Study on Evaluation Indexes for Walking Network

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ABSTRACT

Firstly, the paper analyses the definition and composition of walking network. And then based on the characteristics of walking, accessibility is chosen as an evaluation index for walking network and Cumulative opportunity model as a method to calculate the accessibility. Finally, taking the area within Erhuan Roads in Jinan as an example, the accessibility of public service opportunity based on walking networks before and after pedestrian crossing facilities planning are calculated respectively. Based on the comparison of calculation results, the effect of pedestrian facilities on walking network is evaluated, and the accessibility serving as an evaluation index is proved practical and applicable. The study will provide support for urban road network improvement, walking network refinement and walking-friendly community building.\(^1\)

INTRODUCTION

Walking is the most basic and green traffic mode, which plays an indispensable role in the urban comprehensive transportation system and also an important role in the urban sustainable development. With the rapid development of urbanization, city is faced with the increasingly serious traffic congestion and the resulted energy and environment crisis, and people become to pay more and more attention to this traffic mode. Therefore, the situation that walking was ignored is reversed, and urban planners begin to put more emphasis on the construction of walking facilities and transformation of walking environment. Walking network is the carrier of walking mode, of which the planning and construction plays a key role in the revival of walking.

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Therefore, how to define walking network and what evaluation index to use, are the first two questions to answer. This paper firstly analyses the definition and composition of walking network, and chooses accessibility as the evaluation index, then the definition, calculation and application of this index are researched.

THE DEFINITION OF WALKING NETWORK

Walking network contains sidewalks, crosswalk, elevated pedestrian crossing, pedestrian street and greenway, etc. The topology, connectivity and accessibility are not the same as that of urban road network. In this paper the method is provided with which walking network is created from urban road network to reflect the true network connectivity for analysis: There are central median on Arterial, and therefore sidewalks can only be connected at intersection pedestrian crossing or mid-block crosswalk. And this kind of sidewalks is separated two-way pedestrian links with crossing as their connector. Branch road’s width is less than 30m, and uses double amber lines or single solid line to separate driveway. Pedestrian can cross the driveway to the other side at any position along the road, and so it is believed that sidewalks on both sides are connected along the way, and can be abstracted into a two-way link. In addition, at the intersection between arterial and branch road where traffic organization uses “right-in and right-out” principle, sidewalks on branch road cannot be connected to the other side of sidewalk on the arterial.

With the above-mentioned method, the urban road network in figure 1 can be abstracted into walking network in figure 2, added with pedestrian street, greenway and crossing facilities, which can be complete walking network.

Figure 1. Urban road network. Figure 2. Walking network based on urban road network.
EVALUATION INDEX OF WALKING NETWORK

Evaluation Index

Urban road is the carrier of many traffic modes, which emphasis the utility of motility and accessibility. According to Evaluation Indexes of Urban Transportation Management(2008) [1], the evaluation indexes for urban road network usually contains density, road area proportion and road area per person.

While walking network is exclusive to pedestrian, which have low requirements for width and area, but high for distance and environments. Accessibility is suggested to be evaluation index for walking network because accessibility measures the difficulty that people travel from origin to destination, which is closely related to transportation facilities provision and land use and reflects their integration [2].

The interaction between walking and land use is closer than any other modes, and its effect on walking is obvious. For example, high accessibility means people can easily fulfill their trip by walk, or the high possibility of obtaining more service (job, education, entertainment, shopping, health care etc.) within walkable distance. The more accessible the walking network, the more attractive the walk mode, and therefore the more efficient the walking network.

Calculating Method

Accessibility has been defined by many researchers and calculating method is given respectively, such as space separation model, spatial interaction model, accumulative opportunity model [2].

Accumulative opportunity model defines accessibility is the number of service that person gets in a given distance from trip origin using one traffic mode. Within the given time or fare thresholds, the amount of service is summed:

\[ A_i = \sum_j O_{j, \tau} \]

\( \tau \) is pre-defined fare threshold; \( O_{j, \tau} \) is number of service in zone \( j \); \( j \) is the Zone whose impedance to zone \( i \) is less than \( \tau \)[2].

The implication of this model is in accordance with the evaluation mentioned above, and relating data is easily to obtain, so the accumulative opportunity model is used to calculated accessibility. Accessibility can reflect the relationship between traffic network and land use, and the walking environment, which be in conformity with the principle that evaluation index must be independent, comprehensive and objective. In the following section accessibility is validated to see whether it can meet the need that evaluation index must be operative and sensitive by Jinan example.
EXAMPLE

Taking Erhuan area in Jinan as an example the accessibility of walking networks before and after crossing walk planning for service opportunity of land use of A and B kind to evaluate the planning and validated the adaptability of accessibility as evaluation index.

Computing Process

Step 1 Divide zone
Area within Erhuan is divided into many square zones. The size of zone is fixed as such follows: the minimum walking time is 5min, then distance is 300m. The trip distance within zone whose area is S is square root of S. To make sure that most of walking trip will pass through 2 zones at least, the zone should not be bigger than 300m*300m. then there are 1775 zones in Erhuan area.

