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Research on Evaluation Methods of Network of Bicycle System in Historic Districts--Taking Xi'an City Wall of Ming Dynasty as Example

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Abstract. Under current transport conditions with high level of mechanization, traffic pressure increases rapidly which leads to low traffic efficiency and low resident travel efficiency. Especially for historic districts which located in the downtown areas with high intensity of land development and scarce land resources, main roads and minor roads are always under congestion and traffic delays on by-passes are caused by road occupation by motor vehicles. As a kind of environment-friendly, green and convenient public transportation, bicycles can relieve traffic jams effectively, improve environment quality and traffic efficiency and connect scenic spots. Based on investigations, this thesis demonstrates current situations of bicycle transportation system in quarter of City Wall of Ming dynasty, establishes networks assessment target system in accordance with related rules and builds analysis model with AHP Comprehensive Evaluation. In result, this thesis provides referential evidences for evaluation on making and implementation effectiveness of bicycle transportation system designs and plans in historic districts.

Current Situations of Bicycle-Riding Environment in District of City Wall of Ming Dynasty

Being the center of historic cultural city, the quarter of City Wall dynasty has always been the political, economic and cultural center of Xi'an shouldering most functions[1].Generating from ancient city road structure, the structure of road network belongs to grid road system generally. The road network density of the quarter of City Wall of Ming dynasty is high. However, there are not enough truck roads and minor roads but excessive by-passes. With low accessibility of the road network, there are plenty of "dead end roads" or narrow roads of the by-passes, which is not convenient for motor vehicle transportation. Traffic volume of the quarter of City Wall of Ming dynasty is 630.2 thousand every day. The main sections of relating roads of the gates are at capacity

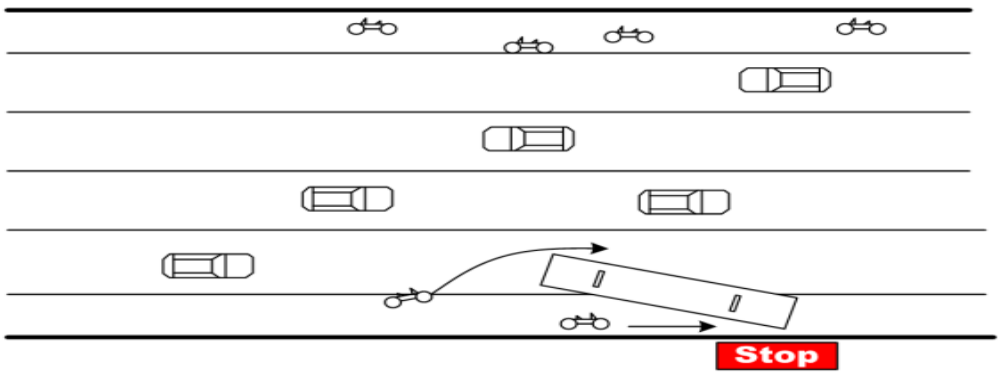

Figure 1. Diagram of bus-parking on bicycle lanes

or almost at capacity, with horrible traffic jam. Besides, the main trunk roads in the quarter are almost at capacity with car speed of 12.4 km/hour on rush hour. At present, there are two kinds of

bicycle layout in the quarter of City Wall of Ming dynasty: non-motored lanes and lanes of motored and non-motored vehicles. The environment of bicycle-riding is not promising and shall be improved. Street parking of motored is a serious problem which influences the continuity and safety of bicycle-riding to some extent. In the quarter of City Wall of Ming dynasty, regardless of types of roads, it is frequent that bus parking on the bicycle lanes. The way of setting bus stops has vital impacts on bicycle rider ad passengers from bus. As is shown as Fig. 1. Generally speaking, the number of bicycle parking is still small. In addition, most parking space is easily surrounded with iron fences or ropes. Besides, the outstanding problem is the difficult of parking and missing.

