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How do metro stations integrate with walking environments? Results from walking access within three types of built environment in Beijing

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ABSTRACT

China is in a period of rapid metro system development. However, there are few empirical evaluations of the complex interactions between the local built environment and metro ridership in the Chinese context. In this study, we collected empirical data on the influence of local environmental characteristics on walking access in Beijing. Walking behaviors and built environment perceptions among commuters (N = 495) were collected at six metro stations in three distinctly different physical settings in Beijing—two in *hutong*, two in *danwei*, and two in *xiaoqu*. Participants recorded walking routes from the metro stations until they arrived at their destinations. Evaluations of the built environment were collected using a questionnaire after the participants arrived. Geographic information system was used to map walking routes and code built environment variables. Walking behavior outcomes were measured as walked time from metro exit to participant's destination. ANOVA compared differences between perceived and measured built environment characteristics and walking behaviors among selected neighborhoods. Multiple regression was used to test for associations between the built environment and metro station routes. We found that mean walking time from the metro station to a destination was 8 min. Recreational and office destinations had similar walking times to the metro station as residential destinations. Metro riders in *xiaoqu* and *danwei* walked longer distances to their destinations compared to metro riders in *hutong*. Physical obstacles to crossing streets made walking times longer. Greater connectivity, both perceived and measured, predicted shorter walking times. Local land use is not well integrated into metro station placement in Beijing. Better connectivity, pedestrian-friendly designs and higher building coverage ratio around the metro station might promote easier walking access and have the potential to capture more metro riders.

1. Introduction

China is in a period of rapid metro system development. Twenty-five cities have built 87 metro systems at a cost of ¥988.6 billion from 2009 to 2015 with additional stations being planned in other cities (Business Sohu, 2010). Public transport systems generally help reduce congestion, improve air quality and promote physical activity in addition to which, transit access and use have been associated with increased walking rates (Edwards, 2008; Morency, Trépanier, Demers, Trépanier Martin, & Demers, 2011; Topalovic, Carter, Topalovic, & Krantzberg, 2012; Wener & Evans, 2007). Transit users may achieve the recommended amount of daily moderate physical activity solely by walking to and from transit (Besser & Dannenberg, 2005). Theories developed especially in relation to cities in North America and Europe have inspired many public transport plans in China. Transit-oriented development (TOD) in particular aims at fostering sustainable travel behaviors in livable urban environments.

TOD principles in practice are largely metric and geometric in nature and are set in a particular urban context, with recognizably different overall characteristics when compared with the general development model in China. In particular, Chinese cities differ significantly from many western cities in terms of density, land use diversity and urban design (Day, Alfonzo, Chen, Guo, & Lee, 2013; Lin, Sun, & Li, 2015). Density and diversity are land use indicators of movement outcomes in conjunction with transport systems. In higher-density neighborhoods, land use is compact and destinations are closer, making walking more feasible and advantageous. Diversity indicates a mix of land use. Being equipped with more land use types that are within walking distance is considered favorable to walking. Design refers to the esthetic or quality of the land use and the streetscape, including the presence and attractiveness of natural sights, recreational facilities, and architectural design (Cervero & Kockelman, 1997; Ewing & Cervero, 2010).

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Density is believed to be a key factor for successful public transport operation (Calthorpe, 1993). Built environment density is often believed to increase metro riders especially for pedestrians, although study results have been mixed. Results from Barcelona suggested that density is a necessary element for the existence of short-distance walking, but beyond a certain level of density, income and sociological factors become increasingly important in determining the intensity of walking for transport (Marquet & Miralles-Guasch, 2014). Studies in Minneapolis–St-Paul revealed that higher density alone does not appear to increase the amount of walking (Forsyth, Oakes, Schmitz, & Hearst, 2007). In addition, the population density of Chinese metropolises may likewise influence decisions surrounding metro station placement. The density threshold, average TOD population density of 8100 persons/km^2 (Calthorpe, 1993), used in the Western cities is not suitable for China (Chen, 2010). Shanghai, for instance, has density of 13,635 persons/km^2. In urbanized areas of Hong Kong, dwelling density reaches over 1250 units/ha, which is in stark contrast to Western cities where inner city areas rarely exceed 125 residential units per hectare (Cerin, Chan, Macfarlane, Lee, & Lai, 2011).