Step 2 Choose parameter
According to accumulative opportunity model, two parameters, fare and opportunity, need to be defined. To simplify calculation, walking distance is fare and area of land is opportunity.

Step 3 calculate opportunity matrix
Opportunity matrixes are calculated for land use respectively:

\[ C_i = (c_{ij})_{i \times 1775} \]  \hspace{1cm} (2)

Where:
- \( C_i \) — the matrix of land use of the i th in A and B kind, actually column vector;
- \( c_{ij} \) —— sum of area of land use of the ith in A and B kind at zone j.

Step 4 Fare threshold
Trip Investigation Report of Jinan in 2013[3]shows that 80% of walking trip time is less than 25min, and walking speed assumed 1m/s, with intersection delay neglected, the corresponding walking distance is 1500m, then fare threshold is 1500m.

Step 5 Create walking network
In accordance with the definition of walking network, based on urban road network, the walking networks before and after crossing walk planning within Erhuan area are created.
Step 6 Calculate impedance matrix
Using “multiple shortest path” command line in Transcad[4], the walking distance matrix $R_1$ and $R_2$ of walking network before and after crossing walk planning are calculated respectively. And intrazonal distance is defined as 150m.

Step 7 Calculate accessibility
Taking the walking network before planning as an example, the obtainment of service opportunity in the area for walkers is calculated using the following formula:

$$A_i = R_i \cdot C_i$$  \hspace{1cm} (3)

Where:
$A_i$ —— Calculated accessibility of walking network before planning;
$R_i$ —— impedance matrix of walking network before planning,
$R_i = (r_{ij})_{1775 \times 1775}$, $r_{ij}$ walking distance from zone $i$ to zone $j$ on walking network before planning.

The results are as follows:

Figure 3. Walking network (before planning).
Figure 4. Accessibility of administrative land use.

Figure 5. Accessibility of commercial and financial land use.
Figure 6. Accessibility of cultural land use.
Figure 7. Accessibility of sports land use.
The accessibility of walking network after crossing walk planning can also be calculated by the same method.

**Results Analysis**

Firstly, taking the accessibility of walking network before crossing walk planning, it is showed that the kinds of land use which have relatively high accessibility are commercial and financial, entertainment, sports and cultural, while low when the kinds of land use are official, administrative and for research. It is because of not only the density of network but also the intensity and diversity of land use. So, it is obvious that accessibility is suitable to evaluate the coordination between walking network and land use, which can be used to guide the optimization of road network and land use planning.

Secondly, by testing whether the accessibility of walking network is improved significantly after crossing walk planning, the effect of planned crossing walk is evaluated. T-test is used in this paper, and there is the hypothesis as follows:
H0: $\mu_1 = \mu_2$ the accessibility of walking network has not been improved significantly after planning.

H1: $\mu_2 > \mu_1$ the accessibility of walking network has been improved significantly after planning.

Where

$\mu_1$ —— the averaged accessibility of walking network before crossing walk planning to the land use of one kind;

$\mu_2$ —— the averaged accessibility of walking network after crossing walk planning to the land use of one kind.

<table>
<thead>
<tr>
<th>Landuse</th>
<th>A1</th>
<th>B1</th>
<th>A2</th>
<th>A4</th>
<th>A5</th>
<th>A3</th>
<th>A7</th>
<th>A35</th>
<th>B2</th>
<th>B3</th>
<th>A6</th>
</tr>
</thead>
<tbody>
<tr>
<td>statistic quantity of $\mu$</td>
<td>$2.320$</td>
<td>$3.348$</td>
<td>$2.071$</td>
<td>$2.641$</td>
<td>$2.021$</td>
<td>$2.955$</td>
<td>$0.828$</td>
<td>$1.222$</td>
<td>$0.912$</td>
<td>$1.600$</td>
<td>$1.714$</td>
</tr>
</tbody>
</table>

Under high significance level, accessibility has been improved significantly after planning, which can prove that the planning can improve the walking network and make walking attractive. It reflects that accessibility is sensitive to changes of walking network and simple to use, which is suitable to be evaluation index.

CONCLUSIONS

Walking network is the carrier of walking mode whose service level have an critical effect on development of walking. This paper tries to answer the question of evaluating walking network service, and points out that accessibility is suitable for evaluation with accumulative model as its calculating method. Example of Erhuan area in Jinan is taken, in which the accessibility before and after crossing walk planning is calculated and compared. The accessibility after planning has been improved significantly, therefore the practicability, sensitiveness and operationality of accessibility as evaluation index is proved. The research conclusion will provide guidance for improvement and construction of walking facility and walkable community.
Next, the impedance of the model will contain qualitative influencing factors such as quality of walking environment and feelings about walking. And attracting points such as transit hub and open space will be concluded as service opportunity, which can make the accessibility more comprehensive and objective.

REFERENCES