International Journal of High-Rise Buildings
March 2021, Vol 10, No 1, 1-8
https://doi.org/10.21022/IJHRB.2021.10.1.1

International Journal of
High-Rise Buildings
www.ctbuh-korea.org/ijhrb/index.php

Analysis of Factors Influencing Street Vitality in High-Density Residential Areas Based on Multi-source Data: A Case Study of Shanghai

Meilun Yuan[1] and Yong Chen[2†]

[1]College of Architecture and Urban Planning, Tongji University, Shanghai, 200092, China
[2]College of Architecture and Urban Planning, Tongji University, Shanghai, 200092, China

Abstract

Currently, big data and open data, together with traditional measured data, have come to constitute a new data environment, expanding new technical paths for quantitative analysis of the street environment. Streets provide precious linear public space in high-density residential areas. Pedestrian activities are the main body of street vitality. In this paper, 441 street segments were selected from 21 residential districts in high-density downtown area of Shanghai as cases, to quantitatively evaluate the influencing factors of pedestrian activities. Bivariate analysis was performed, and the results showed that street vitality was not only correlated with a highly populated environment, but also with other factors. In particular, the density of entrances and exits of residential properties, the proportion of walkable areas, and the density of retail and service facilities, were correlated with the vitality of street segments. The magnitudes of correlation between the street environmental factors and the pedestrian traffic differed across various trip purposes. Segment connectivity factors were more correlated with walking for leisure than for transportation. While public transportation factors were mainly correlated with walking for transportation, vehicular traffic factors were negatively correlated with walking for leisure.

Keywords: Built environment, Street vitality, Walking activities, Transportation environment

1. Introduction

Streets play an extremely important role in urban life, not only as the main carrier of traffic, but also as an important urban open space, and an important spatial carrier for residents to understand the city and perceive its vitality. As Jacobs said, a city is vibrant when streets are vibrant (Jacobs 1992). Therefore, the question of how to evaluate street vitality and its environmental influences, and then design a comfortable and pleasant street environment to enhance the street vitality, is an urgent issue to be addressed.

As for environmental vitality, Gehl (1987) thought mixed function, the slower traffic, and longer stays meant a vibrant city. Jacobs (1992) argued that vibrant streets had the following attributes: short street length, greater pedestrian density, mixed land uses, and a mix of building ages. Katz et al. (1994) argued that compactness of spatial unit, walking conditions, mixed function, and appropriate building density were important factors influencing vitality. Montgomery (1998) argued that a good vibrant space should be fine-grained, human-scaled, of mixed use and high connectivity. These researches were mostly qualitative in describing the influencing factors of street vitality without a robust data support. Most previous quantitative researches on street vitality were limited by the restrictions of technology and the difficulties of data collection, which were prevalently acquired by field survey, photographic documentation and expert scoring. For example, Gehl (2004) conducted a survey on public space and public life based on the "Public Space-Public Life" (PSPL) method, including measuring the building interface, pedestrian flow and stationary activities along the street. Ewing et al. did a series of quantitative studies on urban placemaking, walkability, and habitability, using photographic documentation and expert scoring methods (Ewing et al. 2005, 2006, 2010, 2013). Biddulph (2012) assessed the use of two different types of streets in Cardiff, UK, using all-weather time-lapse cameras.

In recent years, with the development of urban society and the use of science and technology, many scholars began to use new technologies and new data to conduct quantitative studies on street vitality. For example, Rundle et al. (2011) took 37 blocks in New York City as the object of study, combined with Google Street View image data, to verify the impact of aesthetics, physical disorder, pedestrian safety, motorized traffic and parking, infrastructure for active travel, sidewalk amenities and other aspects on commercial and social activities, and confirmed the validity of streetscape data in the study by comparing it with

†Corresponding author: Yong Chen
Tel: +86-13916666540, Fax: +86-21- 65989221
E-mail: ch_yong2011@tongji.edu.cn

traditional measured data. Long and Zhou (2016) used mobile phone signaling data to carry out a quantitative exploration of street vitality in Chengdu. Xu et al. (2016) used POI (Point-of-Interest) data and comment data to characterize the consumption vitality of the city's population. Hao et al. (2016) conducted a study on street vitality using mobile phone signaling data and sitemap POI data, and improved the street-vitality evaluation system based on the comparison of the differences between the influence factors of street vitality in Chengdu and Beijing.

