Neighbourhood Walkability Assessment in Tianjin, China: Needs to be Analyzed from a Complex System Perspective

Guanqiong Che, Baoxing Qiu

(Guanqiong Che, Tianjin University, Cardiff University, 54Richmond Road, Cardiff, peanut1963@yahoo.com)
(Baoxing Qiu, State Council Counselor, professor, Tianjin University, No.92 Weijin Road, Nankai district, Tianjin)

1 ABSTRACT

Walkability is one of the key guiding frameworks for practitioners to design vibrant and healthy neighborhoods through urban planning interventions, especially in current circumstances where concerns over chronic diseases, obesity and apathetic neighborhoods are growing. The objective of this research is to develop a walkability index, with considerations of the uniqueness of the neighborhood built environment, life style, planning framework and requirement of Chinese cities, and apply it to Tianjin. The results show an uneven distribution pattern of the walkability. Further, the influence of the neighborhood's location is identifiable, the closer it is to the city commercial center, the higher the walkability score is. The results indicate that the neighborhood walkability varies with both the built environment within it and its location within the whole city, which calls for more cross-scale analysis.

Keywords: complex system, neighbourhood, walkability assessment, pedestrian, China

2 INTRODUCTION

2.1 Background

Walking and outdoor activity have long been a subject of interest in the field of both health and urban planning. Among public health professionals, walking and physical activity are considered to play a key role in the management of obesity and associated chronic diseases (Ding & Gebel, 2012). In addition, more outdoor pedestrian activity implies a higher probability of a social encounter, which are believed to enhance a sense of trust and connection among people and the places they live in, therefore, being positive to mental health and personal wellbeing (Sarkar, 2013). Meanwhile, walking and outdoor activities are important to planners because they are positively related to less car-oriented transportation, thus lead to traffic congestion and carbon emission reduction (Cao & Fan, 2012). Besides, more walking means more social encounters among neighborhoods, which is vital to improve community vitality and social cohesion. Walking activity depends on the built environment in many aspects, such as the land use, the pedestrian network, as well as the layout and morphology of the surrounding area in different spatial scales. Therefore, identification and understanding of the facilitators and barriers of the built environment for walking is a prerequisite of creating neighborhood that is beneficial to public health.

2.2 Literature review

Walkability is a measure of how amenable an area is to walking. It signifies any assemblage of built features whose components statistically associate with the propensity to walk (Battista & Manaugh, 2018). As have been proved by previous researches, distance (to service facilities such as shops and parks), residential density, land use diversity, and street grid design explain the greatest variation in walkability mode (Barton, 2009; Cho & Rodriguez, 2015). Traffic safety factors like pedestrian infrastructure and roadway characteristics play a smaller though significant role (Giles-Corti et al., 2013). Safety from crime has been linked to walking behavior, though its explanatory power varies depending on pedestrians' characteristics and experiences (Giles-Corti et al., 2011). Urban design elements that make walking more pleasurable, such as trees for shade and benches for rest, marginally associate with walking behavior (Vivienne et al., 2015). Our understanding of these built environment features continues to evolve as researchers use innovative approaches and data to examine walking behavior (Neatt et al., 2017; Battista & Manaugh, 2018). Meanwhile, there is a consensus that each of the epidemiological paradigms, physical and social, when employed simultaneously but independently cannot on their own explain walking behavior (Sarkar, 2013). In other words, attributes of the physical environment that are associated with walking often co-exist and should not be measured in isolation. Walkability index is therefore designed to reflect the various elements by capturing the multiple attributes of a place. Researchers have tailored components and their quantification, and units of analysis to fit their hypotheses because walkability index must be designed specifically with the research population and setting in mind.

