Pedestrian Environment Optimization of Xiaobailou District of Tianjin

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Abstract

Promoting pedestrian activities in cities is an important green transportation approach to mitigate negative modern urban problems such as traffic congestion, air pollution, as well as health issues like obesity. The efficiency of the pedestrian environment connected to an urban transit station is significant for green urban transportation approach. This paper focuses on the pedestrian environment around subway stations and investigates shortcomings on walkability of Xiaobailou District of Tianjin. The research team introduces theoretical findings on walking accessibility and preferences to support urban design applications in Xiaobailou District within the pedestrian accessible scope of the subway station. This paper illustrated spatial phenomena and optimizations from the pedestrian flow system, facilities, street boundary, road cross sections, and so on for improving pedestrian environment. These efforts will create better accessibility to the metro station and consequently improve peoples' preference of taking subway for urban transportation.

Keywords: pedestrian environment, metro station, land use, urban design

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I. Introduction

Due to the rapid development of private cars, there have been more and more urban problems that occurred such as traffic jams, air pollution, excessive road widths, less walking spaces, etc. Different low-carbon approaches such as green traffic, transit-oriented development (TOD), and New Urbanism have been launched and investigated. Public transportation approaches like metro systems are considered among the most important solutions.

The development of metro stations in China is very fast. From 2009 to 2015, there are 25 cities that put their metro systems in use. However, problems occur in the daily usage of the systems, resulting in low use rates caused by poor accessibility and inconvenient linking with the environment (Zacharias & Xu, 2007; Ng, 2014). For example, the rough and narrow walking spaces occupied by cars and squatter settlements, together with unreasonable linking with corresponding land use, could not provide pedestrians a safe, connected, and comfortable environment (Lu, et.al, 2009). The series of problems on the built environment is a key issue that must be addressed to promote the accessibility of metro station. Therefore, creating guidelines for urban planning and design of pedestrian environments around metro stations is necessary.

Accessibility is one of the most important indices to measure service range of metro station by indicating the force between station and destination (Ingram, 1971; Geurs & van Wee, 2004). Built environment and pedestrian characteristics such as age, gender, preference, etc. are deemed the main factors which will have influence on the force—a key for accessibility (Geurs & van Wee, 2004). Since accessibility is an abstract concept, it can be drawn from survey of pedestrian behavior—pedestrian flow, walking distance, walking time, special behavior, etc.—which are the actual performances of accessibility. This paper concentrates on the built environment so the pedestrian characteristics will not be discussed.

Built environment stresses the reality of the environment in cities—society, culture and spaces—where people live in. It includes land uses, buildings, residential activities, transport infrastructure and designs to the entities (Saelens & Handy, 2008). Researches from subjects of urban planning, transportation, environment behavior, and public health have concluded that built environment has quite an influence on pedestrian behavior (Owen, et.al, 2004).

To understand the relationship mechanism and for guidance in urban design around metro station, this paper studied the relationship of pedestrian system and built environment around Xiaobailou metro station in Tianjin as a case study by investigating the influence of land use, street characters, and facilities of the built environment on pedestrian behavior.

II. Literature Review

In developed countries, researches on built environment and pedestrian behavior mainly concentrate on discussions on land use and transportation to reduce cars' driving mileage and to promote the use rate of public transportation (Wilson, 1971). TOD is a developed theory and has a series of plans for central commercial district, residential area, open space, street and transportation systems, walking and bicycle systems, etc. (Peter, 1993). To make the integrated objective built environment measured more subjective, the Theory of Planned Behavior (TPB) is used to help in understanding the influence of the built environment on walking. TPB questionnaires can identify perception, cognition, and preference that affect behaviors (Lin, Sun & Li, 2015). The 3D (density, diversity, design) Theory analyzes the relation of built environment and pedestrian behavior synthetically. Density, diversity, and design are main factors of built environment that have positive influence on travel rate and behavior (Cervero & Kockelman, 1997). However, both mixed land use and high density may influence the walking environment and pedestrian behavior (Cunningham & Michael, 2004). For non-residential destinations, the route, open spaces, recreational walking, density, and distance have little influence (Saelens & Handy, 2008).

These researches are in view of measureable physical spaces to explore pedestrian behavior. But the conclusions are not enough to group a developed series and are even different from each other, not being able to get the influence mechanism clearly. Furthermore, these studied cases are from limited cities and country-specific (Badland & Schofield, 2005; Saelens, Sallis & Frank, 2003). Less of them mentioned situations in moderate and high-density cities. As cities in China are at fast developing speed, both the built environment and pedestrian behavior are greatly different from cities in former researches, resulting to less effective analyses in these studies (Lin, Sun & Li, 2015).

In China, although researches are available about built environment and pedestrian behavior, they are focused more on morphology evolution of traditional radius theory and the residential areas (Chen & He, 2013) as well as pedestrian system and transportation (Dai, et al, 2009). A research in Beijing proved that high density land use and built environment cannot reduce private car usage nor promote pedestrian flow (Yang, et.al, 2011). The researchers found out that convenience is the most important factor for pedestrian behavior, as street scale, crossing and waiting are minor factors only (Dai, et.al, 2009). The difference with developed countries is that there are a lot of characters in China, including the difference between registered urban and rural residents, commercial housing and unit community, etc., which have important influence on the pedestrian behavior in daily life (Bray, 2005; Zhao & Lu, 2010). The theory of TOD provides guidelines for commercial land use around the metro station on regulatory plan. But there are no detailed guidelines about the spatial and functional layout. With lack of theories and data supporting the topic of accessibility in China, more empirical researches of built environment and pedestrian behavior are necessary.

III. Case Study

Xiaobailou is a famous historical district in Tianjin. During 1860s to 1940s, it was a concession or territory and also served as the business center along wharfs, financial streets, and other office buildings (Figure 1). After 1990s, Xiaobailou went into depression as other business districts rose up. Comparing to other developed cities like Tokyo or Montreal, pedestrian flow in Xiaobailou—considered as the Central Business District or CBD according to the Tianjin General Planning (Tianjin Municipal People's Government, et al, 2006)—is too low. Xiaobailou District had been renovated since the beginning of 21st Century through promotion in commercial form and buildings, but only gotten little positive effects. Even after a metro station was built in 2006 to stimulate economic opportunities, it has not worked out yet as expected.