Big data and open data, together with traditional measured data and design literature, constitute a new data environment, which not only expands new technical paths for quantitative analysis of the street environment, but also provides more possibilities for portraying the street environment from both physical and social dimensions. However, the current data research involves multiple levels of urban macro, meso and micro, and it is inappropriate to apply some macro data to the study of street design. For example, mobile phone signaling data, heat map data and other data that can be used to represent the activities of people are not optimal for accurately measuring the activities on the street; as it not only struggles to distinguish between specific types of activities, but also ignores the pedestrian activities of non-mobile phone users, such as the elderly and children. Therefore, the field survey is more suitable for obtaining measured data as for the recording of pedestrian activities at the meso and micro levels of street. Based on the above, this paper selected quantitative indicators and data of the street spatial environment to analyze street vitality and its environmental influencing factors, based on a multi-source database composed of previously collected and new data.

2. Method

2.1. Measurement of Segment Characteristics

In a narrow sense, "the street environment" refers to the space that contains various traffic functions defined by the road property line. In a broad sense, it also includes the space between the line and building, and the building interfaces on both sides. Based on the above description, the street environment studied in this paper included not only the transportation environment, but also the built environment.

2.1.1. Transportation Environment Variables

The transportation environment is the basic environment of the street. The role of traffic space is reflected in the carrying capacity of streets for traffic flows, with the fundamental aim of enabling the transfer of users or goods between origin and destination. Of these, the street segment connectivity on the pedestrian flow is very significant. Space syntax theory confirmed that if there is no special target of attraction, and one excludes the interference of road conditions and other factors, the key factor affecting the urban road network and the flow of people and vehicular traffic is the road network structure itself, which is the theoretical cornerstone of the space syntax - natural movement (Hillier et al. 1993). That is, it is not the particular land use, but the street segment connectivity that primarily shapes the movement patterns of urban users. In addition, there are interactions between different traffic flows, such as private and public motor-vehicle and pedestrian traffic. Motor-vehicle flows cut off the walking space and have a negative impact on walking activities. For example, the volume and speed of car traffic are the most obvious influences on walking safety. Litman (1994) argued that the "barrier effect" caused by large numbers or high speeds of motor vehicles can prompt people to consider changing their routes or movement method in order to avoid accidents; thus, children (Nasar et al. 2015), the elderly, and families without cars may have to reduce their outings. On the contrary, if the public transport and pedestrian systems are sufficiently convenient and accessible, they can effectively increase the number of pedestrian activities on the streets. Related literature suggested that a greater number of public transport stops or transit routes can increase residents' willingness to walk (Zhao et al. 2003, Kuby et al. 2004, Knuiman et al. 2014), and in the age of motorization, the construction of pedestrian space is required to give consideration to the connectivity of public transport and pedestrian activities. Based on the above, this paper examined the transportation environment of streets in terms of both the street segment connectivity and the organization of different traffic modes.

(1) Segment Connectivity Variables

Segment connectivity variables included integration and choice composite[1], the density of entrances and exits of residential properties, and the segment length. The integration and choice composite variable was calculated by Depth Map software after establishing the spatial syntax line segment model by OpenStreetMap (OSM) vector road network data, which measured the combined potential of the street segment to attract arriving and traversing traffic. The density of entrances and exits of residential properties variable and segment length variable were calculated from OSM vector network data via ArcGIS, which measured the connectivity of the street segment to internal neighborhood roads and adjacent roads.

(2) Travel Modes Variables

The travel modes variables focused on the extent to which streets support public and private motorized, and pedestrian transportation. The public transportation variables included the distance to the nearest subway station, the number of bus routes, and the bus stop density, calculated

[1)] Calculated as (value("T1024 Integration R600 metric"))*(log (value("T1024 Choice R600 metric")+2)) by ArcGIS from public transportation data on the AutoNavi Website, to measure the degree of connectivity between pedestrian spaces and public transportation. The vehicle traffic variables included the number of lanes and the width of the roadway, taken from planning drawings, which were used to measure the traffic volume and speed. The pedestrian transportation variables included sidewalk width and the ratio of sidewalk width to roadway width, measured by the planning drawings, which were used to measure the usability and comfort of pedestrian space.

