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Evaluation of the utility efficiency of subway stations based on spatial information from public social media

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ABSTRACT

Subway systems are important for urban transport, and effective subway systems should meet the travel needs of urban transport users. A critical feature of a subway system is the location choice of subway stations. These locations should maximize the utility value of subway stations for residents, thus contributing to ease of accessibility and level of mobility. Traditionally, the utility evaluation of subway systems has been based on static and unilateral information. This study describes the utility efficiency of subway stations in Central Chongqing, China, by assessing the balance between the supplied train services and the travel needs of the population. The information used in this study was taken from public social media; therefore, the decision-making process was bilateral, with the public voting for a subway station with “their feet”. Spatial analysis, including methods of hot spot analysis, buffer zone analysis and spatial stratified heterogeneity analysis, were used to test this process. The results indicated that spatial inequality of utility efficiency of subway stations still exists; however, the extent of the spatial inequality was dependent on the size of the walking catchment area and their location, be it within the city center or in more remote areas.

1. Introduction

Mega infrastructure projects are making significant contributions to social and economic development (Pagliara & Papa, 2011). There has been considerable investment in infrastructure projects worldwide in recent years (Zayed, Amer, & Pan, 2008). The construction of subway systems as part of urban mega infrastructure projects is one example of urban development investment that yields significant benefits and improves both social and economic levels for urban populations.

Planning is one of the early phases in an urban subway system. A unique feature of subway system planning is that it requires public support as these systems provide an important means of daily commuting throughout major cities worldwide (Shen, Wu, & Zhang, 2010). However, problems relating to subway systems, such as long waiting times and long walking distances, due to unreasonable planning, have been identified (Yu, Yang, & Li, 2012).

There are two types of public transport designs: supply-oriented and demand-oriented (Guy & Marvin, 1996). Although the development of subway systems can be supply-oriented and generate its own environment, most are demand-oriented and planned in well-developed areas, where a fixed public service radius has developed. People living and working in these areas need only find the nearest subway station for their travel needs, and the relationship between people and their destination is predefined.

This paper argues that subway system planning should focus on serving people by providing a convenient means of transporting them to their desired urban location, thereby achieving the maximum value. Therefore, consideration of the spatial relations between subway stations and urban services needs to be included in the core planning stages (Xu, Ding, Zhou, & Li, 2015). As the subway system is associated with people's life and work, its efficiency plays an important role in promoting urban development and reducing social problems. Allport (1990) confirmed that evaluating the value of subway projects can be of great assistance in optimizing the planning of a subway line and station; therefore, analysis of utility deviations are required and future improvement in locating subway stations should be based on the results.

Although several subway projects have been implemented or are currently under construction in China, their efficiency has not matched

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expectations (Yue, Zhang, & Liu, 2016). In recent years, attempts have been made to estimate the value of existing infrastructure projects. Shen, Jiao, He, and Li (2015) presented a utility efficiency evaluation index model to demonstrate the utility performance of metro infrastructure projects. This model provides a novel means of evaluating the efficiency of subway projects in different cities in China; however, it lacks quantitatively down-scaled evaluations based on real projects, particularly from a spatial perspective, such as a comparison between urban and rural areas (Wang, Liu, Li, & Li, 2016b; Yeh, Yang, & Xu, 2017).

Utility-cost analysis is the evaluation of different alternatives based on the ratio between their cost and utility (Levin & McEwan, 2000). The term "utility" refers to the degree of one alternative satisfying a criterion or attribute (Girginer & Kaygisiz, 2013). The utility-cost ratio is the comparison between the cost of an alternative and its utility score, and the lowest ratio indicates the best utility value (Levin & McEwan, 2000).

As there are few quantitative studies that evaluate subway systems by analyzing their utility-cost value, the aim of this study is to evaluate the utility efficiency of subway stations based on their spatial location and relationship to popular urban services, using information from public social media. The optimal subway station location should be in an area with the highest utility efficiency, be it within the city center or in more remote areas.

2. Data and methodology

2.1. The integrated framework

This study developed a utility evaluation model to describe subway station utility value. This utility efficiency evaluation model determined the subway station utility efficiency using four steps: local cluster analysis, utility-cost analysis, buffer analysis and spatial stratified heterogeneity (SSH). The local cluster analysis was the fundamental measurement of the spatial layout of urban services. The utility-cost value of the subway station provided information regarding train service and the public's travel needs. The third measurement assessed the spatial relations between subway stations and urban services. Additionally, SSH quantified the spatial inequality of utility efficiency. The data required by this model was collected from public social media.

