URBAN ROAD NETWORK ACCESSIBILITY EVALUATION METHOD BASED ON GIS SPATIAL ANALYSIS TECHNIQUES

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Commission II, WG II/3

KEY WORDS: Accessibility; Road Network Evaluation; GIS; Spatial Analysis

ABSTRACT:

The urban road network plays a key role in the urban spatial structure. It is the main city social-economy activities and transportation carrier. Today, more and more researchers pay attention on road network. One of the most important problems is how to evaluate the accessibility of road network. This paper tries to discuss it. Firstly, road accessibility concept and some appraisal methods are discussed. Then, the spatial analysis method on road network assessment has established based on the GIS spatial analysis technology, some urban road network accessibility evaluation models are built up. The models use ESRI Corporation's ArcGIS Engine components and Microsoft Corporation. Net Framework, and focus on the road network connectivity, the shortest travel time and the weighted average travel time. The paper presented three main road network accessibility evaluating indicators, introduced theory basis of the model construction in detail, and the model construction process. Taking Foshan city as an example, the models were tested using the urban road network data. Finally, further urban road network accessibility evaluation models are discussed.

1. INTRODUCTION

The urban road network plays a key role in the urban spatial structure. It is the main city social-economy activities and transportation carrier. Today, more and more researchers pay attention on road network. One of the most important problems is how to evaluate the accessibility of road network.

Hansen proposed the accessibility concept for the first time, defines it as the transport network in various nodes interaction opportunity (Hansen, 1959). Hereafter, the accessibility widely applied in research and road network plan, construction, and evaluation. In the transportation geography, the road network accessibility evaluation has taken as an important problem.

But accessibility does not have a unification concept till now. Generally speaking, the accessibility is the weight of a place to another place's simple degree and efficiency. Yang and Zhou thought that the accessibility is a place's convenience degree which arrives from other place. It can be a spatial distance, topological distance, trip distance, travel time or transportation costs(YANG Jiawen, ZHOU Yixing,1999).

The accessibility has both spatial and time features. It displays the convenience degree of a place as a spatial entity. And time is the main impedance factor of accessibility.

2. EVALUATION MODEL OF ROAD NETWORK ACCESSIBILITY

There are many evaluation indicators are proposed by researchers. We use three evaluation indicators to establish our model:

1-Shortest Time Distance(STD). It refers to the total time that one node need to all other nodes in the road network by the shortest time spending route. The lower STD value that a node has indicates that the node's accessibility is higher. The model expression is:

$$A_i = \sum_{j=1}^{n} T_{ij} \quad \left(i, j \subset (1, n)\right) \cdots (1)$$

In the formula, A_i for the node accessibility value, its value may change from 0 (the self node) to $+\infty$ (not connect node); T_{ij} is the least travel time from node i to node j; n is the total number of road network nodes.

2-Weighted Average Travel Time(WATT). It is the weighted summation of the total time that a node needed to all other nodes in the road network by the shortest time spending route. The weight represents the importance of a node in the road network, it can be calculated by population density or economical indexes. The WATT value is mainly related to the node's position in the road network . For example, the node in the central region usually has a smaller value. The model expression is:

$$A_i = \sum_{j=1}^{n} T_{ij} \times M_j \Big/ \sum_{j=1}^{n} M_j \cdots (2)$$

In the formula, A_i for the node accessibility value, its value may change from 0 (the self node)to $+\infty$ (not connect node); T_{ij} is the least travel time from node i to node j; M_j is node j's weight; n is the total number of road network nodes.

3-Accessibility index. It is a normalized index for the shortest travel time and the weighted average travel time. The formula is:

$$A_i^{'} = A_i \Big/ \left(\sum_{i=1}^{n} A_i \Big/ n \right) \cdots (3)$$

In the formula, $A_i^{'}$ is the accessibility index; A_i is one node's accessibility value; $\sum_{i=1}^{n} A_i \Big/ n$ is the mean value of accessibility.

3. METHOD OF ROAD NETWORK ACCESSIBILITY EVALUATION

The work flow is shown in figure 1.

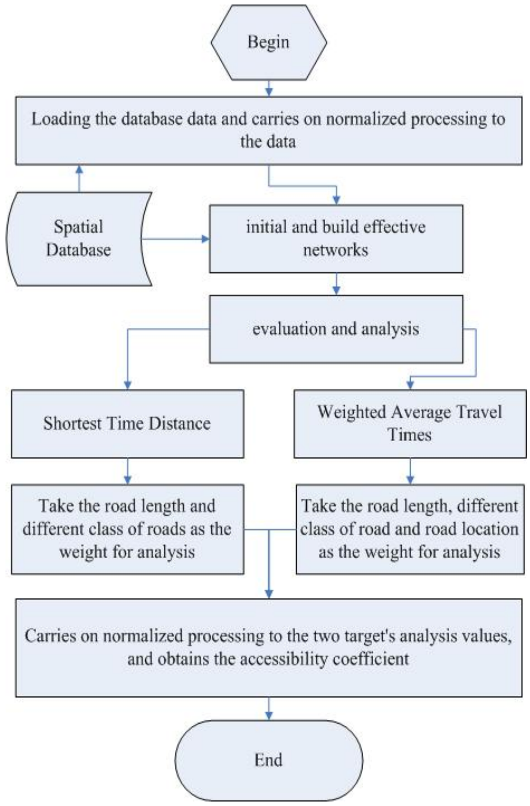


Fig.1 Road network accessibility evaluation flowchart

3.1 The method of road network accessibility evaluation

- We select ESRI PersonalGeodatabase to deal with data, and build up the FeatureDataset, construct effectiveness network (it calls the Utility Network), use the INetworkCollection class to carry on the geometry network to built CreateGeometricNetwork. Its foundation method is:

```
//network class
INetworkCollection m_NetworkCollection = (INetworkCollection)m_FeatureDataset;
//create utility network
IGeometricNetwork m_GeometricNetwork = m_NetworkCollection.CreateGeometricNetwork(
    "MyNet", esriNetworkType.esriNTUtilityNetwork, true));
```

