Rural Road Network Layout Based on FCM Clustering Algorithm and Traffic Location Method

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ABSTRACT

Rural road networks, together with national and provincial road networks constitute a complete road network system. It is widely distributed, covering most parts of the rural areas. Road network layout is a core part of the road network planning system; its rationality and feasibility directly impact the success of road network planning. Based on the characteristics and research of rural road network layout, a method combines FCM (Fuzzy C-Means) clustering algorithm and traffic location method. The validity of the method is tested through an application example.

1. INTRODUCTION

Rural road network is an important part of the road network system. It promotes the development of township enterprises and the prosperity of rural economics. Besides, the coordinated development of the national road network construction can be ensured by a perfect rural road network.

Most of the existing research and methods of rural road network layout is based on main line network planning. The core of it is to expand and optimize line road networks，but it fails to consider the functions, features and clients of rural roads. Based on the specificity of rural road network layout, a method combining FCM clustering algorithm and traffic location method is presented to complete the layout of rural road network.

2. METHODS SURVEY

Directly linking method, four-stage method, FCM clustering algorithm and the traffic location method are mainly methods for road network layout.

Directly linking method is an essentially expert experience method, which is strongly influenced by subjective factors. Using this method, the road network layout is completed by means of limited research and estimates (Dai, 2009).

Successful use of the four-stage method needs lots of preliminary work, and its foundation is through a comprehensive collection of surveyed OD data. Because the function of rural road networks is different from that of national and provincial road networks, its traffic flow is discrete. The OD survey for rural road networks will take

high costs, which greatly reduces the operability of four-stage method (Danyang Statistical Yearbook, 2010).

FCM clustering algorithm is the method which partitions class to the clustered objects as required of thing's characteristics.When determining the nodes' indicators, there is a certain degree of uncertainty and fuzziness about relative information in the process of collecting, describing and processing data, which can be solved by FCM clustering to get the optimal fuzzy partition and clustering of data sets.

Based on economic-oriented, the traffic location method is looking for areas of high incidence of traffic. Because of the uncertainty of potential factors in road network, the method is difficult to be quantified and still needs to be improved.

By analyzing the advantages and disadvantages of current methods, a method combining FCM clustering algorithm and traffic location method is presented. It will complete the rural road network layout based on a "point-line-network" layout idea.

FCM Clustering Algorithm. The conventional FCM partitions the data X = $\{X_1, X_2, \ldots, X_n\}$ into c ($2 \le c \le n$) clusters based on the minimization of quadratic objective function.

$$J(U,V) = \sum_{k=1}^{n}\sum_{i=1}^{c}(\mu_{ik})^m \| x_k - v_i \|^2 \tag{1}$$

Where m is weighting exponent on each fuzzy membership and is usually set as 2. U is a fuzzy partition matrix, V is a cluster matrix, and $\|x_k - v_i\|$ is the Euclidean distance between i-th cluster and the k-th data point. μ_{ik} is the membership value of the k-th data point in the i-th cluster which satisfies the following formulation:

$$\sum_{i=1}^{c}\mu_{ik} = 1 \tag{2}$$

In addition, cluster centers are calculated using the following formulation:

$$v_{ij} = \frac{\sum_{k=1}^{n}\mu_{ik}^m x_{kj}}{\sum_{k=1}^{n}\mu_{ik}^m}(i = 1,2,\cdots,c \ j = 1,2,\cdots,m) \tag{3}$$

Where x is a fuzzy variable describing data point, in essence, fuzzy partitioning is performed through an iterative optimization utilizing the following formulation:

$$u_{ik}(s+1) = \frac{1}{\sum_{j=1}^{c}\left(\frac{d_{ik}(s)}{d_{ij}(s)}\right)^{\frac{2}{m-1}}} \tag{4}$$

Finally, the best available solution within a predefined accuracy criterion is determined by:

$$\| U(r+1) - U(r) \| \le \varepsilon \tag{5}$$

Where ε is error level for the termination of literation, which varies between 0 and 1. In detail, this iterative procedure converges to a local minimum of J. Algorithmically, the FCM clustering algorithm can be achieved through calling the program in Matlab.