2.1.2. Built Environment Variables

In addition to the transportation environment, the street must also have a built environment, through which people's basic daily needs can be met. Streets are enclosed by a defined architectural interface on both sides, which offers the possibility to use the street not only as a circulation space, but also as a destination for recreational walking. Appropriate building density can shorten the distance between residential and activity points and reduce people's reliance on cars. Leslie et al. (2007) suggested that a high-density built environment built up the difficulty and time consumption of driving and parking, thus attracting people to walk or connect to public transport on foot. Lee and Moudon (2006) confirmed that increased residential density was strongly associated with increased pedestrian activities. Ewing et al. (1994) showed that an intensive mix of building features can shorten the walking distance of residents from their homes to various daily services, and increase the variety of travel destinations over short distances; thus, walking is encouraged. In addition, Gehl (2010) proposed that the most attractive streets around the world can find the same rhythm, i.e., streets with 15-20 storefronts per 100 meters, and a rich commercial interface can enhance the visual experience of pedestrians, thus increasing the attractiveness of streets for pedestrian activities. Based on the above, this paper studied the built environment along the street from three aspects: building capacity, land use and ground-floor interface.

(1) Building Capacity Variables

The building capacity variable was the development floor area ratio per unit area of a street segment within a certain range, calculated by ArcGIS from the building vector data on the AutoNavi Website, which was used to measure the development intensity of the land around the street segment.

(2) Land Use Variables

The land use variables focused on the density, type, mix, distance and use of functional facilities. The variables of density, type and mix of functional facilities were calculated by ArcGIS from the POI data of the AutoNavi website, to measure the coverage, richness and balance of the daily street life and service facilities, respectively. The distance variables included the distance from the center of the street segment to the nearest large commercial, medical and educational facilities, calculated by ArcGIS from the POI data of the AutoNavi website, to measure the convenience of the street segment to large facilities. The variable “comment number of functional facilities” indicated the use of the street segment in the Internet consumer environment, calculated by ArcGIS from the comment data of Dianping.com, to measure the degree of recognition of the street's service facilities among Internet consumers.

(3) Ground-Floor Interface Variables

The ground-floor interface variables included the proportion of building (commercial) interfaces and the density of retail interfaces along the street, the former measuring the transparency of the interface, and the latter measuring the richness of the interface.

2.1.3. Vitality Variables

Pedestrians are the main body of street vitality, and the number and density of pedestrian activities are important reference indicators for the external representation of street vitality, which to some extent reflects the degree of satisfaction of pedestrians' needs in the street. According to Gehl (1987) and Chang (2000), pedestrian activities in this paper were classified into transportation walking and leisure walking, based on the necessity and purpose of pedestrian activities. Transportation walking activities included commuting to and from work, to and from school, and other daily necessary and purposeful activities, as well as non-daily necessary and purposeful activities such as eating out, shopping and participating in community activities. Leisure walking activities were non-daily necessary and aimless pedestrian activities, including strolling, staying, resting and sitting, playing, fitness activities, commercial activities and street performances.

2.2. Subjects of Survey

The Space Syntax theory considers street segments as the elementary components of street networks. Each street segment is defined by the intersection between two points in an axial line, or otherwise a street.

In this paper, the street segment was the research object. Four hundred forty-one street segments in 21 residential districts with clear peripheral boundaries, a certain population size and complete supporting facilities were selected as cases to investigate how street segment environments correlated with walking activities (see Figure. 1).

2.3. Survey Procedures

This paper obtained data on walking activities on live streets through field surveys. On weekdays when the weather was fine, walking activities on the street segment were recorded by time periods (5:00-7:00, 7:00-9:00, 9:00-11:00, 11:30-13:30, 17:00-19:00, and 19:00-21:00) and by area.