Investigating associations between physical environments and walking also requires consideration of the spatial scale: how to capture exposures in an area that is sensitive to walking. In consideration of the multi-dimension and complexity of the relationship, the micro and macro-levels of causal analysis have been encompassed. The micro level often refers to the household (locational characteristics) and the buffer area surrounding it. Sarkar (2013) points out that a higher correlation is synonymous with a greater homogeneity in the walking behavior of individuals within a neighborhood, which, in-turn reflects the potential effects of the neighborhood physical environment upon the determinants of walking behavior. At this spatial scale, factors of cumulative population level and neighborhood context such as the density and the presence of externalities from proximate land uses can be better captured and addressed. Most studies employed data aggregated at the levels of census defined regional and local geographies. Using GIS software, the neighborhood are usually delineated as a buffer, a boundary placed around an area or a house (point) using a predefined scale as either a straight-line (Euclidean) or a network distance (Sarkar, 2013). A Euclidean distance-generated neighborhood buffer constitutes a circular area with the center as the individual's geocoded residential postcode, whilst a network distance-generated buffer is an irregular polygon defined by the street network around the residential location. The scale of the buffer area is usually defined within walking distance, considering the regular pedestrian walking speed, 4km/h, and the distance decay effect. Besides, the degree of homogeneity within each neighborhood and the heterogeneity among different neighborhoods should be defined carefully so that it can capture the population level socio-economic and environmental characteristics more accurately.

At the macro level, the within-city between-neighborhood studies are conducted to identify the differences in walking behavior between clusters of homogeneous neighborhoods as well as uncover specific cross-level impacts of city size, urban morphology and urban sprawl on walking behavior and their interactions. When the spatial scope is expanded from the neighborhood to region, the number of retail facilities or jobs in a region is an externally determined factor rather than a factor that is affected by the neighborhood built environment (Cho & Rodriguez, 2015). In analyzing the different impacts from the neighborhood and the regional scale, Handy (1993) developed two concepts of accessibility, namely the local accessibility and regional accessibility. The former is defined with respect to convenient establishments such as supermarkets, drugstores or dry cleaners. While, the latter refers to the positional characteristics of the neighborhood in its region, and the relationship between each neighborhood (a partial space) and the metropolitan area to which it belongs (the whole space). Regional accessibility can be measured as distance (accessibility) to downtown and employment centers, as well as public transfer center, such as the railway station, which attract customers from a wide geographic area. The two concepts relate to each other closely but convey qualitatively different dimensions. Usually, the effect of high levels of local accessibility is greatest when regional accessibility is low and vice versa. Næss (2005) distinguished an urban structural factor and a detailed-urban form factor. He identified that the spatial distribution of facilities within a region or the location of a residence relative to the facilities may influence travel patterns, and this effect can be separable from the influence of the built environment within a specific neighborhood. Other studies in transportation and regional science have used distance to jobs, distance to parks and distance to public transport transit centers to characterize the neighborhoods walkability from the regional perspective (Ewing & Cervero, 2010; Rodriguez et al., 2009; Van Acker et al., 2007).

In analyzing the relation between the walkability and the more abstract topological properties, space syntax is adopted to assess the impact of spatial configurations on different behavioral phenomena, walking included (Hillier, 2012; Mansouri & Ujang, 2016; Sharmin & Kamruzzaman, 2018). The theory argues that the configuration of the urban grid itself is the main generator of movement, which yields attraction inequalities and privileges to some urban spaces over others for movement and activities without the consideration of land use attractors (Hillier, 2012). The studies using the space syntax measures, however, show various findings. Baran, Rodríguez, and Khattak (2008) identified a positive association between total utilitarian walking and two of the syntactic measures (choice and integration). They concluded that the lower the number of axial lines and direction changes in a system, the more accessible and integrated the network is. On the other hand, Koohsari, Karakiewicz, and Kaczynski (2013) found that these two measures have negative associations with the amount of walking. In addition to the above directional inconsistencies, further evidence of inconsistency was found in the magnitude of association. For example, Lee and Seo (2013) revealed that connectivity has a weak correlation with pedestrian volume, whereas Pont and Marcus

(2015) reported a strong correlation in a study in UK. Explanations for such results with different directions and magnitudes can be attributed to the different measurements (choice or integration), different methods (axial or segment), as well as different operational approaches (topological, angular and metric) applied.