Traffic Location Method. Traffic location is the place where transport activities and transport resources congregate. Traffic location method reflects the geometric relation of road network geospatially. It provides a basis for traffic planning, especially long-term road network layout.

Traffic location line is different from the actual existing line (road, railway, etc.); it is represented by some broken lines that connect adjacent node, and it isn't restrained by geomorphic characteristics (Li, 2011).

Based on the concept of Traffic location line, the Traffic location method is applied to settle road network layout. For the sake of qualitative factors in this method, it is difficult to accurately determine how the potential factors will affect road network layout. A method combining quantitative FCM clustering algorithm and qualitative traffic location method could be used to achieve a relatively ideal result.

The main part of the traffic location method is the layout of connecting lines between nodes. Most high-grade nodes are covered by high-grade roads, and so on, for other grades of nodes. Good connection between nodes can be created, and then an effective transport network can be formed. Thus, the road network can function maximally.

3. THE RURAL ROAD NETWORK LAYOUT OF DANYANG CITY

Danyang is located in the south of Jiangsu Province. Its traffic mileage has already exceeded 2084 kilometers at the end of 2011, including 297 kilometers of county road and 689 kilometers of village road.

There are some insignificances of Danyang City rural road network:

(1)The amount of rural roads is low, and most of them are low-grade roads.

(2)The basic skeleton of rural road networks have been formed, but the ring-radial structure is not yet fully accomplished. The connectivity and accessibility of the rural road networks need to be improved so that people, as many as possible, can go to the main cities or regional center conveniently.

(3)Because of the unreasonable design of road alignment, traffic speed is low. Comfort and safety of driving also need to be improved.

Node Selection and Clustering Analysis. The characteristics, status, level and role of road networks are often treated as the basis of node selection. Based on the developmental needs of the regional social economy, politics and defense, nodes within a reasonable range are selected as the control point of road network layout. If the grades of node division are divided too coarsely, layout accuracy will be reduced; on the contrary, excessively accurate division will make research too complicated (Wang, 2002).

According to the basic information and their demands, 13 townships of Danyang City are selected as the nodes of the rural road network. Based on the Danyang Statistical Yearbook (Zhao, 2008), several indexes are chosen to reflect the township economy, the level of industrial development, the transportation demand and the

business functions. Some of the indexes are quantitative, such as total population per capita rural income（yuan), financial revenue（ten thousand yuan), regional GDP （billion yuan）and retail sales (billion yuan). The rest are qualitative, such as road traffic condition and policy support.

Using FCM clustering algorithm, 13 nodes are divided into three categories. Heyang, Jianshan, Qianai, Hengtang, Zheliu, Jiangshu, Lizhuang and Yunhe are merged with other towns in 2005, so they are not included in the classification range. But considering the connecting function, these towns are divided into Class 4.

The index value of three cluster centers and membership of each township can be obtained by importing relevant data of 13 townships into the FCM function in Matlab. The results are summarized in Table 1 and Table 2.

Table 1. Index Value of Three Cluster Centers

	Total population	Per-capita rural income	Financial revenue	Regional GDP	Retail sales	Road traffic condition	Policy support
Class 1	31438	15464	50060	9.17	39.35	6	10
Class 2	46156	15466	35125	4.67	12.21	7	8
Class 3	54497	11176	14169	2.54	5.88	8	4

Table 2. Membership of Each Township

	Situ	Yanling	Fangxian	Daoshu	Huangtang	Houxiang	Yunyang
Class 1	0.0019	0.0004	0.0003	0.0060	0.0011	0.0634	0.9998
Class 2	0.0729	0.9890	0.9943	0.5017	0.0261	0.2614	0.0001
Class 3	0.9252	0.0106	0.0054	0.4923	0.9728	0.6752	0.0001
	Xinqiao	Erling	Jiepai	Picheng	Lvcheng	Lingkou	
Class 1	0.0013	0.0018	0.0015	0.0051	0.0056	0.0017	
Class 2	0.9704	0.9627	0.0193	0.0563	0.3313	0.9678	
Class 3	0.0283	0.0355	0.9792	0.9386	0.6631	0.0305	

According to the calculation results, node importance classification can be shown in Table 3.