Figure 1. Samples of selected street segments. Captured by Baidu streetscape on September 4, 2020.

The survey method for transportation walking was based on Jan Gehl's "observation point count", also called "gate count" in space syntax, i.e., the total number of people transportation-walking through a certain cross-section in a certain time.

Leisure walking was investigated by recording the total number of leisure walks occurring within the street segment at a given moment. To eliminate the effect of street segment size on the amount of leisure walking, this paper used the number of leisure walkers per unit length as a quantitative indicator of leisure walking, i.e., the number of leisure walkers per unit length of street segment in a given time.

3. Data Analysis and Results

The 21 residential districts selected for this paper differed in population density, and according to the Pearson correlation study (see Table 1), the population density of residential districts was found to have a certain positive correlation with the amount of transportation walking ($r = 0.410$, $p < 0.001$) and leisure walking ($r = 0.400$, $p < 0.001$), indicating that the construction of a highly-populated living environment had an obvious role in promoting walking activities; yet, walking as a kind of movement with slow speed, over short distances, and for different purposes, can also be correlated with other environmental factors. Therefore, in this section, correlation analysis of the transportation and built environment variables selected above with the indicators of transportation walking and leisure walking was conducted to further compare the magnitudes of correlation between street environmental factors and walking activities.

3.1. Analysis of the Impact of Street Segment Transportation Environment

3.1.1. Segment Connectivity Variables

According to the correlation analysis of segment connectivity variables and walking activities (see Table 1), the magnitudes of correlation between segment connectivity variables and walking activities was in the following order: the density of entrances and exits of residential properties variable ($r = 0.381$, $p < 0.001$ and $r = 0.524$, $p < 0.001$) > the integration and choice composite index ($r = 0.282$, $p < 0.001$ and $r = 0.407$, $p < 0.001$) > segment length ($r = –0.122$, $p = 0.010$ and $r = –0.264$, $p < 0.001$). All types of segment connectivity variables had a greater correlation with leisure walking than with transportation walking, mainly because there were clear destinations for residents' transportation walking. When the segment connectivity did not match the distribution of destinations, it weakened the correlation with transportation walking, while aimless leisure walking was more easily influenced by segment connectivity.

3.1.2. Travel Mode Variables

According to the correlation analysis between travel-mode variables and walking activities (see Table 1), the three public transportation variables of distance to the nearest metro station, number of bus lines and bus stop density had a greater correlation with transportation walking ($r = –0.354$, $p < 0.001$, $r = 0.170$, $p < 0.001$, $r = 0.239$, $p < 0.001$) than with leisure walking. ($r = –0.225$, $p < 0.001$, $r = 0.024$, $p = 0.613$, $r = 0.146$, $p = 0.002$), which was mainly due to the greater dependence of transportation walking (especially commuting activities) on public transit

Table 1. Correlation between Street Environment Variables and Walking Activities

	Street Environment Variables	Transportation walking	Leisure walking
Neighborhood population density		.410**	.400**
Transportation environment variables			
Segment connectivity variables			
	Integration and choice composite variable R600	.282**	.407**
	Density of entrances and exits of residential properties	.381**	.524**
	Segment length	–.122*	–.264**
Traffic modes variables			
Public transportation variables	Distance to the nearest subway station	–.354**	–.225**
	Number of bus lines	.170**	.024
	Density of bus stops	.239**	.146**
Vehicle traffic variables	Number of lanes	–.219**	–.311**
	Width of roadway	–.275**	–.367**
Pedestrian transportation variables	Width of sidewalk	.177**	.179**
	Width of sidewalk / width of roadway	.347**	.378**
Built environment variables			
Building capacity variable			
	Average floor area ratio	.215**	.252**
Land use variables			
Density, types and degree of mixing	Density of functional facilities	.394**	.379**
	Density of cultural and recreational facilities	.229**	.214**
	Density of fitness and leisure facilities	.053	.098*
	Density of amenities	.499**	.492**
	Density of health-care facilities	.245**	.228**
	Density of catering and shopping facilities	.479**	.496**
	Density of education facilities	.188**	.130**
	Density of business accommodation facilities	.186**	.129**
	Density of residential areas	.201**	.271**
	Type of functional facilities	.444*	.368**
	Mix of functional facilities	.415**	.343**
Distance	Distance to the nearest large functional facility	–.270**	–.301**
	Distance to the nearest large commercial facility	–.040	–.176**
	Distance to the nearest large medical facility	–.225**	–.231**
	Distance to the nearest large educational facility	–.265**	–.278**
Usage	Number of comments on functional facilities	.180**	.146**
Ground-floor interface variables			
	Architectural (commercial) interface ratio	.390**	.401**
	Density of retail interfaces along the street	.472**	.530**