Xiaobailou Station has four exits. Exit A and D are linked with Langxiang Street, an underground shopping center with two floors that was built in 2009. People can go to the famous commercial street—European Shopping Street—through these two exits. Exit B is linked with a street corner park while Exit C is connected to a new shopping mall.

A. Land Use

From the land use map shown in Figure 1, it can be seen that there are lots of commercial lands around the station. East to the station, the commercial lands are grouped together. On the other hand, there are lands with facilities that separate commercial lands at the western part of the station. Grouped commercial lands usually have stronger power than the separated ones although they are equal in scale.

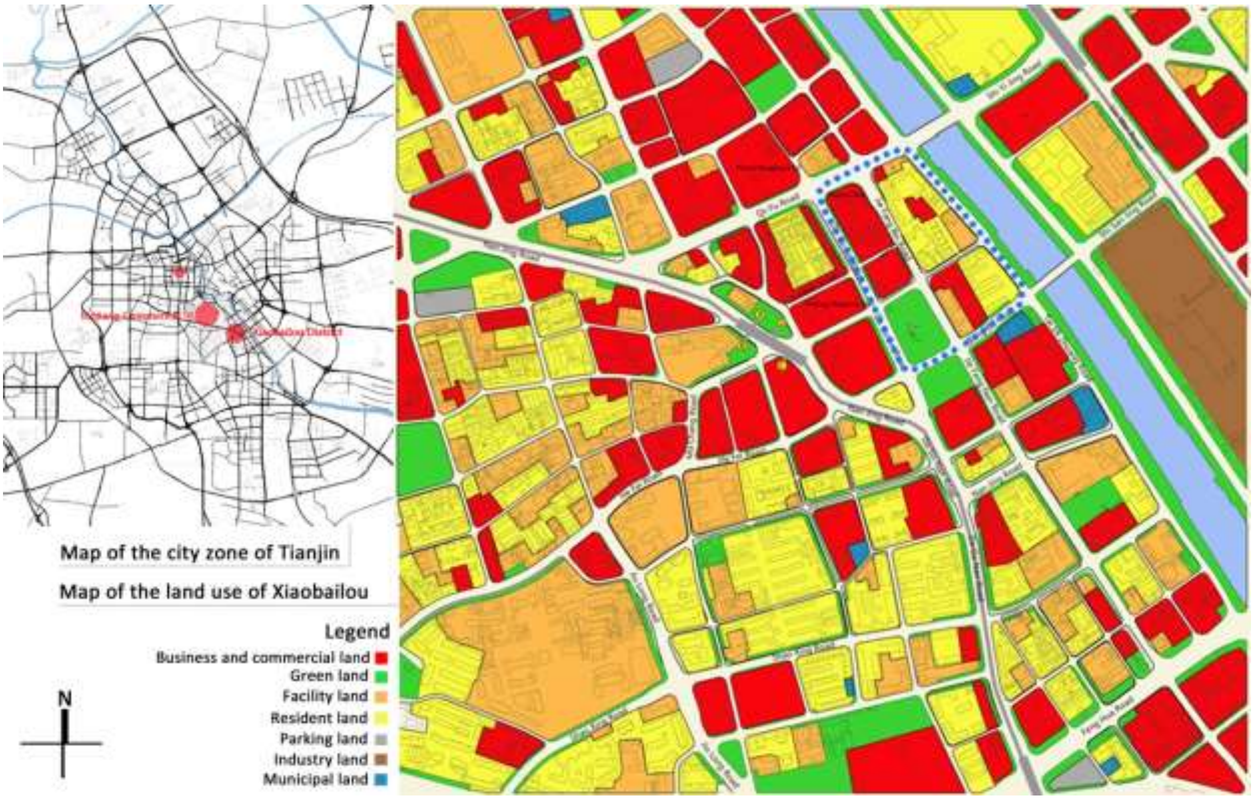

Figure 1. Location of Xiaobailou District, Tianjin.

Figure 2. The crossing between station exit and European Commercial Street.

B. Pedestrian System

Commercial land use occupies a high percentage of land within the central area of Xiaobailou. They are composed of malls and shopping streets. But the actual pedestrian system does not satisfy pedestrian needs.

- Rest space

  According to the survey conducted, rest spaces with convenient facilities like street furniture around commercial lands are limited. Even along the famous European Shopping Street, there are only a few seats without shade or landscape pieces on this outdoor street market.

- Crossing street

  The most common design for intersections is the zebra line and there are only a few footbridges. Even the intersection between the station exit and the famous European Shopping Street does not have any traffic light. Pedestrians have to compete with the vehicles when crossing the street (Figure 2).

- Sidewalk

  According to the survey on the central district, the sidewalk width ranges from 0.0 meters (no sidewalk) to 7.0 meters (mostly under 3.5 meters). Some sections are narrow (1.5 meters) and do not meet the national standards (Figure 3). Some sidewalks are occupied by cars or other facilities so people have difficulty in passing and have to walk along the vehicular lanes. Consequently, it influences the vehicular traffic.

- Signage

  There are only some directional signage and road name signs. Most of these signs are designed for the vehicular traffic but not for pedestrians. Xiaobailou District is famous for various kinds of shops, restaurants and shopping streets. However, there are hardly any signage, map or directory to show the whole district. More suitable signs should be added.