Evaluation System of Bicycle Transportation Networks in the Quarter of City Wall of Ming dynasty

Evaluation Standard. Bicycle transportation system in the quarter of City Wall of Ming dynasty can not only provides convenience for tourists, but also can help fulfilling demands of urban residents for communication. At the same time, it is an important action of protecting cultural relics of Ming dynasty and surrounding environment. So the evaluation standards can be classified as followings: Standard A: Play the tourism function of the City Wall of Ming dynasty in act comprehensively and enrich tourism contents for tourists; Standard B: Provide convenience for daily communication of residents and relief traffic jam; Standard C: Advocate bicycle-riding to improve city environment; Standard D: Collective function quality of locations of bicycle lanes; Standard E: Integrated city plan to promote implementation.

Establishment of Plan Evaluation and Selection Index. Index selection. Through the research on general thoughts on plans of bicycle lane home and abroad and purposes of implementation and careful thoughts on organization and develop future of the quarter of City Wall of Ming dynasty in Xi'an, the evaluation indexes adopted are as followings in Table 1.

Table 1 Analysis of evaluation index system

Evaluation subsystem	Evaluation Index	Character of index	Index types
A Play the tourism function of the City Wall of Ming dynasty in act comprehensively and enrich tourism contents for tourists	A1[Coverage of scenic spots in bicycle networks]	quantitative index	Positive
	A2[Conditions lane views]	quantitative index	Positive
B Provide convenience for daily communication of residents and relief traffic jam	B1[Coverage of land in bicycle networks]	quantitative index	Moderate
	B2Increasing rate of communication]	quantitative index	Positive
C Advocate bicycle-riding to improve city environment	C1[Ratio of main road to minor road]	quantitative index	Positive
D Collective function quality of locations of bicycle lanes	D1[Connectivity of bicycle networks]	quantitative index	Moderate
	D2[Complexity coefficient of crosses	quantitative index	Negative
	D3[Average capacity of bicycle networks]	quantitative index	Moderate
E Integrated city plan to promote implementation	E1[Coordination of bicycle lane and traffic organization]	quantitative index	Positive

Definitions of Index. Spots coverage rate of lines distribution network of bicycles. Definition: Spots coverage rate of lines distribution network of bicycles is the ratio of the sites involved in the influential area of lines distribution network of bicycles to all the sites in the occupied area. It is used to reflect the rationality of lines distribution network and whether satisfy the tourist functions or not. The higher spots coverage rate of lines distribution network of bicycles is, the more sites

tourists can arrive through bicycles lines, the more perfect the tour functionality of lines distribution network of bicycle is.

Computational method: According to the different categories, compute the ratio of spots weighing value of both sides within 300 meters of lines distribution network of bicycles to that of all the sites.

The land coverage rate of lane distribution network of bicycles. Definition: The land coverage rate of lane distribution network of bicycles is the ratio of urban land use area served for lane distribution network of bicycles to regional area. The coverage rate of lane distribution network of bicycles is used to reflect the residents' mobility brought by bicycles system. Computational method:

$$\delta = \sum_i a_i / A \tag{1}$$

In this equation: δ——the land coverage rate of lane distribution network of bicycles; ai——the both sides' land use area of Road i within 300 meters of lines distribution network of bicycles; A——total land use area of City Wall of Ming dynasty

The average saturation of lane distribution network of bicycles. Definition: The average saturation of lane distribution network of bicycles refers to the average ratio of bicycle flow in every road segment of lane distribution network of bicycles to set design traffic capacity. The average saturation of lane distribution network of bicycles is an indicator to measure uniformity of bicycle flow distribution in lane distribution network of bicycles. It is also an indicator to reflect the operation efficiency of bicycle lane system. Computational method:

$$s = \sum_i V_i / \sum_i C_i \tag{2}$$

In this equation: s——the average saturation of lane distribution network of bicycles; Vi——forecasting traffic volume of Road i in lane distribution network of bicycles; Ci——design traffic capacity of Road i in lane distribution network of bicycles.