There are two main purposes of this paper. Firstly, to create a neighborhood walkability index considering the uniqueness of Chinese cities and apply it in the walkability assessment in Hexi district, Tianjin. Secondly, to examine the relationship between the neighborhood walkability and its location within the city. To achieve this, this paper is organized as follows. In the next paragraph, the neighborhood walkability index is created, whose measures are selected based on walk score initiated in America and literatures researching on the association between the built environments and walking, and are adjusted considering the land use classification of China and service facility use frequency. Then, the index is applied to Hexi district, Tianjin to assess the overall walkability of the area and variations among different neighborhoods. On the basis of the measurement, the significance and magnitude of the regional influence on the neighborhood walkability is analyzed to provide more accurate evidence for urban planners to improve walkability.

3 METHOD

3.1 Study area

The study area, Hexi district lies at the southwest bank of Haihe, the main development axis in Tianjin. As one of the metropolitan areas of Tianjin, it covers an area of 42km2 and accommodates a population of around 870,000 with well-furnished, however, unevenly distributed service facilities. The area it covers extends from the inner city to the out perimeter of the metropolitan area from north to south, which makes it a suitable case for studying the role of both locality and location on walkability (fig.1).

Fig. 1: study area

3.2 Data collection

The spatial data used in this research include the road network, the distribution of land use, building and service facility. The first three are collected from the Tianjin Planning Bureau. The service facility is retrieved as poi, which are acquired with Octopus Network Data Crawler. They are further classified according to the Urban Land Use Classification Standard issued by the Ministry of Housing and Urban-Rural Development of China. The population data is extracted from the Statistical Yearbook in 2019. All data are stored and managed in ArcGIS 10.2. In defining the neighborhood, we firstly identify the residence buildings by overlying the layer of residential land use with the building. Then the residential buildings are aggregated when they belong to the same residential area and fall into the same grid that is enclosed by road. The following step is to create a road network-generated buffer area with a 400m radius for each centroid of the divided residential area. 400m is applied because it is the walking distance of 5 minutes, within which walking activity happens most frequently and without distance decay effect (James et al., 2014). The residential area is applied instead of the household unit because there is homogeneity of the contextual built environment for the household of the same residential area. 227 neighborhoods are identified eventually (fig.2).

Fig. 2: neighborhood identified with 400 buffer

3.3 Creating the walkability index

In reviewing the evidence of the published studies, four principle measurements of walkability at the neighborhood level are applied in this paper, namely: density, diversity, destination accessibility and street connectivity (table1).

measurement	Definition
density	quantity of people distributed per neighborhood
diversity	the degree of heterogeneity of land uses within each neighborhood
destination accessibility	the road network-generated distance from the centroid of each neighborhood to the multiple destinations (daily service facilities and public transport stops) within the same neighborhood
street connectivity	number of intersection within each neighborhood

Table1: measurements of walkability

Density, refers to the quantity of people, dwelling units, jobs, specific service destinations distributed per unit land area, among which population density and residential density are most commonly employed in studies on the correlation between the built environment and walking behavior. As the land use density increases, trip origins and destinations are brought into greater proximity to one another resulting in greater accessibility to service destinations. Besides, density may substitute walking trips for out off-neighbourhood vehicular trips (Cao & Fan, 2012). Consequently, high density compact neighborhoods tend to shorten trip lengths, while facilitating the increase of the number of trips and walk activity. This paper employs the population density. We calculate the population capacity of each household by multiplying the floor space by the height. Then the population acquired at the district level is distributed to each household by the population capacity ratio. The population of each neighborhood is the aggregation of that of each household within it.

