The GIS-Based Research of Measurement and Planning on Walkability of Educational Public Service Facilities - a Case Study in Wuhan

Yin Jie

Wuhan University, 64673543@qq.com

Abstract

Pedestrian traffic--- the most encouraged way of developing the "green travel mode" nowadays, makes urban walking quality an important index to measure city residents' quality of life. While the needs of vehicular traffic were continuously met, the pedestrian traffic should be taken into consideration as well. This paper exemplifies an empirical study on walkability measurement towards the educational public service facilities of Wuhan (capital of Hubei Province, China) and integrates the factors of transport , population and land use on the basis of GIS, to verify the rationality of the layout of these facilities. Mainly by analyzing the allocated situation of the city's educational service facilities and grade distribution of walking demands, together combining with the attenuation of both walking distance and pedestrian conditions, it draws some conclusions (assisted by application of GIS overlay analysis calculation) on the city's comprehensive pedestrian grade distribution with regard to the city's educational public service facilities, which will propose some beneficial guidance for the layout planning of facilities.

1. Introduction

City walking quality has become a vital indicator of city residents' quality of life, in that pedestrian traffic nowadays is becoming the most encouraged way to develop the "green travel mode". Comparatively speaking,

city's extensional development is oriented towards cars popularity, whereas walking leads an active lifestyle as well as a pollution-free green way of travel.

A variety of advantages can be achieved by taking walking trips, including social, economical and environmental benefits. On the social dimension, the destination provides residents with various facilities and accesses to services; meanwhile, it creates more chances for walkers' intercommunication and intra-exchange with other services-offering personnel, No doubt that it will strongly enhance residents' sense of community. In terms of economy aspect, city's advancement is bound to produce kinds of social activities with higher frequency and increasing density, and traffic jam unavoidably occurs in many of central areas, which results in the waste of resources. Fortunately, the walking mode can effectively alleviate this tendency. As a substitution for cars, walking is also cost-saving, waste-reducing and health-giving for travelers. When referring to the environmental benefits, as a pollution-free green way of travel, walking exerts little influences on the environment by effectively reducing the greenhouse gases emissions, such as CO2. This paper makes a research towards the walkability measurement of educational public service facilities and evaluates the walking system in related fields of Wuhan City, with the purpose of offering advisory guidance for the layout planning of facilities.

In China, the human-oriented idea was advocated in the fields of urban programming and traffic planning in 1980s. But until now, as the principal part in road using, people are still crowded out by a wide range of modern transportation, which induces the city's pedestrian space and its environment extremely harsh. Evidently, the reality is we emphasize "car priority "instead of people-oriented in China. In city's planning, pedestrian activity spaces are gradually swallowed, consequently, walkers are actually living in the crack between vehicle traffic and buildings along the streets. Pedestrian space become the piece of fat meat everyone want to get, slow speed lanes and sidewalks are occupied by vehicles who are supposed on speedy lanes , causing lacks of walking space and difficulties on road-crossing. The entire above are not only seriously damage the walkers' rights which should be protected, but also affect a full play of efficiencies concerning other types of transportation. The reason for this phenomenon is the focus of China 's economic development. The goal of urban transport is in order to be more efficient and faster. Pedestrian traffic is put slight emphasis on in the fast-growing motorized cities.

2. The development course of pedestrian traffic

In early cities, people rarely have other substitutions for walking. So the city road is just a simple but practical walking system. During this period, conflicts between walkers and vehicles didn't stand out. In the middle of the Nineteenth Century, strong appeals from the public for opening the public space and walkways forced the authorities of British and German, to design a batch of new parks, such as Birkenhead Park designed by Joseph Paxton. Paxton separated roads according to different traffic modes: the park includes a carriage road and two completely independent walking lanes. Thirty years later, Fredrich Law Olmsted and CalvertVaux designed the Central Park in New York, who Paxton adopted a similar system with Paxton : each mode of transportation has a completely independent set of road network --- flyover in intersections, and the expected crossing roadways together with forest road into metropolitan park system.

In late Nineteenth Century and early Twentieth Century, with the emergence of motorized traffic, there existed an imbalance in road using between vulnerable groups (pedestrians and cyclists) and motor vehicles, thus, the original texture of the city was destroyed. In order to avoid negative developments led by the destruction of city's early industrialization, the concept of "city needs planning and controlling" appeared. At the end of Nineteenth Century, German attempted to conduct street grading in accordance with the traffic flow .The view of Reinhard Baumeister and Hermann Joseph Stübben exemplified such typical thought. They held that a good street network should include a variety of transportation services to the main streets and related auxiliary streets which are suitable for living, rather than traffics on highways or park roads. The one side of residential units connects roadway (branch or the end of road), and the other side connects walking lane system. When these two clashes, that is, walking lanes have to cross through the roadways, strada sopraelevata or tunnels are necessarily applied.

