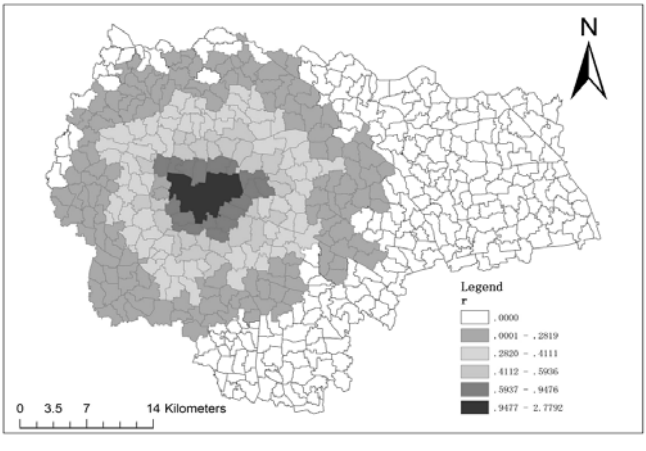

Fig. 2. Accessibility to county hospitals in Dancheng County by gravity-based method ($\beta = 1$)

As Fig. 2 shows, the highest accessibility is generally found in the county seat and declines outward to other settlements. This means that the improved road system has benefited the rural people in Dancheng County. The r of the settlements in the east and southeast part of the county was 0, because their distances to the county hospitals were longer than 20 km. In addition, the r value of a few settlements in the north and west part of the county was also 0 for the same reason. It should be noted that the r of one settlement in the north part of the county, which was surrounded by the

settlements with $r > 0$, was 0; similarly, two settlements near the county seat have a lower r. The reason was that these settlements had no direct road connecting the county seat.

5 Discussion

The county seat of Dancheng is not located at the center of the county. The county level hospitals are all located at the county seat. Because of these two factors, the residents in the east and southeast part have difficulties in access to the county level hospitals. Therefore, the paper suggests that the county government build a county level hospital in the east part of the county to improve the accessibility of the residents living in the east and southeast part of the county. This county level hospital can be upgraded based on one town hospital that is located at this area. This policy has been adopted by some county governments to improve residents' accessibility to health care [9, 10].

For those villages that now have no direct road connecting the county seat, the paper suggests that the county government build the new roads to shorten the distance from the villages to the county seat. Furthermore, to date, the road level of Dancheng County is low. This situation has a negative impact on the residents' overall accessibility to health services within the county. Therefore, the paper suggests the central and local governments not only connect the rural areas by paved roads, but also increase the road level in rural areas. Roads with a higher level in rural areas will reduce rural people's travel time to the county seat, improving their access to health services at the county level.

In this study, we only considered the situation that travel friction coefficient was 1.0. Different coefficient can be taken into account in a future study. Such research will demonstrate the relationship between accessibility and the efficiency of road networks. Furthermore, accessibility to health services at county level is not determined by physical travel distance (time), but also by the transportation systems. In rural China, the majority of people normally take the bus to travel to the count seat. Thus, the network of bus routes is another important factor that impacts on rural people's accessibility to health services.

6 Conclusion

This study investigated accessibility to county hospitals in Dancheng County. The result demonstrates the highest accessibility is generally found in the county seat and declines outward to other settlements. Thus, the residents in the east and southeast part of the county have worse accessibility to county hospitals. The paper suggests the county government rebuild a county level hospital in this region to improve people's accessibility to health services. Furthermore, increasing the level of rural roads can improve rural people's overall accessibility to county hospitals. The paper suggests that the government should improve the road standard in rural areas. Finally, bus routes and timetables should be considered in a future study.

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