Diversity or the land use mix measures the number of different land uses as well as their spatial arrangement for a given geographic unit. A multiplicity of different land uses located in a compact neighborhood shorten trip distances to different destinations by integrating services at a much finer grain of proximity. Researches have shown that high land use mix are positively related to less vehicle travel hours, as well as more frequent and longer non-motorized travels (Ewing et al., 2015). Furthermore, the heterogeneous mix pattern may result in agglomerations of more population and services. The consequent urban form thus comprises of fine grained neighborhood blocks with enhanced permeability, connectivity and accessibility, thereby encouraging walking activity. This paper adopts the diversity measurement pioneered by Frank et al. (2010) as follows:

$$LUM = \left(-\frac{\sum_{i=1}^{n} p_i . \ln p_i}{\ln N}\right)$$

where pi is the proportion of estimated square footage of land use i and N is the number of land uses. The diversity values normally range from zero to one, with zero representing a homogeneous, single land use environment, while one represents a heterogeneous neighborhood comprising of more permutations and combinations of land use categories. In the selection of the land use categories, the Urban Land Use Classification Standard issued by the Ministry of Housing and Urban-Rural Development of China is taken into consideration to adjust the mostly used categories in previous researches (table 2). In this way, more specific and accurate advices can be given in urban planning to improve walkability.

Destination category	Land use code	weight
Cultural facility	A2	1
Educational facility	A3	1
Sports facility	A4	1
Medical care	A5	1
Retail mall	B111	1
Retail supermarket	B112	2
Restaurant	B13	2
Recreational facility	B3	1
Park	G1	1
Square	G3	1
Transport transit	S4	2

Table 2: Land use category in measurement of diversity and destination accessibility

Destination accessibility can be defined as the relative ease with which goods, services, activities and generally, 'destinations' or 'opportunities' can be reached from a given origin, essentially the dwelling location of an individual (Ding & Gebel, 2012). It implies multi-purposes short trips, thereby encouraging residents to walk and cycle as well as reducing dependence on cars. Indirectly, with more destinations closer to one another and more people on the streets, a sense of community and community safety are fostered, which in turn encouraging more walking behavior. Among all the destinations mentioned in previous researches, the retail (shops and commercial establishments), the green space (parks, squares and playgrounds), recreational and physical activity resources (book stores, gyms, and swimming pools) all show significant correlations with walking behavior. Besides, the presence of public transport transits (stops) at walkable distances tends to encourage residents to walk to and from the stops. In Europe, the threshold distance is around 400 meters, beyond which the proportion of residents opting to walk declines progressively and the corresponding car dependence rate increases. In addition to the destinations mentioned above, this paper includes more destinations which are frequently used by residents, such as the primary school and medical care service facilities. Residents’ demand and use frequency vary with different types of destinations. The higher demand and use frequency, the greater the influence it may exert on walking behavior. To reflect the effects of destinations’ proximity to walkability more accurately, we give each type of destinations a weight according to their use frequency (Lu, 2013) (table 2). The distance is measured as street network-generated distance rather than Euclid distance.

Street connectivity and network morphology measures the street level accessibility. It indicates the feasibility and ease of travel between trip origins (household) and various destinations (work place, retail shops, green space etc) following the existing configuration of urban network. Typically, dense urban grids comprising highly interconnected straight streets crisscrossing at right angles shortens the access distance, provides more routing options, thereby shaping individual walking behavior. However, results from some studies show that street connectivity is negatively or not correlated with walking behavior (Wang st al., 2013). Such mixed findings may be partly explained as while increased street connectivity may increase access to destinations, smaller block sizes may also create more conflicts between motorists and pedestrians, making less connected street networks more safe and desirable for walking (Ewing et al., 2015). The attributes of street network morphology have been enumerated in the form of intersection density, percentage of 4-way intersections, number of intersections per unit length of street network as well as block based measures such as block perimeter, block size and so on (Baran et al., 2008). This paper quantifies the street connectivity as the density of intersections with more than three ways within each neighborhood.