*$p < 0.1$, **$p < 0.05$; dark gray $r \geq 0.3$, light gray $0.1 < r < 0.3$

facilities. In addition, the more significant correlation of the distance to the nearest subway station variable and the bus stop density variable with walking activities compared to the number of bus routes variable. The two vehicle traffic variables, the number of lanes and the roadway width, had a greater negative correlation with leisure walking($r = –0.311$, $p < 0.001$ and $r = –0.367$, $p < 0.001$) than with transportation walking ($r = –0.219$, $p < 0.001$ and $r = –0.275$, $p < 0.001$), mainly because leisure walking was more easily influenced by vehicular space on walking comfort and safety. The two pedestrian transportation variables, the sidewalk width and the ratio of sidewalk width to roadway width, had similar correlation with transportation walking (r = 0.177, $p < 0.001$ and r = 0.347, $p < 0.001$) and leisure walking (r = 0.179, $p < 0.001$ and r = 0.378, $p < 0.001$). Compared to sidewalk width, the ratio of sidewalk width to roadway width had a more significant correlation with walking activities, i.e., compared to the actual size of the walkable space, pedestrians paid more attention to the status of street walkable space relative to vehicle space, i.e., whether the street is pedestrian-oriented or vehicle-oriented.

3.2. Analysis of the Impact of the Street Segment's Built Environment

3.2.1. Building Capacity Variables

According to the correlation analysis of building capacity variable and walking activities (see Table 1), transportation walking (r = 0.215, $p < 0.001$) and leisure walking (r = 0.252, $p < 0.001$) were higher on streets with higher building density, indicating that the high-density built environment can provide streets with a higher amount of walking activities.

3.2.2. Land-Use Variables

According to the correlation analysis of land use variables and walking activities (see Table 1), it was found that the density, type and mixture of functional facilities had a significant correlation with walking activities. Among them, the density of amenities and the density of catering and shopping facilities had the most significant correlation with both transportation walking (r = 0.499, $p < 0.001$ and r = 0.479, $p < 0.001$) and leisure walking (r = 0.492, $p < 0.001$ and r = 0.496, $p < 0.001$). The distance to large functional facilities had a certain correlation with walking activities. Among them, the distance to large educational and medical facilities variables had a strong correlation with transportation walking (r = –0.265, $p < 0.001$ and r = –0.225, $p < 0.001$) and leisure walking (r = –0.278, $p < 0.001$ and r = –0.231, $p < 0.001$), while the distance to large commercial facilities variable had a weak correlation (r = –0.040, $p = 0.405$ and r = –0.176, $p < 0.001$). The number of comments about functional facilities variable had a weak correlation with both transportation walking (r = 0.180, $p < 0.001$) and leisure walking (r = 0.146, $p = 0.002$). This may be due to the fact that the walking activities of the residents of the living street were not significantly affected by the evaluation of the functional facilities on the Internet, as compared to their in-person assessment of the commercial street.

3.2.3. Ground-Floor Interface Variables

Based on the correlation between the ground-floor interface variables and walking activities (see Table 1), it was found that the proportion of building (commercial) interface and the density of retail interfaces along the street had a significant correlation with both transportation walking (r = 0.390, $p < 0.001$ and r = 0.472, $p < 0.001$) and leisure walking (r = 0.401, $p < 0.001$ and r = 0.530, $p < 0.001$). A transparent and rich street interface can increase the likelihood of pedestrians interacting with the street interface, and makes the street more attractive to pedestrians.