Connectivity of lane distribution network of bicycles. Definition: Connectivity of lane distribution network of bicycles refers to the ratio of the number of edges adjoined by nodes in line distribution network of bicycles to the number of all edges. It reflects maturity of a network. The bigger the ratio is, the less the break road sections are, the higher the rate of cycle-forming and network-forming is. On the contrary, the rate of network-forming is lower. Computational method:

$$J = 2M / N \tag{3}$$

In this equation: J——connectivity of lane distribution network of bicycles; N——total nodes of lane distribution network of bicycles; M——total number of edges (number of road sections) of lane distribution network of bicycles.

It is worth noting that this indicator reflects its maturity just from an overall point of view. As for specific intersection, it is not better to link up more edges in that the more edges are linked up, the more complicated the intersections are, the more difficult traffic organization is.

Complexity coefficient of average traffic operation in intersections.Definition: Complexity coefficient of average traffic operation in intersections refers to the average of complexity of traffic management in intersections of lane distribution network of bicycles. It reflects the convenience and safety of traffic operation in intersections and avoids partial trouble affecting the whole net operation efficiency. Computational method:

$$K = \sum_j K_j \tag{4}$$

In this equation: K——complexity coefficient of average traffic operation in intersections; Kj——complexity coefficient of average traffic operation in Intersections j. The ratio is relevant to conflict form and angle of traffic stream. After analyzing complexity of traffic operation in intersections, it can be seen that complexity of bicycle traffic operation is mainly limited by intersection mode (crossroads, T-junctions and annulus) and intersection degree (main roads, minor road and slip roads).

The increase of communication. Definition: The increase of communication refers to the number of locations covered by lane distribution network of bicycles which promote communications among bicycle lane users. Firstly, bicycle lanes distribution networks connect the locations where hold various public activities, squares, transportation junctions and city parks which help increase the communication among bicycles users and other residents, encourage residents to adopt bicycle as soon as possible in certain sense and alleviate traffic pressure. Secondly, if simply evaluate the increased number of the quarter of City Wall of Ming dynasty's tourists; it is possible that the increased tourists are just passers-by. Taking the opportunity of visitation, we should not only treat tourists as guests, but form a participant mechanism in order to allow tourists actively participate in public activities such as performance and rally, thus enhancing the attraction of Xi an towards domestic and overseas tourists. We hope that lane distribution network of bicycles can pass by the locations where hold various public activities, squares, transportation junctions and city parks in order to increase communication among residents. Computational method: number of the locations where hold various public activities, squares, transportation junctions and city parks within 300 meters of the surrounding bicycle line.

Road landscape conditions. Definition: Landscape status of the road that lane distribution network of bicycles passes by and the possibility of further transformation. Tour-functioned bicycle lanes aim to explore tourism of Xi an in a better way and improve the operation environment of bicycle to appeal more bicycle users. Therefore, its road landscape conditions play an essential role. Computational method: According to landscape status of the road that lane distribution network of bicycles passes by and the possibility of further transformation, and combined with grading scores towards landscape status of the each road section by evaluation of users' mental factors, final overall average is regarded as the index value of designed road landscape conditions.

Coordination with traffic planning. Definition: The coordination of bicycle lanes of the road section and its traffic planning. After investigating the coordination of bicycle lanes of the road section and its traffic planning, redundant construction could be avoided, thus prompting coordination of set bicycle lanes and traffic planning within the quarter of City Wall of Ming dynasty. Computational method: From the perspectives of designed width of boundary line, planning grades and setup of designed bicycle lanes, the coordination of bicycle lanes of the road section and its traffic planning qualitatively analyzes the road and give grading scores. Finally, the average score of every road sections' is regarded as the index value.

The proportion of main and minor roads. Definition: The share of main and minor roads among all the roads that bicycle lanes pass by. The indicator shows the environment-protecting ability after advertising bicycle lanes and advocating people using bicycle. Computational method: The mileage ratio of main and minor roads that bicycle lanes pass by to all the bicycle roads.