After World War II, most of German cities reconstructed, and cars are regarded as the most important motive force to a post-war economic revitalization. Therefore, in order to create more space to operate motor vehicles, Germany regained a significant amount of road construction in the mid of 1950s. The city center faced enormous challenges by a complete mechanization, which impelled Germany to take stimulative policies on development of public transport and motorized traffic as well; almost at the same time, walking was in gradual advancement. Compared with Germany, the British more concerned about traffic restrictions. As car ownership rates and vehicle speeds ascended, experts were increasingly worried

about traffic accidents plague, so issues on how to improve road safety and traffic flow growth became important aspects of road traffic policy. Alker Tripp advocated road grading, which suggested more strict traffic controlling measures so as to protect specific areas from motor disturbances, it definitely guaranteed safety of pedestrians and cyclists. He puts forward the concept of functional block (precinct). In brief, boundaries of different forms of areas were defined by secondary distributor roads, such as commercial areas, residential areas, working areas and historical buildings protected areas.

Since 1960s, big scales of road construction and unlimited proliferation of cars caused a series of city problems. In order to cope with that and improve living conditions, also to create the vitality of the city, western countries have implemented revival plan for inner cities. The large-scale promotion of walking was considered as an essential step to create a more humane city. Many cities have the changing process: from the urban commercial center to the suburbs, and then the return to city centers again. The layout presented the development like that: from commercial trunk roads to fully-enclosed or semi-enclosed pedestrian streets; from the spontaneous formation of commercial neighborhoods to multi-functional island-type commercial pedestrian streets; from a single print business installation for shopping, to the comprehensive space using of three-dimensional giant commercial complex underground and on-the-ground; from the ground walking districts to the two-layer planar system of pedestrian overpass business areas and underground commercial streets. Walking provides effective means in the improvement of traffic conditions and renewal of cities. Not only does it reduce all kinds of traffic conflicts, but also it stimulates commercial development and improves the quality of city environmental arts.

The large-scale propulsion of walking system eased the pressure on urban traffic and improved the urban environment, but it also brought some negative impacts inevitably. Firstly, walking system just transferred the motorized traffic to other places instead of eliminating them, thus the ratio of road area increased significantly; then, the pure walking system affected reachability of regions and also weakened commercial performances, especially the attractiveness of the commercial closely- linked motor traffic. In addition, due to the low population density in Europe and the United States, the complete separation of the motor vehicles and walking trails led to a decline in security of the driveway, thus walking trails reduced the diversity of activities and affected vitality of cities.

"The shared streets" is a transportation planning and new topic of designing in Western automotive social ascendant; a qualitative change appeared in handling disputes of walking and motor vehicles. And the con-

cept of separation of people and vehicles gradually replaced by the idea of equal co-existence. People try to find a reasonable planning and designing management measure for all road users to improve the road environment, making the equal co-existence between street walkers and vehicles could be achieved. In that case, all kinds of traffic can live harmoniously; conflicts of pedestrians, cyclists and vehicles will be reduced; meanwhile, business economic benefits are bound to be enhanced. All that means to restore the human scale controlled by traffic situations, rather than restricting traffic to an unacceptable level. Studies from the planning, from areas and reasonable distribution of city's road network should be done to solve mixed problem of traffic and the activities along streets, to maintain a balance of all kinds of traffic.

3. The concept and organization of walkability measurement

Walkability is used to describe the guiding capability the space offers to people, which specifically refers to the spacey adjacency from departure to destination, and extents of convenience and comfort items between those two sites. The factors which affect walkability mainly include the travel distance, walking conditions and walking demands of areas. Only when the destination is within walking distance range, it is possible for people to choose walking trip. Besides, only when the pedestrian conditions are suitable, people are able to adopt walking mode, such as the design of streets, which consists of streets density, scale, and intersection of the organization, etc. In addition, regional population size, such as its density, is also a crucial element on walkability.

In regard to the concept of "Walkability Measurement", American researchers came up with idea of "Walk Score" based on daily facility layout. It grants parameters to suitable walking degrees, which has extensively employed in the United States, Canada, Australia, New Zealand and other countries.