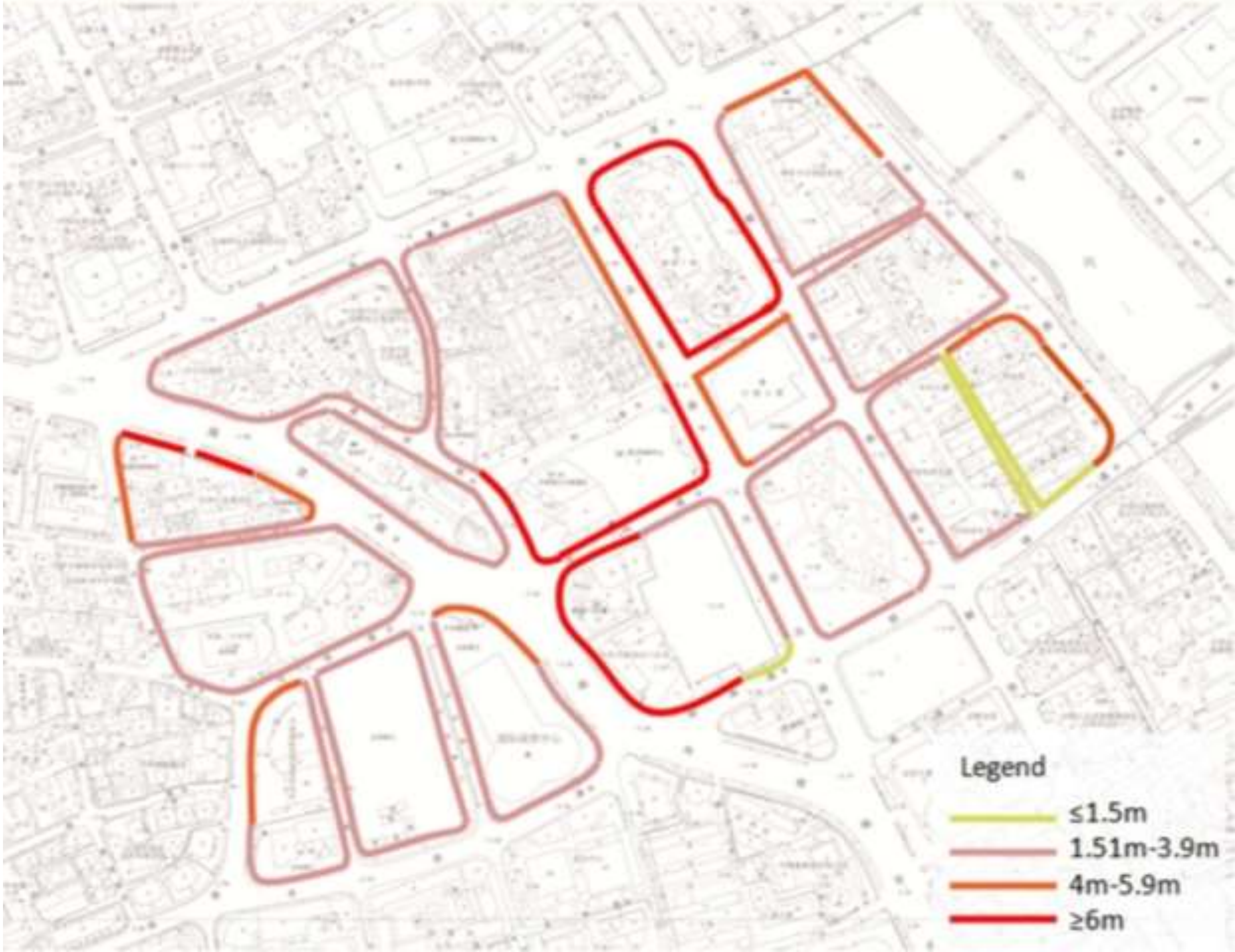

Figure 3. Width of sidewalks in the central area of Xiaobailou District.

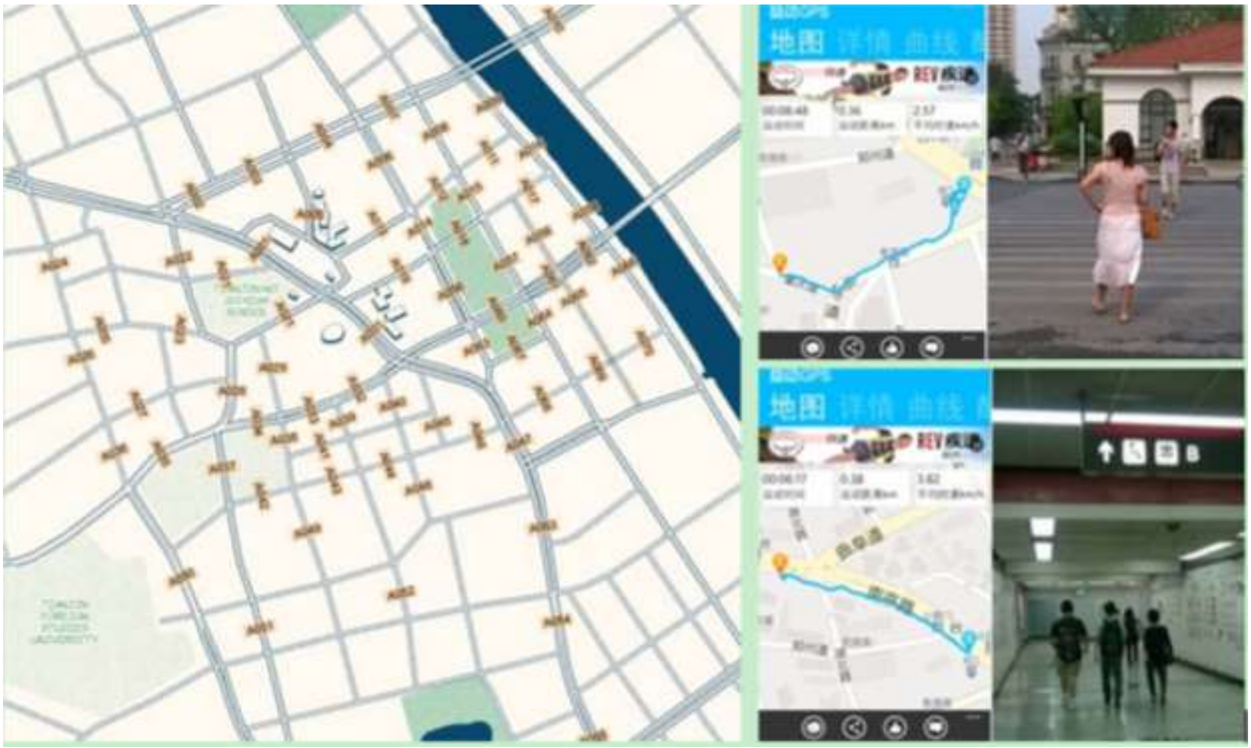

Figure 4. Survey on pedestrian flow and tracking.

IV. Research Methodology

The aim of the study is to look into the relationship between the built environment and pedestrian behavior, particularly on the subject of accessibility, and to create guidelines in designing and planning of pedestrian environments around metro stations. This paper used both qualitative and quantitative methods to analyze factors of built environment that affect pedestrian behavior.