In addition, a wide range of variations exists in neighborhood built environments in China. Traditional *hutong* and *lilong* still constitute major areas in the urban core in Beijing and Shanghai, respectively. *Hutong* contain the traditional built form of Beijing from the Yuan dynasty, until 1949, and are located in the city center. *Hutong* consist of streets measuring 3 to 5 m, single-floor or low-rise courtyard buildings, and a highly connected street grid that facilitates walking and cycling and limits motorized traffic (Zhao, 2013). The legacy of socialist *danwei* (or work unit) system still impacts the city structure and travel behavior (Wang & Chai, 2009). *Danwei* was the social and spatial organization in Chinese cities from the 1950s to the 1970s (Wang & Chai, 2009). Large urban compounds consisting of several to tens of acres are typically laid out in blocks of 6-floor walk-up buildings, interspersed with community facilities and worksites, with walkways laid out between the blocks and only minimal connections with the local streets. After the economic reforms in the 1980s, *danwei* residential areas were gradually reincarnated as *xiaoqu* (Bray, 2005). *Xiaoqu* built environments borrow concepts and built forms from the *danwei* but also include gated communities (Webster, Glasze, & Frantz, 2002), though not all located in suburban areas (Wu, 2005). *Xiaoqu* internal streets are isolated from city street networks, while external surrounding streets are typically wide arterials, making walking to destinations outside of residential neighborhoods indirect. Because *xiaoqu* are also large, involving hundreds of acres and thousands of residents, traveling between the superblocks among *xiaoqu* requires walking long distances (Zhao, Lü, & de G, 2010). The built forms tend to be high-rises arranged in novel layouts, with much of the ground area devoted to elaborate landscaping. While the local building typologies may impact walking access, the transformed built environment features may likewise contribute to declining non-motorized travel rates (Day et al., 2013). However, few studies on walking behaviors in the context of metro station placement are available to help guide metro station planning in China.

In addition, transit stations have been described as the focal points of multi-modalism by catalyzing revitalization of land use around the stations (Kim, Ulfarsson, & Todd, 2007; Vale, 2015). There is comparatively little evidence on the role of metro development on land redevelopment in the Chinese context. Without in-depth knowledge of the complex interactions between the local built environment and metro walking access, well-intended metro system investments in China may fail to produce the desired outcomes.

The study was conducted in Beijing. Three distinct built environment styles were selected for their different spatial and physical characteristics: *hutong*, *danwei* and *xiaoqu*. We collected empirical data on the influence of characteristic local building and street layouts on walking access from the three types of built environment. In general, we sought to address the concerns that station planning should devote considerable attention to the integration of local built environment and walking access conditions.

2. Methods

2.1. Study site selection

We examined all metro stations located within the fifth ring of Beijing, which represents the urban areas of Beijing. A radial buffer from each metro station was applied to extract the surrounding built environments. We set ≥60% of the surrounding environment belonging to one type of built environment as the criteria for selecting candidates of our study sites, whether in *hutong*, *danwei* or *xiaoqu*. Transit-oriented developments (TODs) in China and the United States have been modeled conventionally with an 800 m radius as a reliable walk catchment area (Calthorpe, 1993). New research has emerged to challenge this standard (Canepa, 2007). Du and Jiang found that the average walking catchment of Beijing metro stations is 900 m (Du & Jiang, 2005). Jiang and his colleagues found that the largest walk catchment of a transit station reached 1350 m in Jinan, China (Jiang, Christopher Zegras, & Mehndiratta, 2012). In this study, we therefore used a 1200 m radial buffer to define the surrounding walking access environment of study participants.

In total, seven metro stations were located within *hutong* environments, four metro stations within *danwei* environments and thirty-two metro stations within *xiaoqu* environments. It should be noted that there are urban areas with *danwei* and *hutong* morphology but no metro stations located within them were excluded (Beijing Wenwu Bureau, 2004). Two metro stations were randomly selected for each category, accounting for 28.5% of *hutong*, 50% of *danwei*, and 6.2% of *xiaoqu* environments. An even geographic distribution of the study sites was also considered. The stations were located in three broad location categories, namely, the inner city, the fringe of the city, and the area between the inner city and the fringe. The six candidate metro stations were then reviewed by content experts, a group of academic urban planners. The procedure was continued until we achieved a sample of six study areas that met all of the requirements described above. The study sites are shown in Fig. 1. We assigned each built environment a typology code as follows: H-XS = Xisi station located in a *hutong* environment; H-ZZZ = Zhangzizhong station located in a *hutong* environment; D-BSQN = Baishiqiaonan station located in a *danwei* environment; D-SLP = Shilipu station located in a *danwei* environment; X-JS = Jinsong station located in a *xiaoqu* environment; and X-MDY = Mudanyuan station located in a *xiaoqu* environment.

The descriptive data of the six study sites are shown in Table 1. The coverage of each built environment type in each study site is shown in Fig. 2, along with the corresponding street view and bird's eye view of the three types of built environment styles in Fig. 3.

2.2. Participant recruitment and research design

Metro rider intercept surveys took place simultaneously at the six stations over a 12-h period between 07:00 and 19:00 over a two-day period in November 2014. Twenty-four research assistants from the Peking University were recruited and trained to administer the survey and collect walking behavior tracking data. Four assistants were assigned to each station in four quadrants from the station exits. All metro riders between the age of 18 and 65 were invited to take part in the survey. The main purpose of the intercept survey was to determine the walking access patterns of current metro riders and assess whether the surrounding environments of metro stations influenced these walking access patterns. The number of riders who declined to complete the survey was recorded.

We intercepted the metro riders and inquired their willingness to participate in this research. Written informed consent was obtained