4. Conclusions and Recommendations

The results of the study indicated that in the street segment transportation environment, the magnitudes of correlation between transportation environment factors and walking activities differed in relation to various trip purposes. Among them, segment connectivity factors were correlated more with leisure walking than with transportation walking, mainly because there were clear destinations for residents' transportation walking; when segment connectivity did not match the distribution of destinations, it weakened the correlation with the transportation walking, while aimless leisure walking was more easily influenced by segment connectivity. Public transportation factors were mainly correlated with the transportation walking, because most of the destinations of transportation walking (especially commuting activities) were public transportation facilities. Vehicle traffic factors were mainly negatively correlated with leisure walking, which was more easily influenced by vehicular space on walking comfort and safety. Pedestrian transportation factors had similar correlation with transportation walking and leisure walking. Comprehensive analysis of various transportation environment factors showed that the density of entrances and exits of residential properties, and the proportion of walkable areas were important factors correlated with walking activities of street segments. This was due to the fact that the entrances and exits of residential properties surrounded by dense retail and service facilities, and public transportation facilities were essential to the daily lives of the residents. However, most residential districts in China have a large block scale, which makes it impossible for the city pedestrian system to penetrate into the residential districts, and for public activities in the community to continue into the living street, thus reducing street vitality. In addition, the ratio of sidewalk width to roadway width had a more significant correlation with walking activities than sidewalk width, number of lanes and roadway width, i.e., the pedestrian atmosphere created by the right-of-way allocation was more important. This showed that, theoretically, the greater the width of the roadway, the lower the level of pedestrian unsafety. However, this is not always absolute. If the width of the sidewalk is equal to that of the roadway, combined with other elements suitable for walking, it still has the potential to become a walkable street, such as the Champs Elysees in Paris.

In the street-segment built environment, the magnitudes of correlation between built environment factors and walking activities were similar for various trip purposes. Among them, the density of retail and service facilities, and the density of retail interfaces along the street, were important factors correlated with walking activities. The more retail businesses, the more choices and accessibility to relevant destinations, the more likely residents were to walk, and the more local employment opportunities within walking distance (Leslie et al. 2007). In addition, large functional facilities, such as educational and medical facilities, can be attractive to walking activities, but compared with retail facilities along the street, large commercial facilities were less attractive to pedestrian activities. This was mainly due to the fact that people tend to drive to one-stop shopping malls, and the large number of parking spaces in malls also encourage driving, which has a negative impact on the walking environment. In addition, most shopping malls in China tend to be large in size, with a lack of façade diversity and an unattractive pedestrian experience along the perimeter of the mall, whereas the ground-floor retail interfaces along the street are more closely related to pedestrian activities. The denser the retail interfaces along the street, the richer the visual experience for pedestrians and thus, the more attractive.

Therefore, as for the traffic environment of the street, it is first suggested to increase the pedestrian entrances and exits of residential properties appropriately along the streets with dense retail interfaces and public transportation facilities, to strengthen the permeability of the pedestrian network and to facilitate the daily life of pedestrians. Meanwhile, it is also suggested to develop a scientific and reasonable right-of-way allocation policy, and to reasonably plan the width of the sidewalk based on the scientific prediction of the pedestrian flow of the street. For streets with high traffic volumes, the proportion of walkable space can be appropriately increased to reduce the negative impact of roadways on walking comfort and safety. Whereas, for the built environment of the street, it is firstly recommended to appropriately increase the proportion of retail and service facilities. At the same time, it is suggested to increase the intensity of the pedestrian environments where commercial facilities and large educational and medical facilities are located.

Acknowledgements

This research was supported by The National Natural Science Foundation of China (No. 51278339 and No. 51678414). The authors acknowledge all reviewers for their valuable comments and guidances.

References

Biddulph, M. (2012). "Radical streets? The impact of innovative street designs on liveability and activity in residential areas." *Urban Design International*, 17, pp. 178-205.

Chang, H. S. (2000). *Environmental Psychology and Interior Design*. China Architecture & Building Press, Beijing, China.

Ewing, R., Clemente, O., and Handy, S. (2005). *Identifying and Measuring Urban Design Qualities Related to Walkability-Final Report*. Robert Wood Johnson Foundation, Princeton, NJ, USA.