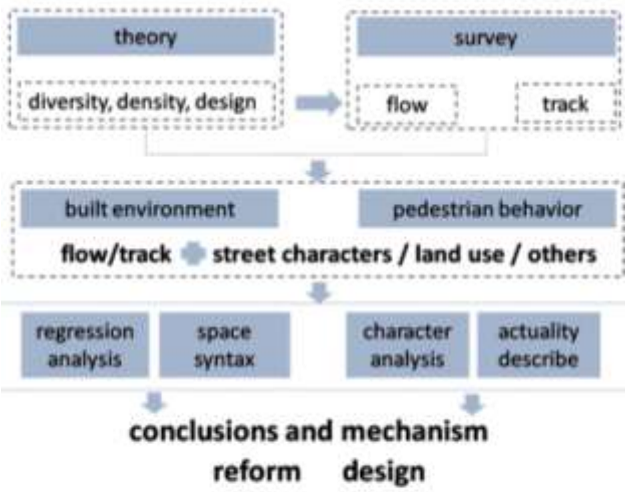

Figure 5. Research methodology diagram.

A. Study Design

This paper takes Xiaobailou District as a case study to analyze the factors of built environment that possibly influence the pedestrians. According to the literature review and actual situation, the land use, street characters, and facilities were chosen as main factors that have influence on pedestrian behavior in hypothesis:

1) The factor of land use pertains to the detailed land use around the station area.
2) Street characters include street width and the calculated Integration and Nach indices. Integration and Nach are both indices that show the connection of an area or street with the whole network in Space Syntax. Integration stands for the convenient degree to get an area or street from another. Commonly speaking, it is whether it is easy to get to an area or not. On the other hand, Nach is the degree (or frequency) of an area or street being passed by. It shows whether people like to choose an area or street to pass by with the view of the whole street network (Hiller & Hanson, 1984).
3) Facilities mainly include convenient facilities of pedestrian system. Since pedestrian behavior is complex, pedestrian flow and tracking data were used to analyze it.

Because of the variety of data, both qualitative and quantitative methods were needed. As the relationship between pedestrian behavior and built environment cannot be observed directly, mathematical models with regression analysis and space syntax were introduced. Quantitative method was used to analyze the relationship of land use and street characters with pedestrian flow. Qualitative method was used to analyze the facilities data and some tracking data that are not suitable to be parameterized. The integrated conclusions can be used in reform and designs optimization (Figure 5).

B. Data Collection

In this study, there are two kinds of data. The first part includes the data describing the three factors of built environment. The other one includes pedestrian flow and tracking data representing pedestrian behavior.

- Land use data

  According to digital map and street views, a land use map of 12 types can be obtained, including catering, shopping mall, store, residence, office, hotel, public service facility, parking, park, other station, non-high-rise office, and building site. Definition of land uses is adapted based on researches by Carmody and Sterling (1986).

- Street characters

  Street width can be measured on the survey map. Integration and Nach are calculated in Depthmap software by taking a radius of 800 meters.

- Facilities

  Survey of the convenient facilities of pedestrian system includes rest spaces, shadows, signs, supporting facilities, and so on.

- Pedestrian flow

  Pedestrian flow pertains to the number of people passing through a street section. According to the street integration map (R=800m) by Depthmap and actual situation, observation points were located. Investigators recorded numbers of automobile vehicles, bicycles and pedestrians separately in two minutes at survey points. Considering the difference of flows in different times for a single day, flow samples between 8:00-9:00, 11:00-12:00, 16:00-17:00, and 19:00-20:00 were recorded. The average and peak flow in one day were calculated afterwards. The difference between weekday and weekend was also considered and recorded accordingly (Figure 4).

- Tracking

  An investigator follows a passenger randomly at the turnstile gate and records the beginning time, ending time, destination, and special behavior during the route until the passenger enters into a building more than five minutes and does not come out. Every tracking route is put into the Depthmap to get a whole distribution map. Tracking data is mainly done to show the behavior between different people and their preferences. It also indicates the characteristics of the built environment. A total of 179 tracking routes were collected. Considering the limited amount of pedestrian tracking data, qualitative analyses were used instead of quantitative approach in the current stage (see Figure 4).

C. Data Analysis

As mentioned, qualitative method for facilities and tracking routes while quantitative method for the factors of land use and street characters were used in this study. In Depthmap regression analyses of land use and street width were used, as well as Integration and Nach for both pedestrian and vehicle flows. The value of R^2, which stands for the positive correlation between the independent and dependent variables, was obtained. Both maximum and mean flows on weekend and weekday were calculated afterwards.

From the tracking data, some strange behaviors appeared. The convenient facilities of special streets were recorded in detail, taking the European Shopping Street as an example. With the conclusions in the quantitative analyses together, the synthetically derived conclusion for the influence mechanism can be achieved.

V. Results

With the methodology and survey data, the following results were obtained:

A. Pertinence of Streets Width, Integration, Nach and Flow

With regression analyses of flow and street width, Integration, and Nach in Depthmap, the results were calculated as shown in Table 1.

According to Table 1, R^2 shows that the vehicle-flow is strongly related with the characters of streets. On the other hand, the pedestrian-flow almost has little relation with the width, Integration and Nach of streets, which means they have no influence on pedestrians.

B. Pertinence of Land Use and Flow

As mentioned in methodology, land use was classified into 12 types. Every type got evaluated and weighted. After having regression analyses, the results were tabulated in Table 2.

Table 2 illustrates the strong relationship of mean value of weekday pedestrian flow with land use. Comparing with Table 1, the relationship between land use and pedestrian flow is much higher than the relationship between characters of streets and pedestrian flow. Based on these results, the land use is an important factor for pedestrian behavior. In Figure 6, it is shown that the commercial land type usually attracts pedestrians the most.