Table 3. Node Importance Classification

Node type	Number	Node name
Central node	1	Yunyang
Important nodes	6	Yanling, Erling, Daoshu, Lingkou, Fangxian, Xinqiao
Less important nodes	6	Situ, Picheng, Lvcheng, Huangtang, Jiepai, Houxiang
General nodes	8	Heyang, Jianshan, Qianai, Hengtang,Zheliu, Jiangshu, Lizhuang, Yunhe

Traffic Location Line Layout of Danyang City. According to Table 3, considering the economic development, industrial planning and road network status, the traffic location line layout of Danyang City can be shown in Figure 1.

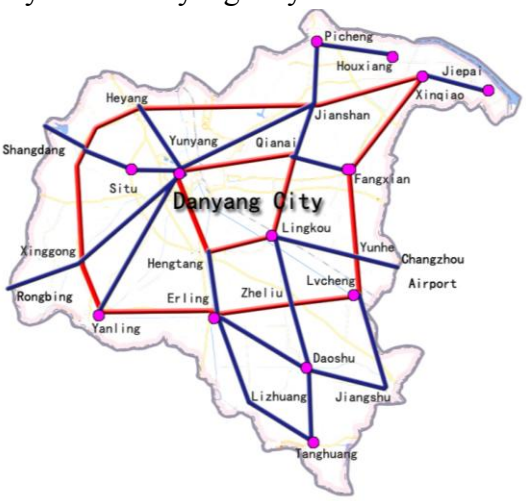

Figure 1. Traffic Location Line Layout of Danyang City

Based on the traffic location method, the traffic location line layout of Danyang City can be constructed as a ring-radial structure.

Ring location lines:

The inner ring consists of 4 nodes: Yunyang-Hengtang-Lingkou-Qianai. The outer ring consists of 10 nodes: Erling- Zheliu- Lvcheng- Yunhe-Fangxian-Xinqiao-Jianshan-Heyang-Xinggong-Yanling, the location line between Heyang and Erling covers Danxi Road.

Radial location lines:

Lingkou-Zheliu-Daoshu-Huangtang, this line connects to Qianai, Jianshan, Picheng and Houxiang through the inner ring, and gets through a north-south major thoroughfare in the eastern region. Lingkou-Yunhe-Changzhou Airport, this line coordinates the connections between roads and other means of transportation. Yunyang-Situ-Shangdang, this line connects to Shangdang Freeway, improves the connectivity of the rural road network of Danyang City.

Apart from the above radial location lines, there are other lines such as Erling-Daoshu-Jiangshu, Erling-Lizhuang-Huangtang, Yunyang-Xinggong-Rongbing and so on. Combined with ring location lines, the network of traffic location lines is formed.

4. PROGRAM EVALUATION

The evaluation of rural road network layout aims to evaluate the adaptability and use function of the layout program, mainly from the following analysis:

To meet the high requirement of bus transit roads, a bus route network with a more rational road hierarchical structure and high-grade roads is needed. The reasonable road network layout provides a good foundation for the layout of bus

route network.

Benefit from the reasonable road network layout, the contact between Danyang City and surrounding areas has been strengthened; the travel time to the airport, port and external areas has been shortened. Besides, the exchange between main townships of Danyang City has been enhanced; the radiation effect from urban and other developed areas to townships has been improved.

The process of urbanization has been accelerated because of the reasonable road network layout. The ring-radial structure forms several transport corridors, improves the economic benefit of road transport. Besides, the economic axis and industrial belt have developed rapidly. These changes will accelerate the transformation of farmers to urban areas, which will fundamentally change their lifestyle, and improve the quality of life.

5. CONCLUSIONS

Rural road network layout is an important basic work for promoting rural economic development. Taking rural road network as the research object, applicability for current methods of network layout is analyzed. Based on the characteristics and research of a rural road network layout, a method combining FCM clustering algorithm and traffic location is presented. The validity of the method is tested through an application example. Finally, according to the adaptability and using function of the rural road network layout program, a reasonable evaluation is made.

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