Ewing, R., Handy, S., Brownson, R., Clemente, O., and Winston, E. (2006). "Identifying and Measuring Urban Design Qualities Related to Walkability." *Journal of Physical Activity and Health*, 3, pp. 223-240.

Ewing, R. and Cervero, R. (2010). "Travel and the Built Environment." *Journal of the American Planning Association*, 76(3), pp.265-294.

Ewing, R. and Clemente, O. (2013). *Measuring Urban Design: Metrics for Livable places*. Island Press, Washington, D.C., USA.

Ewing, R., Haliyur, P., and Page, G. W. (1994). "Getting Around a Traditional City, a Suburban Planned Unit Development, and Everything in Between." *Transportation Research Record*, 1466, pp. 53-62.

Gehl, J. (1987). *Life Between Buildings: Using Public Space*. Van Nostrand Reinhold, New York, USA.

Gehl, A. (2004). *Towards a Fine City for People: Public Spaces and Public Life*. Transport for London, London, UK.

Gehl, J. (2010). *Cities for People*. Island Press, Washington, D.C., USA.

Hao, X. H., Long, Y., Shi, M., and Wang, P. (2016). "Street Vibrancy of Beijing: Measurement, Impact Factors and Design Implication." *Shanghai Urban Planning Review*, 3, pp.37-45.

Hillier, B., Penn, A., Hanson, J., Grajewski, T., and Xu, J. (1993). "Natural Movement: Or, Configuration and Attraction in Urban Pedestrian Movement." *Environment and Planning B: Planning and Design*, 20, pp.29-66.

Jacobs, J. (1992). *The Death and Life of Great American Cities*. Vintage, New York, USA.

Katz, P., Scully, V. J., and Bressi, T. W. (1994). *The New Urbanism: Toward an Architecture of Community*. McGraw-Hill, New York, USA.

Kuby, M., Barranda, A., and Upchurch, C. (2004). "Factors Influencing Light-rail Station Boardings in the United States." *Transportation Research Part A: Policy and Practice*, 38, pp.223-247.

Knuiman, M.W., Christian, H.E., Divitini, M.L., Foster, S.A., Bull, F.C., Badland, H.M., and Giles-Corti, B. (2014). "A Longitudinal Analysis of the Influence of the Neighborhood Built Environment on Walking for Transportation: The RESIDE Study." *American journal of epidemiology*, 180, pp. 453-461.

Long, Y. and Zhou, Y. (2016). "Quantitative Evaluation on Street Vibrancy and Its Impact Factors: A Case Study of Chengdu." *New Architecture*,1, pp.52-57.

Litman, T. (1994). *Transportation cost analysis: techniques, estimates and implications*. Victoria Transport Policy Institute, Victoria, Australia.

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., and Hugo, G. (2007). "Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes." *Health & Place*, 13(1), pp.111-122.

Lee, C. and Moudon, A. (2006). “Correlates of Walking for Transportation or Recreation Purposes. ”*Journal of Physical Activity and Health*, 3(1), pp.77-98.

Montgomery, J. (1998). “Making a City: Urbanity, Vitality and Urban Design.” *Journal of Urban Design*, 3(1), pp.93-116.

Nasar, J., Holloman, C., and Abdulkarim, D. (2015). “Street characteristics to encourage children to walk.” *Transportation Research Part A: Policy and Practice*, 72, pp.62-70.

Rundle, A., Bader, M., Richards, C., Neckerman, K., and Teitler, J. (2011). “Using Google Street View to Audit Neighborhood Environments.” *American journal of preventive medicine*, 40(1), pp.94-100.

Xu, Y. F., Zheng, S. Q., and Wang, J. H. (2016). “Urban Vitality: The Demand and Supply of Local Consumption Amenities.” *New Architecture*, 1, pp.26-31.

Zhao, F., Chow, L. F., Li, M. T., Ubaka, I., and Gan, A. (2003). “Forecasting Transit Walk Accessibility: Regression Model Alternative to Buffer Method.” *Transportation Research Record*, 1835(1), pp.34-41.