C. Tracking

From the aggregation of 179 tracking routes shown in Figure 7, it is evident that most of the people went to the European Shopping Street and the shopping mall south of the station, with the positive scope about 350 meters in radius. Figure 8 shows the routes to different categories of destination, including home, work, service, education, catering, transfer, retail, travel, and others. Every sort of destination has a different scope. The relationship of pedestrian preference with accessibility of different destinations needs more tracking data. In the survey, there was a phenomenon that eight passengers came out from Exit D, went across the 50-meter wide street without traffic lights to the side of Exit C, and then left along the street. Three of them went back then to the east side of the street. The researchers were not able to determine why they did not come out from a nearer exit. More data may support the hypothesis that if the signs are mixed and limited, people prefer to walk more on the ground than through a more convenient shortcut underground aside from other possible reasons.

Table 1. Pertinence of streets width, Integration, Nach and flow.

R^2	*Vehicle-flow*				*Pedestrian-flow*			
	weekday		weekend		weekday		weekend	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean
street width	0.551	0.631	0.745	0.740	0.129	0.092	0.139	0.095
Integration	0.607	0.666	0.595	0.570	0.067	0.033	0.007	0.003
Nach	0.411	0.485	0.435	0.471	0.087	0.055	0.014	0.462

Table 2. Pertinence of land use and flow.

	Max-weekday Vehicle-flow	Mean-weekday Vehicle-flow	Max-weekday Pedestrian-flow	Mean-weekday Pedestrian-flow
R^2	0.34	0.36	0.48	0.52
	Max-weekend Vehicle-flow	Mean-weekend Vehicle-flow	Max-weekend Pedestrian-flow	Mean-weekend Pedestrian-flow
R^2	0.31	0.29	0.27	0.35

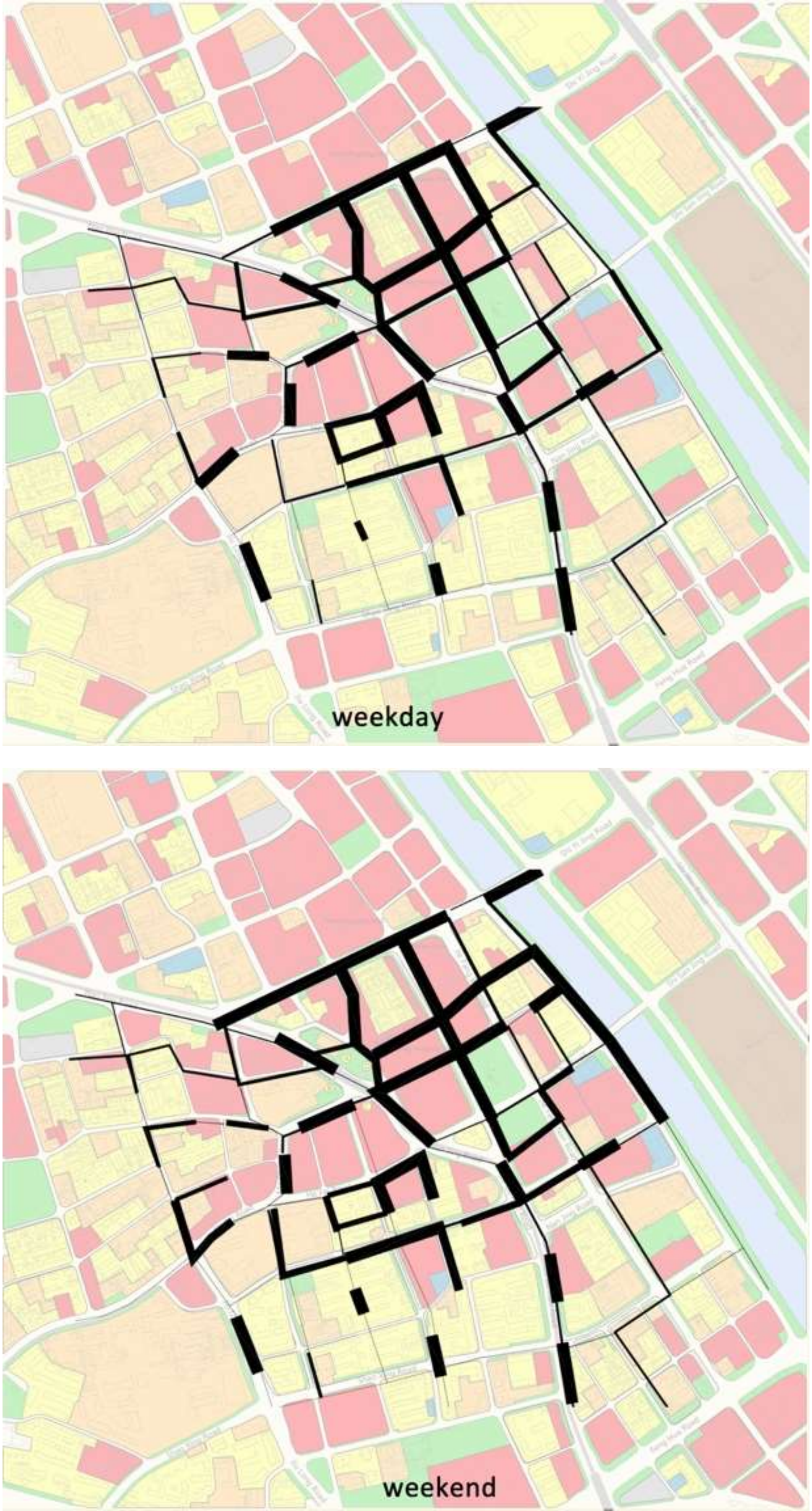

Figure 6. Peak flows of pedestrians.