This paper focuses on the measurement of the main urban zone's educational public service facilities in Wuhan City and integrates the factors of transport , population and land use . The first step is to weigh and confirm the walking demands in accordance with the population density distribution of grades; secondly, according to walking distance and decay rates of walking conditions, the author makes overlay calculations towards walking needs, so as to obtain the walkability index of educational service facilities.

$$E_{walk} = P * D_a * I_a * R_a$$

E_{walk} is the result of the comprehensive evaluation. P is the grades og the population density distribution. D_a is the attenuation rate of walking distances. I_a is the attenuation rate of Intersection density. R_a is the attenuation rate of Road density.

The technical routes are shown in Figure 1.

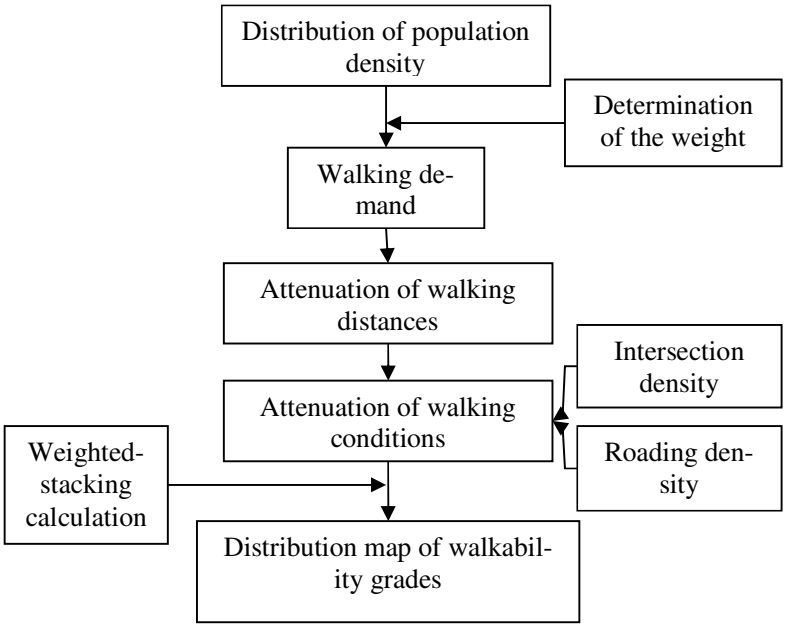

Fig. 1. The technical route map of walkability measurement on educational public service facilities (by the author)

The detailed steps are as follows: (1) sorting out the collected relating factors, and utilizing existing vector data by editing or format conversing; (2) leading the classified figures into ArcGIS9.3 respectively and establishing the data layer. As to those factors need a buffer zone, operating them by using "multiple ring buffer" tools, and giving assignments for each level of buffer class; (3) rasterizing each factor evaluation grade map; (4) doing weighted-stacking analysis of each sub-factor data according to their respective weights, getting a comprehensive evaluation map and giving the

reclassification by “Natural Break” method, then the divided five classes represent the walking suitability degrees of educational public service facilities (from high to low).

4. Case study

4.1. Study area and data

The city of Wuhan, located in the central hinterland of China, the intersection point between Yangtze River and Han River, is the capital of Hubei Province and acts as a significant transportation hub. It has a usual fame for the "the thoroughfare of nine provinces". Geographically, it is situated at 113°41′-115°05′East Longitude and 29°58′-31°22′North Latitude. The four composed directions are---the eastern end: Mountain General, Liuhe Township of Xinzhou District; the western end: Yaowan Village, Chenggong Township of Caidian District; the southern end: Lliujunbu Village, Husi Township of Jiangxiia District; the northern end: Xiaduanjiatian Village, Caidian Township of Huangpi District. In the Cartesian coordinate plane, Wuhan City has the maximum transverse distance of 134 km and the longitudinal distance of about 155 km, the Yangtze River and Han River vertically also horizontally intersect through the downtown, forming the Tri-Cities Separation pattern of Wuchang, Hankou, Hanyang.

The total number of existing educational public service facilities in main urban zone is 2294, including preschool education, primary education, junior secondary education, secondary education, adult higher education, technical school education, regular higher education, special education, occupation school education, technical training, high school education, etc, and the location of whom are mainly in the old city districts of Hankou and Wuchang, as shown in Figure 2.

The data in this article comes from Wuhan City Planning Information Center , and it includes the distribution of educational public service facilities in Wuhan , the distribution of population in the main urban zones of Wuhan and the road traffic system of the main urban zones .