The neighborhood built environmental variables mentioned above often come as a parcel of highly correlated measures. Areas with higher residential density are often more diversified and more interconnected. The degree of correlation between these variables is a function of their inherent synergy in creating a walkable urban environment. However, it also creates model estimation problems associated with interactive variables or spatial multi-collinearity. To avoid this problem, a walkability index was established that integrates the variables, among which z-score represents the standard score.

Walkability index=z-score of density+ z-score of diversity+ z-score of destination accessibility+ z-score of street connectivity

3.4 Regional influence measurement

To measure the regional influence, in other words, the locational characteristic on neighborhood walkability, two methods are applied. The first one is by measuring the distance between each neighborhood and the city commercial center, which is defined according to the Urban Master Plan of Tianjin (fig.1). This measurement is applied according to previous research findings that the neighborhood's proximity to city center may influence its walkability. The other method is the integration rate calculated through space syntax. Integration, quantifying how close a given street is from all other streets, is considered as a key measurement to explain pedestrian movement (Hillier, 2012). It also gives us clues as how the overall structure and morphology of the city influence the neighborhood walkability with a specific location. Enter regression is adopted using SPSS to analyze the correlation as the neighborhood walkability being the dependent variable, its distance to city commercial center and the integration degree as independent variables respectively. Then, stepwise regression is applied to analyze the influence effectiveness and magnitude of these two independent variables simultaneously.

4 RESULTS

Among all the 227 neighborhoods identified, the walkability score shows an uneven distribution pattern, with the neighborhoods at the northern part show a higher scores than the rest of the area (fig.3). In analyzing the standard deviation (SD), we find that the SD of the walkability index is larger than that of those contributing factors. In other words, aggregately, the uneven distribution of the contributing factors resulting in a more dispersed walkability score.

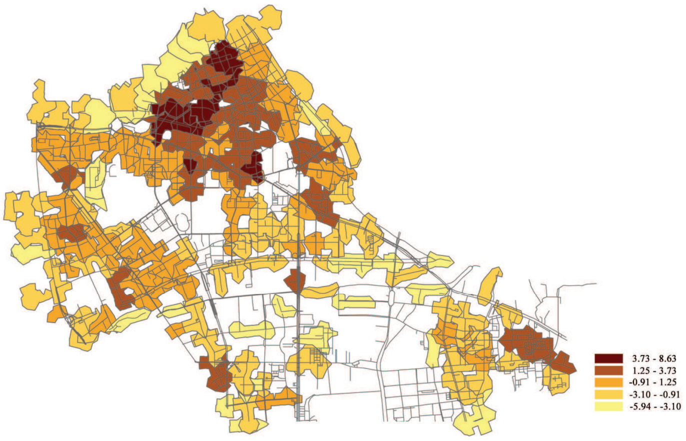

Fig.3: walkability scores and their distribution

In further analysis of the relationship between the neighborhood locational characteristics and its walkability score, the influence of the neighborhood's integration rate within the urban area is noteworthy when it is added to the regression analysis as the only independent factor. It's influence becomes indistinctive, however, in comparison with the distance from each neighborhood to the city commercial center when both of the factors are added as independent factors in stepwise regression (table 3) (table 4). The results indicate that the closer the neighborhood is to the city commercial center, the higher its walkability score is.

variables	mean	SD	min	max
Walkability	0.04	2.7	-5.94	8.62
Distance to city commercial center	-1.06	1	-1.72	2.32
Integration ratio	-1.31	1	-1.80	2.33

Table 3: Descriptive statistics for neighborhood walkability and location characteristics

Variables	coefficient	p
Distance to city commercial center	-0.41	＜0.05
Integration ratio	0.23	0.485

Table 4: Stepwise regression analysis between the walkability and locational variables