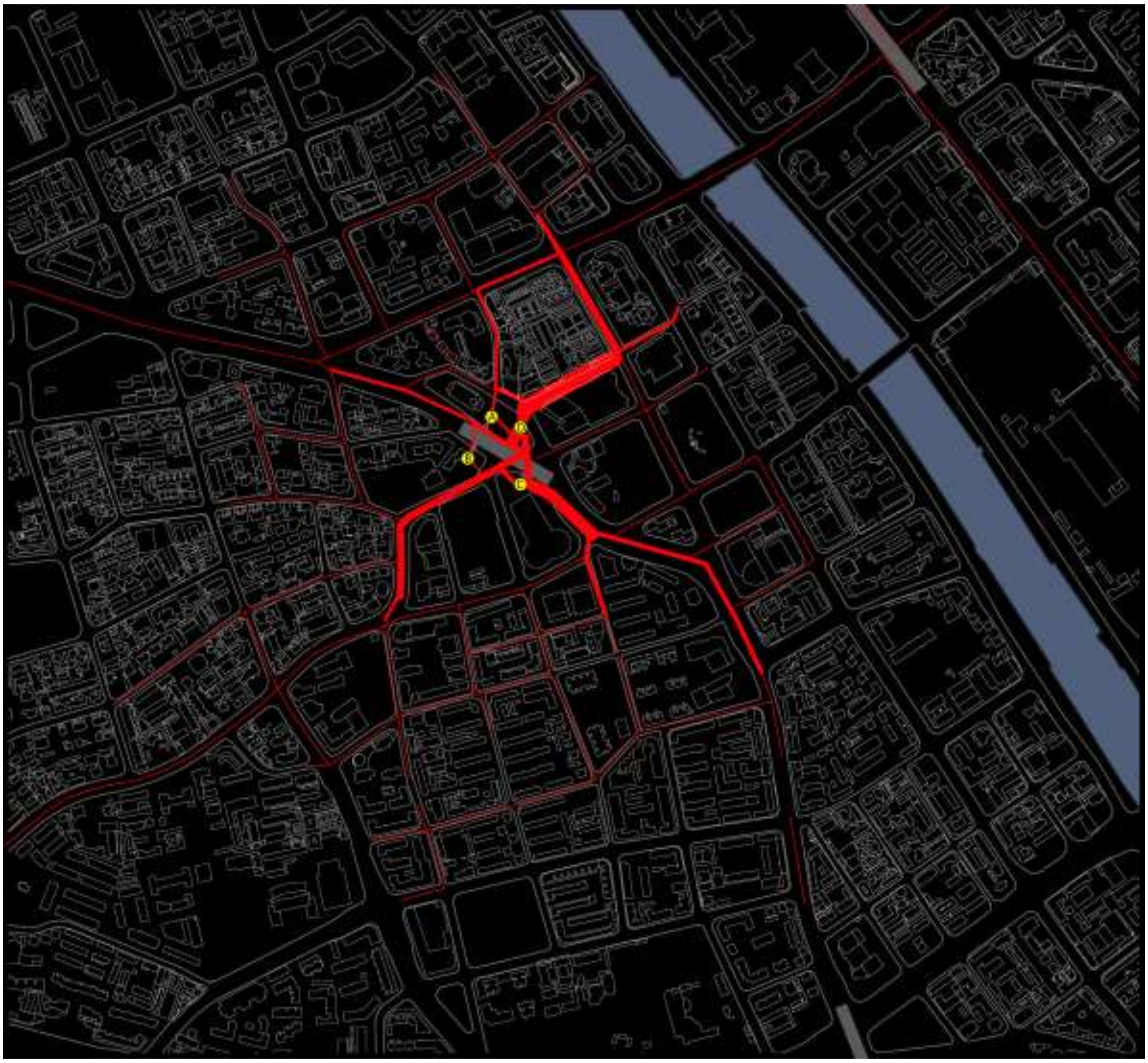

Figure 7. Aggregation of tracking routes.

D. Discussion

Based on the pedestrian flow and tracking data, a special phenomenon was recorded. There are two possible ways from the station to Friendship Shopping Mall (Figure 9), with each path having almost equal length. *Way A* goes through the famous European Shopping Street and the Haisen Plaza. *Way B* goes by residential buildings, service buildings and some stores. These two paths have totally different degrees of attraction to pedestrians, but they also do not have obvious difference on pedestrian flow number. As observed with the paths, there were some people who went to Friendship Shopping Mall via Way B instead of Way A that has more interesting features. Way B has a more quiet environment and umbrage as compared to Way A (Table 3).

Table 3. Characteristics of the two ways.

	Way-A	Way-B
Commercial	Shopping malls and characteristic restaurant and shops	Only some stores
Width of walking way	Single walking way, 12 meters	Double walking ways, 2.5-3 meters
Noise	From shops and pedestrians, higher	From vehicles, lower
Plants and shadows	No	Yes , with a street corner park
Length	420 meters	400 meters