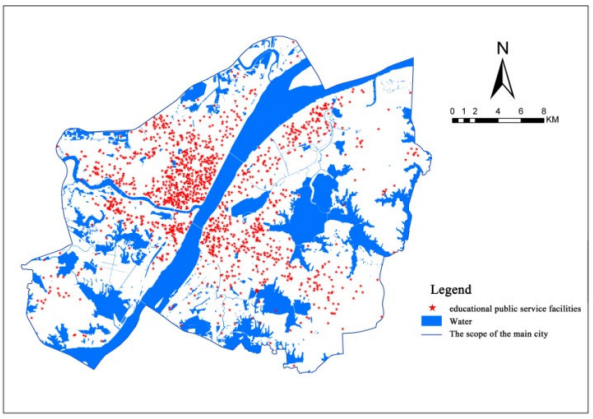

Fig. 2. The distribution of Wuhan municipal educational public service facilities

4.2. The distribution of pedestrian demands

The core of walkability measurement is human, in that human determines whether to walk or not, so the size of population distribution should be the priority to the measurement of walkability. In the evaluation, the population size is larger, the demand for walking is stronger; while the area with a smaller population has less demand for walking. In conclusion, the regional population distribution should be the precondition of walkability measurement for public service facilities. Furthermore, the attenuation of walking distances and pedestrian conditions should be set up based on distribution of walking demands.

This paper adopts a simple sort encoding method, which divides the population density into five levels; and next distributes them in accordance with the natural number sequence from large to small, respectively 9, 8, 7, 6, 5, and then normalizes and determines the weights finally. According to the distribution of population density in Wuhan, the five grades (low, moderate, general, high and higher) are categorized. The initial weights of different partitions are not the same, in the context of educational public service facilities. As shown in Figure 3.

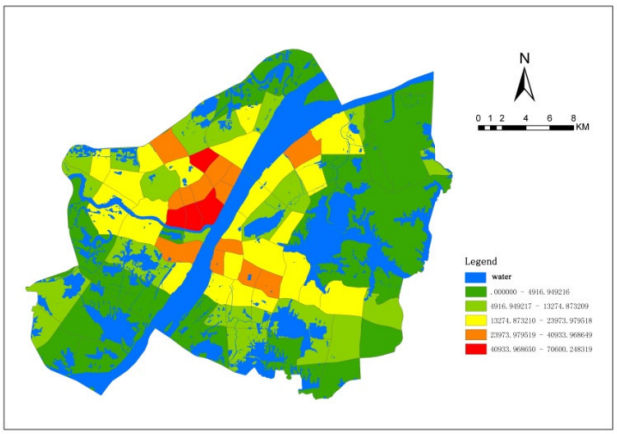

Fig. 3. The distribution of Wuhan municipal population density in main urban zone

Chart 1. The distribution of Wuhan municipal population density in main urban zone

Population density divided district	Population Density (people / sq km)	Sort coding	Weights
Low	0~4917	5	0.14
Moderate	4917~13275	6	0.17
General	13275~23874	7	0.20
High	23874~40934	8	0.23
Higher	40934~70601	9	0.26

4.3. The attenuation of walking distances

Distances Attenuation Rule refers to regular attenuations with the increased distances from starting point to destination place. According to the standard of walking speed (5km/ hour), people can arrive at the range of 0.4km in 5 minutes. Analogously, the 1.6km range in 20 minutes, the range of 2.5km in 30 minutes. The rule, which reveals the fact that the increases of distances and walking time is inversely proportional to the declined demands for walking, can be the guideline of establishing an attenuation curve of walking demands. When the distance between facility and starting point is within 0.4km(namely, 5 minutes time-cost) , the distance decay will not occur ; when the distance is more than 0.4km, a dramatic

decay. When the distance is within 1.6km, the attenuation rate is 50%; when the distance continues to increases, attenuation speed slows down. Until the distance is 1.6~2.5km, the attenuation rate is close to 1 with 30-minutes walking time, and this paper reads value of 90%. In other words, if the distance from starting point to destination place goes beyond 2.5km, there exists almost no influence upon walking index. In terms of the calculation of superposition, educational public service facilities layout diagrams and the open road network maps go first, and attenuating weights based on the attenuation rule of the periphery facility distance within the range of 2.5km, and then a fundamental walking index can be gained, as shown in Figure 4.