General Plan Evaluation. Bicycle transportation is considered an important service for the tourists and urban residents in the quarter of City Walls of Ming Dynasty. As it is both multiobjective and multifunctional with multiple variation, it is difficult to assess the alternatives or to assign the sequence of priority only by means of quantitative analysis or logical judgment. However, by quantifying the quantitative analysis, comparing the relative important degree of each one of the evaluated index with scale of assessment, analytical hierarchy process makes it possible to sort the alternatives through and provide references for the final decision. [5]

The AHP method serves as an effective way of determining the index weigh. Amid the evaluation process, analytical hierarchy process is combined with consultations of experts to determine the weight of the system and the index in order that an objective and reasonable distribution of weigh is in position. The determination of weigh is essential to the comparison and assessment of the alternatives, therefore the analyzing process shall be conducted cautiously. [6]

According to the combination of analysis with the consultations of experts and computation of the analytical hierarchy process, the determination of the evaluating index weigh is listed in Table 2 as follows:

Table 2 The distribution network of the evaluating index weigh

Subsystem	Weigh of Subsystem	Evaluating Index	Index Weigh
A.To sufficiently bring the function of tourism and leisure of the quarter of the City Walls of Ming dynasty and to enrich the point of sightseeing	0.2	A1 The coverage of cycle track linear network	0.71
		A2 Conditions of road landscapes	0.29
B To meet urban residents' need to commute by bicycle, and alleviate the traffic tension	0.16	B1The coverage of site of cycle track linear network	0.58
		B2 The increasing of communication	0.42
C To advocate commuting by bicycle to improve urban environment	0.08	C1 The proportion of primary to secondary trunk road	1
D Good performance in general of cycle track scheme	0.4	D1 The connection degree of bicycle linear network	0.32
		D2 The complexity coefficient in general of intersections	0.27
		D3 The average saturation of cycle track linear network	0.41
E In accordance with city planning to promote the implementation	0.16	E1 The coordination of cycle track with transportation planning	1

Comprehensive evaluation method of network. The structure of bicycle network of the quarter of City Wall of Ming dynasty is a complex system which involves many other aspects of cultural life in a city. The evaluation is no doubt a multilevel and multivariable problem. Multi-index evaluation method is to transfer several statistical indexes describing subject that belong to different aspects and different dimensions into non-dimensional evaluation values and generalize these values to establish a evaluation system of the object. At present, there are many multi-indexes evaluation methods adopting Generalized Indicator Functions. In addition, the calculation steps are: on the base of calculation of rating index of each evaluation index and index weight of the system, Generalized Indicator Functions is adopted to calculate the generalized utility values of different networks. The formulas are as followings: Eq.5 the grade of each subsystem Ui:

$$U_i = \sum W_{ij}(1) \times f_{ij} \tag{5}$$

In which: $W_{ij}(1)$ ——representing the first subsystem the jth index wright f_{ij} ——represents the weight of corresponding index

Eq.6 the grade of whole system U:

$$U = \sum W_i(B) \times u_i \tag{6}$$

In which: $W_i\ (B)$ ——represents the weight of subsystem i; u_i ——representing grade of corresponding subsystem. The size of U is taken as the base of the ranking and selection of network plan.

Conclusion

Based on the investigation of bicycle system in the quarter of City Wall of Ming dynasty in Xi'an City, this thesis concludes the current situation of bicycle transportation system and establishes a networks evaluation index system with a analysis model using AHP Comprehensive Evaluation System, a structure that can be modified according to different regional characters in the future. AHP is relating to the professional qualities of decision-makers and the determination method can be further discussed. An environmental-friendly bicycle transportation system can be

helpful in improving environment, history inheritance and sustainable development of historic districts. Research results of this thesis provide referential evidences for evaluation on making and implementation of bicycle transportation system plan in historic districts.

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