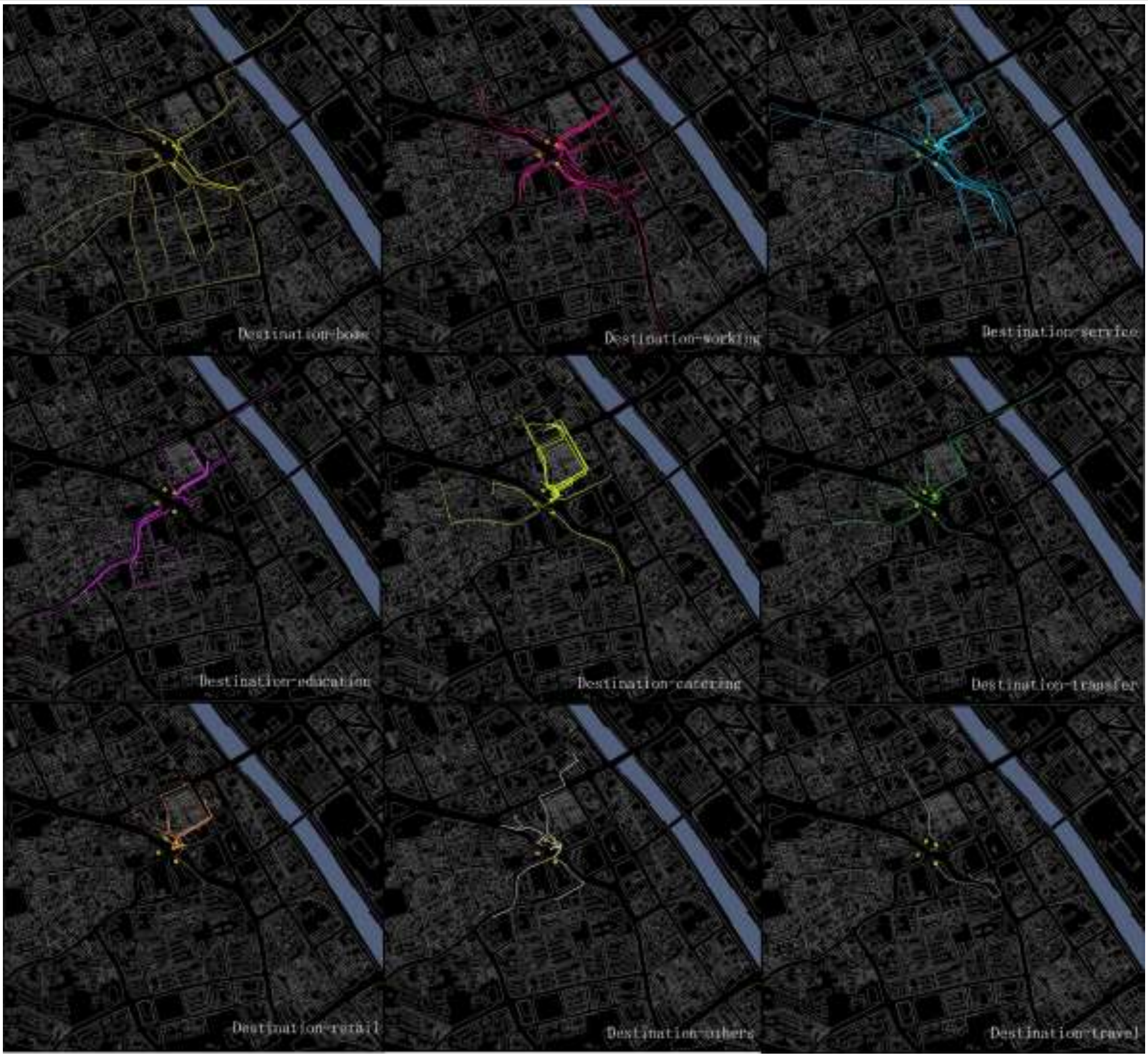

Figure 8. Tracking routes to different categories of land use.

Figure 9. Two ways from station to Friendship Shopping Mall.

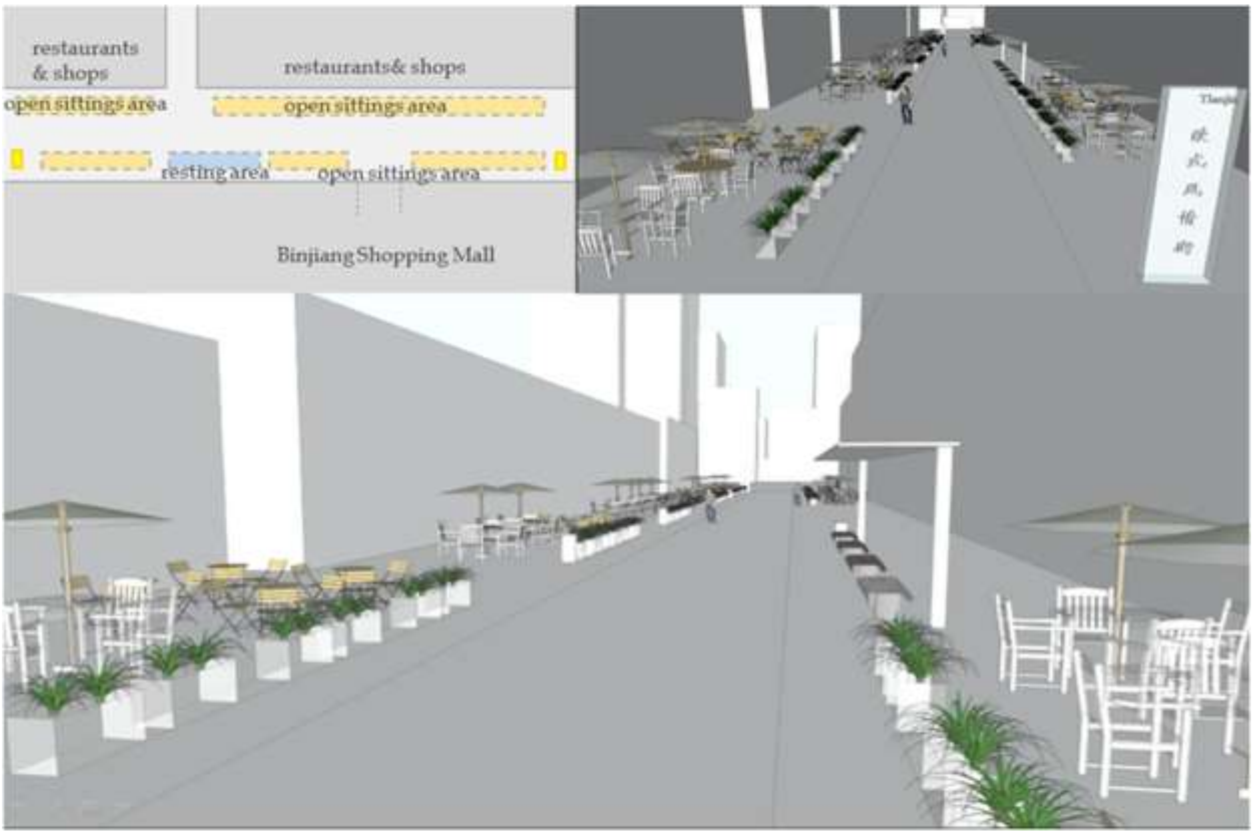

Figure 10. Proposed designs for European Shopping Street.

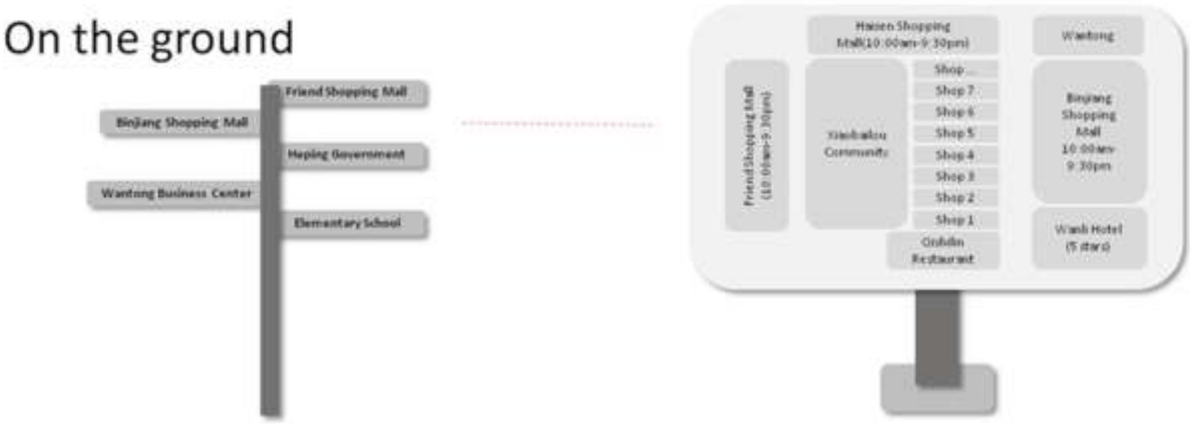

Figure 11. Signs for pedestrians.