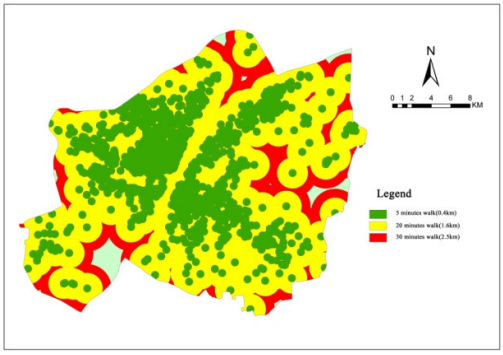

Fig. 4. BUFF analysis chart of educational public service facilities within walking distance

Chart 2. The comparison table of walking distances attenuation

The walking Time (minutes)	Walking distance (km)	Attenuation rate (%)
5	0.4	0
20	1.6	50
30	2.5	90

4.4. The attenuation of pedestrian conditions

Pedestrian conditions attenuation mainly refers to the pedestrian demanding degrees affected by unsuitable pedestrian condition factors. The street length, intersection form, intersection number, pedestrian bridges and underground tunnels, street interface design ,street density and so on ,are all

included in pedestrian conditions. This paper mainly extracts two indexes of road and intersection density to evaluate pedestrian conditions as well as establishes the attenuation rule. First of all, building 1000*1000m square grids in the main urban areas; and then counting road and intersection density of each grid combined with the road system, as shown in Figure 5. The intimate relationship between road & intersection density and walkability presents a proportion: the higher road density, the better walkability; likewise, the higher intersection density, the better walkability as well. In 1000*1000m square grids, the higher road density reflects more advanced pedestrian road facilities and better road accessibility. Meanwhile, the higher road intersection illustrates the stronger road dredging performance. Thus, the shorter road and space distances of two paths, then the better accessibility road will possess.

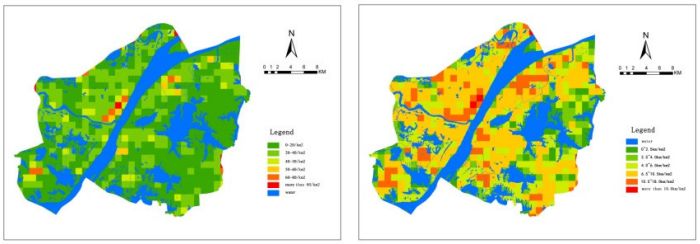

Fig. 5. the grade distribution of road & intersection density

Chart 3. the comparison table of intersection density and street length attenuation.

Intersection density (/ km^2)	Attenuation rate (%)	Road density(km/ km^2)	Attenuation rate (%)
≥80	0	≥18.0	0
60~80	1	10.5~18.0	1
50~60	2	6.5~10.5	2
40~50	3	4.0~6.5	3
20~40	4	2.5~4.0	4
≤20	5	≤2.5	5

4.5. Comprehensive evaluation

The conclusion was drawn on Wuhan Municipal walkability measurement of educational public service facilities. The five-grade levels respectively

are: high-reliance on cars, low-reliance, general, suitable, very suitable (as shown in Figure 6.)Those are analyzed according to prepared procedures : the initial weights distribution are acquired to the distribution of population density accordingly ; on the basis of that , making integrated superposition calculation analysis combined with walking distance attenuation, road traffic and intersection density attenuation ; then reclassifying them by employing the "Natural Break" method. All above are on the factual basis of Wuhan City. From the chart we can find that those educational public service facilities are relatively concentrated, resulting in concentrated district-blocks whose walkability measurements of facilities are originally good. They respectively are Wuluo Road and its alongsides in Wuchang District, Wuhan Zoo peripheral in Hanyang District and Jianghan District. By contrast, areas with poor walkability measurement are neighboring to the East Lake, Jiangxia District and Hanyang District. Apparently, these areas should be appropriately arranged some educational public service facilities, in order to enhance their regional level walkability.

The scale of regional car-dependent land is 346.7 square kilometers, accounting for 50% of the total main urban lands ; the scale of regional land with poorer walkability is 129.6 square kilometers, which occupies 19%; regions with general walkability have land scale of 58.8 square kilometers, 8% of the total land in urban area; the land scale of regions suitable for pedestrian is 142.0 square kilometers, taking up 20% of the total; the suit-best land area is 17.4 square kilometers, a 3% -occupation of all lands. As a whole, areas with educational public service facilities which is suitable for pedestrian in Wuhan account for 30% of the total lands.