5 DISCUSSION AND CONCLUSION

The neighborhood walkability index is created based on factors that have been proved by previous research that have significant influences on walking behavior. It is adjusted in terms of the selection of service facilities that is used in diversity and destination accessibility assessment to make it more suitable and practical for Chinese cities. This research provides some clues to city planners and designers as what aspect of the neighborhood physical environment can be improved to encourage walking behavior, however, it's accuracy in reflecting and predicting the actual walking behavior remains to be verified. In the analysis of the locational impacts on walkability in this research, the influence of the distance to city center from each neighborhood is significant, the higher the proximity to city center, the higher the neighborhood walkability whereas the influence of the integration rate is not distinctive. We speculate that areas around downtown are more densely populated, diversified and well connected, which may increase the opportunity to walk out of as well as within the neighborhood boundary. The restricted influence of the integration rate in this research may be attributed to several causes. One is the mismatching of the road types included in neighborhood walkability and integration rate assessment, for the former includes more bypass while the latter is mainly based on the main road and sub-main road. The correlation may be revised when bypass and sidewalks are included in integration rate analysis. The other is that the buffer area of 400m is not big enough to reflect the connectivity and accessibility of this neighborhood within the city. When the buffer area is expanded to 800m or 1200m, the correlation may be stronger. This may also be explained as in previous research that high integration rate may lead to confliction between motorized travel and pedestrian travel especially at the neighborhood level, which indicates a negative correlation between them.

There are several limitations to the present study. This index needs to be verified and adjusted by the actual pedestrian flow, so that the weight given to the destinations and all variables in measuring the walkability can be more accurate. Buffer area need to be expanded to 800m, 1200m. In this case, the influence of integration rate on neighborhood walkability may be illustrated less ambiguously. Moreover, findings concerning the variations of influence factor on neighborhood walkability with different spatial scales can be achieved. Another limitation is that the study did not measure how the presence of sidewalks and walking trails might affect levels of walking behavior. Besides, the integrality and continuity of the walking space deserves more attention, such as how the main road without sidewalks obstructs walking behavior. What's more, potential effects of self-selection or attitudinal predetermines of neighborhood choice, or the choice to walk need to be accounted for.

The results of this study indicate that multiple measures are supposed to be taken systematically rather than separately to improve neighborhood walkability. With more research on the residents' demographic characteristics, their preferences in choosing neighborhoods, their spatial-temporal limitation as well as their interaction with walking behavior, more accurate and targeted plan and design actions can be taken to improve neighborhood walkability, thereby improve residents' well-being.

6 REFERENCES

Baran, P. K., Rodríguez, D. A., & Khattak, A. J. Space syntax and walking in a new urbanist and suburban neighbourhoods. Journal of Urban Design, Vol.13, Issue1, pp. 5–28, 2008.

Barton H. Land Use Planning and Health and Well-being. Land Use Policy, Vol.26, Issue 12, pp.S115-S123, 2009.

Billie Giles-Corti et al. School site and the potential to walk to school: The impact of street connectivity and traffic exposure in school neighborhoods. Health & Place, Vol. 17, Issue 2, pp. 545-550, 2011.

Billie Giles-Corti et al. The influence of urban design on neighbourhood walking following residential relocation: Longitudinal results from the RESIDE study. Social Science & Medicine, Vol. 77, pp. 20-30, 2013.

Cao X, Fan Y. Exploring the Influences of Density on Travel Behavior Using Propensity Score Matching. Environment and Planning B: Planning and Design, Vol.39, Issue 3, pp. 459-470, 2012.

Chinmoy Sarkar. The Science of Healthy Cities: Deciphering the associations between urban morphometric and health outcomes. Cardiff University, pp.23-147, 2013.

Ding D., Gebel K. Built environment, physical activity, and obesity: What have we learned from reviewing the literature? Health & Place, Vol. 18, pp.100-105, 2012.

Ewing R & Cervero R. Travel and the built environment: A meta-analysis. Journal of the American Planning Association, Vol. 76, Issue 3, pp. 265–294, 2010.