The selection of people on Way B may be due to the comfortable environment of the path and the clear aim of the people on Friendship Shopping Mall as their destination. Except for the land use, the level of comfort can also be considered as one of the important factors that affect the preference of pedestrians.

Considering the low pedestrian flow along the European Shopping Street, more shading devices and facilities should be added to improve comfort of pedestrians, allowing people to use the pedestrian environment efficiently. Specialty stores are present at the north end of Way A, but the presence of vehicles passing by has a negative effect on the pedestrian (refer to the lower right photo in Figure 9). Serving as an important link from Friendship Shopping Mall to European Shopping Street, the path walk for pedestrians in this area needs to be widened and improved.

VI. Proposed Design Optimization for European Shopping Street

According to the results and discussion in the previous sections, the famous European Shopping Street should be improved with regards to open spaces and facilities. First, the fences and the walls of the restaurants and shops give people a strong sense of isolation. To make a friendly environment, the said fences and walls should be replaced with plants and landscape pieces. Figure 10 illustrates a solution for the open sitting areas. Second, with just a few seats and no other street furniture along the street, the resting areas with shading devices and convenient establishments should be placed (see also Figure 10).

Considering the importance of signage for pedestrians, a series of signs should be designed and installed. Around the exits, signs should be installed to direct people towards the important destinations. Poles with directional signs are also needed to be located on the ground outside every exit. At each strategic location such as the European Shopping Street, a table with information of all shops and malls is suggested to be installed (Figure 11). With all these signs, pedestrians can get the total scale of the area. It can also help them in choosing the right way.

VII. Conclusion and Future Studies

There are various factors that have influenced pedestrian behavior. According to the study, land use is one of the important factors, while facilities also have significant influence. Grouped commercial lands tend to attract more pedestrians. Different sorts of land have different effects on pedestrians. However, there is no detailed conclusion yet based on the study alone. More data are needed in order to study the quantitative and dynamic mechanisms between the factors and pedestrian behavior. The different importance of land use and facilities should be separated and valued for future studies.

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References

Badland, H. & Schofield, G. (2005). Transport, urban design, and physical activity: An evidence-based update. *Transportation Research Part D* 10, pp.177–196.

Bray, D. (2005). *Social Space and Governance in Urban China: The Danwei System from Origins to Reform*. Stanford: Stanford University Press.

Carmody, R. & Sterling, J. (1986). *Underground Space Design*. New York: Wiley.

Cervero, R. & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment* 2(3), pp.199–219.

Chen, Y. & He, N. (2013). Analysis of walkable environment and influential factors in rail transit station areas: Case study of 12 neighborhoods in Shanghai. *Urban Planning Forum* (6), pp.96-104.

Cunningham G. & Michael, Y. (2004). Concepts guiding the study of the impact of the built environment on physical activity for older adults: a review of the literature. *American Journal of Health Promotion*, pp.435–443.

Dai, J., Zhang, N., He, T. & Chen, H. (2009). Impact of walking environment on the attraction area of rail transit stations. *Urban Rapid Rail Transit* 22(5), pp.46-49.

Geurs, K. & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography* 12(2), pp.127–140.

Hiller, B. & Hanson, J. (1984). *The Social of Logical Space*. Cambridge: Cambridge University Press.

Ingram, D. (1971). The concept of accessibility: A search for an operational form. *Regional Studies* 5(2), pp.101–107.

Lin, H., Sun, G. & Li, R. (2015). The influence of built environment on walking behavior: Measurement issues, theoretical considerations, modeling methodologies and Chinese empirical studies. In Kwan, M. et al. (eds.) *Space-Time Integration in Geography and GIS Science*. Dordrecht: Springer Netherlands, pp.53–75.

Lu H., Zhang, Y. & Liu, Q. (2009). A methodology for urban pedestrian system planning. *Urban Transport of China* 7(6), pp.53-58.

Ng, S. (2014). Pedestrian system design in cities with high-density development: Example of Hong Kong. *Urban Transport of China* 12(2), pp.50-58.

Owen, N., Humpel, N., Leslie, E., Bauman A. & Sallis, J. (2004). Understanding environmental influences on walking: Review and research agenda. *American Journal of Preventive Medicine* 27(1), pp.67–76.

Peter. C. (1993). *The Next American Metropolis: Ecology, Community and the American Dream*. New York: Princeton Architectural Press.

Saelens, B. & Handy, S. (2008). Built environment correlates of walking: A review. *Medicine & Science in Sports & Exercise* 40 (Supplement), pp. S550–S566.

Saelens, B., Sallis, J. & Frank, L. (2003). Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. *Annals of Behavioral Medicine* 25(2), pp.80–91.

Tianjin Municipal People's Government, China Academy of Urban Planning and Design, Tianjin Urban Planning & Design Institute (2006). *Tianjin General Planning for 2005-2020*. Tianjin: Tianjin Municipal People's Government.

Wilson, A. (1971). A family of spatial interaction models, and associated developments. *Environment and Planning* 3(1), pp.1-32.

Yang, J., Shen, Q., Shen, J. & He, C. (2011). Transport impacts of clustered development in Beijing: Compact development versus overconcentration. *Urban Studies* 49(6), pp.1315-1331.

Zacharias, J. & Xu, M. (2007). The underground system as economic generator for Montreal's central city. *Urban Planning International* 22(6), pp.28-34.

Zhao, P. & Lu, B., (2010). Exploring job accessibility in the transformation context: An institutionalist approach and its application in Beijing. *Journal of Transport Geography* 18(3), pp.393-401.