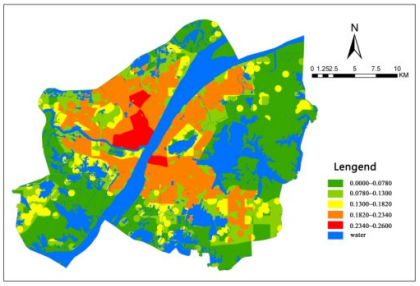

Fig. 6. the grade distribution on walkablity of educational public service facilities

Chart 4. The evaluation of walk measurement.

coulor	Detail	Land area (square kilometers)
red	best	17.4
Orange	better	142.0
yellow	common	58.8
Light green	Poor	129.6
Dark green	car-dependent	346.7

5. Conclusion

Walking index mainly reflects the rationality of daily facility configuration within certain walking distance, which was indentified as one of the basis of the efficiency evaluation of urban daily facility configuration. Walkability measurement was born with the concept of "Smart Growth", " Low Carbon City" and it aims at highlighting the sustainable development and environmental protection as well as enabling the city's social benefits. The relevant researches in developed countries are already quite mature while China is still in practice and exploration stage. This is inseparable from China's national conditions---China is still in the primary stage of socialism, the productivity level and concerns on walking way are not enough. When comparing the car possessing capacity, there were already 200 million in America as early as in many years ago while China has just exceeded 100 million which is actually limited.

There were some deficiencies existing in this study. For instance, it has not made classifications for the weights of educational public service facilities, because the walking demand of each educational public service facility is certainly different. In the meantime, walking measurement itself exits some shortages, such as less considered pedestrians' subjective feelings and needs; the failure to fully reflect the walkability, especially it cannot well satisfy the needs for comfort required by walkability. Hence, how to fully reflect the effects of both subjective and objective factors is a significant direction to promote and perfect the measurement of walkability in future.

References

Lu Yintao, Wang De (2012) Walkability Measuring in America and Its Enlightenment. J International Urban Planning,27(1):10-14.

Li Huaimin (2007) From "Pedestrian Venice "to" One Square Mile Map"—A Probe into the Feasibility of Urban Pedestrian Network . J Planners, 23(4):21-26.

Dai Desheng, Yao Di (2010) Research on Strategies for Walking Under Context of Global Pedestrian Culture :a Case Study on Zurich .J Urban planning , 34 (8): 48-55.

HAN Yan-hong, LU Yu-qi (2012) Accessibility Assessment and Planning of Public Service Facilities for Education: A Case Study on Senior High Schools in Yizheng City. J Scientia Geographica Sinica.

LU Hua-pu , ZHANG Yong-bo, LIU Qing-nan (2009) A Methodology for Urban Pedestrian System Planning. J Urban Transport of China 7(6):53-58.

Ko Ko Lwin ,Yuji Murayama (2011) Modeling of urban green space walkability: Eco-friendly walk score calculator. J Computers, Environment and Urban Systems 35:408–420.

Fabíola Stollar, Joaquim C.Rodrigues a (2012) Six minute walk test Z score: Correlations with cystic fibrosis severity markers. J Journal of Cystic Fibrosis 11:253–256.

Walk Score Methodology [EB/OL].(2010-12-17).http://blog. Walkscore.com/research/.

Ritsema van Eck J R (1999) Accessibility analysis and spatial competition effects in the context of GIS—supported service location planning .J Computers, Environment and Urban Systems, 23(2): 75-89.

Jong T de , Ritsema van Eck J R, Toppen F (1991) GIS as a tool for locating service centers. J Utrecht: EGIS Foundation 509-519.

Saelens B E,J F Sallis ,L D Frank (2003) Environmental Correlates of Walking and Cycling: Findings from the Transportation ,Urban Design ,and Planning Literature. J Annals of Behavioral Medicine 25(2):80-91.

[12]Wood L, L D Frank , B Giles-Corti (2010) Sense of Community and Its Relationship with Walking and Neighborhood Design. J Social Science and Medicine 70(9):1381-1390.

Hansen W G (1959) How accessibility shapes land-use. J Journal of the American Institute of Planners 25:73-76.

Ritsema van Eck J R (1999) Accessibility analysis and spatial competition effects in the context of GIS—supported service location planning .J Computers, Environment and Urban Systems 23(2):75-89.

Knox P L (1979) the accessibility of primary care to urban patients: a geographical analysis .J Journal of the Royal College of General Practitioners 29(200):160-168.

Martin D, Williams H C W L (1992) Market-area analysis and accessibility to primary health-care centres .J Environment and Planning A 24(7):1009-1019.

Zou Fang□2009□A Quantity Evaluation of Middle School Planning——with Wuchang as An Example. J Chinese & Overseas Architecture 11□46-48.