The evaluation model was followed by a case study to test its effectiveness. Central Chongqing was selected as the study area due to its large spatial scale and the large investment in subway system planning and construction in the last 15 years. An effective subway system layout plan should maximize the utility efficiency of stations from different walking catchment distances in the city center to remote areas. This analysis was a practical application of the utility evaluation model and the resulting subway station utility value provided a guideline for evaluating the rationality of the Central Chongqing subway system. The results from this study could also support the development of future subway station locations.

2.2. Study area

The selected study area was Central Chongqing, China, which incorporates nine districts: Yuzhong, Dadukou, Jiangbei, Nan'an, Shapingba, Jiulongpo, Beibei, Yubei and Ba'nan. It covers 5472.68 km^2 and had a total population of 8.348 million in 2015 (Chongqing Municipal Bureau of Statistics, 2016).

Chongqing Subway is also known as Chongqing Rail Transit. Its first line commenced operation on June 18, 2005, and was the first subway in the Western region of China. Until December 30, 2015, there were four operating lines (numbered 1, 2, 3 and 6), with 120 stations and 202 km of operating distance, covering all nine districts (Fig. 1). Central Chongqing is a typical polycentric urban structure divided into 28 groups, 19 of which are serviced by the subway system.

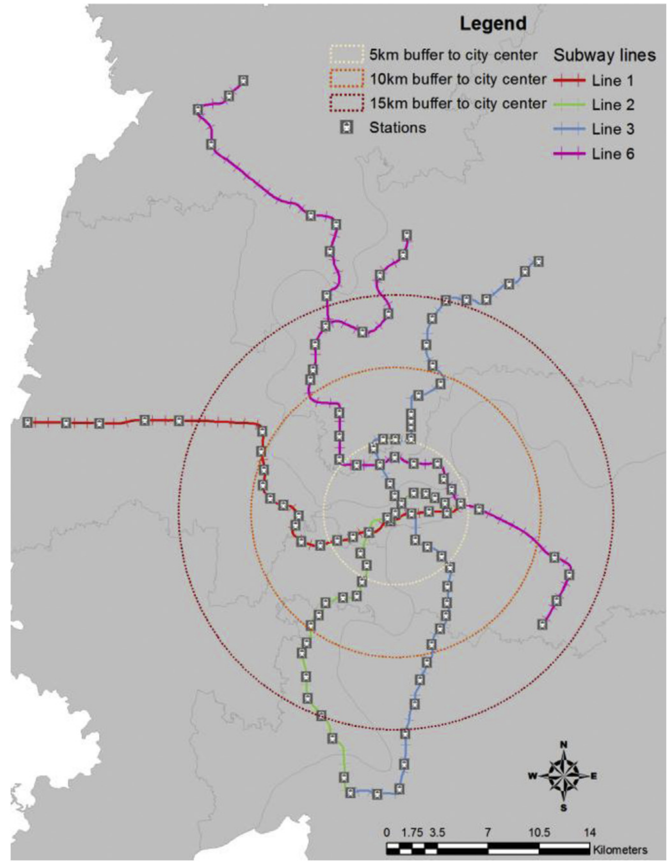

Fig. 1. Distribution of subway lines, subway stations and three buffer ring zones in Chongqing.

The transport connections between these 28 groups were one of the priorities in designing the Chongqing subway system. In addition, construction costs, such as minimizing demolition cost and facilitating construction site layout, was another factor that was taken into account. However, the passengers' needs, particularly accessibility from urban services, were rarely discussed or evaluated in previous studies.

2.3. Data description

2.3.1. Subway and administrative boundaries

Spatial data on administrative boundaries and associated features were obtained from publicly accessible open-resource data released by Chongqing Geographic Information Center. Data relating to subway station locations and the subway line path were obtained from the Chongqing Municipal and Rural Construction Committee Office in November 2015.

2.3.2. Web-captured information

One of the largest network media websites in China is "dianping.com", which publishes crowd-sourced reviews about local business performance. Information available on this website includes business name, business type, customer scoring and reviews, and geographic location linked to an online map.

Points of Interest (POI) spatial clustering is based on user-based collaborative filtering to derive residents' preferences (Ye, Yin, Lee, & Lee, 2011). Geospatial points representing local businesses (27,208) in Central Chongqing were collected in November 2015, using the sources listed above. Each data unit was a POI data point containing four information categories: business name, category (including educational, medical, entertainment, shopping and food), spatial coordinates and customer feedback (including usage frequency and evaluation). The