Ewing R, Tian G, Goates J P, et al. Varying Influence of the Built Environment on Household Travel in 15 Diverse Regions of the United States. Urban Studies, Vol.52, Issue 13, pp. 2330-2348, 2015.

Frank, L., Kerr, J., Rosenberg, D. & King, A. Healthy aging and where you live: Community design relationships with physical activity and body weight in older. Americans. Journal of Physical Activity and Health, Vol. 7, pp.S82-S90, 2010.

Geoffrey A. Battista, Kevin Manaugh. Stores and mores: Toward socializing walkability. Journal of Transport Geography, Vol. 67, pp. 53–60, 2018.

Gi-Hyoug Cho, Daniel Rodriguez. Location or design? Associations between neighborhood location, built environment and walking. Urban studies, Vol. 52, Issue 8, pp. 1434–1453, 2015.

Handy, Susan. Regional Versus Local Accessibility: Implications for Nonwork Travel. Transportation Research Record, No. 1400, pp. 58-66, 1993.

Hillier, B. Studying cities to learn about minds: Some possible implications of space syntax for spatial cognition. Environment and Planning B: Planning and Design, Vol. 39, pp. 12-32, 2012

James P, Berrigan D, Hart J E, et al. Effects of Buffer Size and Shape on Associations between the Built Environment and Energy Balance. Health & Place, Vol.27, Issue 3, pp.162-170, 2014.

Kevin Neatt, Hugh Millward, Jamie Spinney. Neighborhood walking densities: A multivariate analysis in Halifax, Canada. Journal of Transport Geography, Vol. 61, pp. 9-16, 2017.

Koohsari, M. J., Karakiewicz, J. A., & Kaczynski, A. T. Public open space and walking the role of proximity, perceptual qualities of the surrounding built environment, and street configuration. Environment and Behavior, Vol. 45, Issue 6, pp. 706–736, 2013.

Lee, S., & Seo, K. W. Combining space syntax with GIS-based built Environment measures in pedestrian walking activity. The 9th International Space Syntax Symposium, Seoul, Korea, pp. 1–14, 2013.

Mansouri, M., & Ujang, N. Space syntax analysis of tourists' movement patterns in the historical district of Kuala Lumpur, Malaysia. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, pp. 1–17, 2016.

Næss P. Residential location affects travel behavior. But how and why? The case of Copenhagen metropolitan area. Progress in Planning, Vol.63, Issue 2, pp. 167–257, 2005.

Pont, M. B., & Marcus, L. What can typology explain that configuration cannot? The 10th International Space Syntax Symposium, London, UK, pp. 1–16, 2015.

Rodriguez DA & Mojica CH. Capitalization of BRT network expansions effects into prices of non-expansion areas. Transportation Research Part A: Policy and Practice, Vol. 43, Issue 5, pp. 560–571, 2009.

Samia Sharmin & Md. Kamruzzaman. Meta-analysis of the relationships between space syntax measures and pedestrian movement. Transport Reviews, Vol. 38, Issue 4, pp. 524-550, 2018.

Van Acker V, Witlox F & Van Wee B. The effects of the land use system on travel behavior: A structural equation modeling approach. Transportation Planning and Technology, Vol. 30, pp. 331–353, 2007.

Vivienne C. Ivory, Marie Russell, Karen Witten, Carolyn M. Hooper, Jamie Pearce, Tony Blakely. What shape is your neighborhood? Investigating the micro geographies of physical activity. Social Science & Medicine, Vol.133, pp.313-321, 2015.

Wang F, Wen M, Xu Y. Population-adjusted Street Connectivity, Urbanicity and Risk of Obesity in the US , Applied Geography,Vol.41, Issue4,pp.1-14, 2013.

Yin tao, Lu. Walkability Evaluation based on People s Use of Facilities by Walking. City Planning Academic Journal, Vol. 5, pp. 113-118, 2013.