- Carries on normalized processing to the data precision, the line feature connection precision is 0.001 meter (i.e. two line feature connected node tacitly approves in 0.001 meter for connection).
- Geometry network analysis
  - Calculates each node network connectivity, the following is the key code:

```
//An initialization network flows object
```

```
ITraceFlowSolverGEN traceFlowSolver = new TraceFlowSolverClass();
//Use the transfer network flow method to carry on connection essential factor tracing
traceFlowSolver.FindFlowElements(esriFlowMethod
    .esriFMConnected,
    esriFlowElements.esriFEJunctionsAndEdges, out
    m_JunEnumNetEID, out m_EdgeEnumNetEID);
```

■ Calculates each node's most short-path, the following is the key code:

```
//set the Weight
INetSchema NetSchema = Network as INetSchema;
INetWeight NetWeight =
NetSchema.get_WeightByName(WeightName);
NetSolverWeights.FromToEdgeWeight =
NetWeight;
NetSolverWeights.ToFromEdgeWeight =
NetWeight;
//find the path
traceFlowSolver.FindPath(esriFlowMethod.esriFM
Connected,
    esriShortestPathObjFn.esriSPObjFnMinSum,out
    m_JunEnumNetEID, out m_EdgeEnumNetEID,
    intCount - 1, ref vaRes);
```

◆ According to formula 1 and formula 2, we calculate the values of STD and WATT, then carry on normalized processing, get the accessibility coefficient value.

```
//STD values
for (int i = 0; i < n; i++)
    TotalSTDValue = TotalSTDValue +
STDValue[i];
STDAcc[i]= STDValue[i] / TotalSTDValue / n;
//WATT values
for (int i = 0; i < n; i++)
    TotalWATTValue = TotalWATTValue +
WATTValue[i];
WATTAcc[i]= WATTValue[i] / TotalWATTValue
/ n;
```

◆ The analysis data processing

■ Uses the report form to express the values of STD, the values of WATT and the accessibility coefficient values;

■ Carries on the sector classification to each node by the accessibility coefficient's difference, and carries on the rank exaggeration on the graph;

3.2 The road network evaluation system

We take the central region of Foshan city as an example, the road data of 2008 were used in the test. The nodes (the green dots) distribution is shown in figure 2.

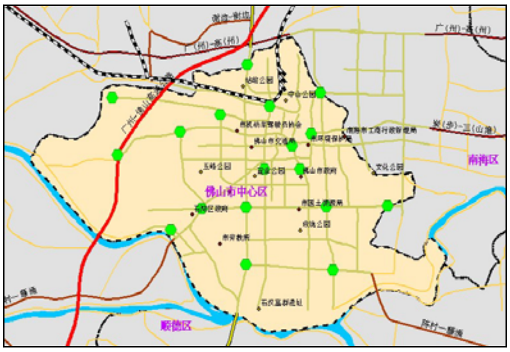
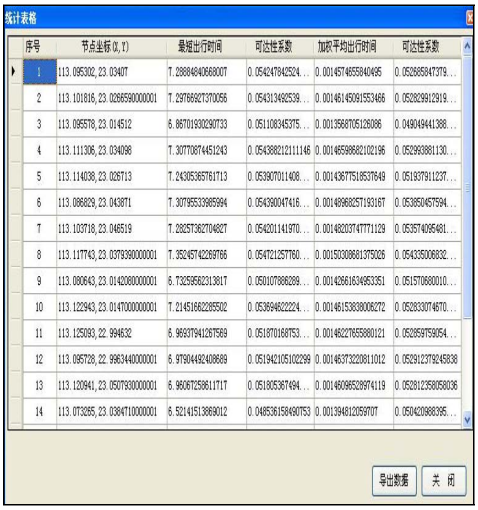


Fig.2 Sample nodes' location

The shortest travel time. The weighted average time as well as normalized process to the data, the processed result is as following (Fig.3).



统计表格

序号	节点坐标(X,Y)	最短出行时间	可达性系数	加权平均出行时间	可达性系数
1	113.095302, 23.03407	7.28884840668007	0.054247842524...	0.0014574655840495	0.052685847379...
2	113.101816, 23.0266590000001	7.29766927370056	0.054313492539...	0.00146145091553466	0.052829912919...
3	113.095578, 23.014512	6.86701930290733	0.051108345375...	0.0013568705126086	0.049049441388...
4	113.111306, 23.034098	7.30770874451243	0.054388212111146	0.00146598682102196	0.052993881130...
5	113.114038, 23.026713	7.24305365761713	0.053907011408...	0.00143677518537649	0.051937911237...
6	113.086829, 23.043871	7.30795533985994	0.054390047416...	0.00148968257193167	0.053850457594...
7	113.103718, 23.046519	7.28257362704827	0.054201141970...	0.00148203747771129	0.053574095481...
8	113.117743, 23.0379390000001	7.35245742269766	0.054721257760...	0.00150308681375026	0.054335006832...
9	113.080643, 23.0142080000001	6.73259562313817	0.050107886289...	0.00142661634953351	0.051570680010...
10	113.122943, 23.0147000000001	7.21451662285502	0.053694622224...	0.00146153838006272	0.052833074670...
11	113.125093, 22.994632	6.96937941267569	0.051870168753...	0.00146227655880121	0.052859759054...
12	113.095728, 22.9963440000001	6.97904492408689	0.051942105102299	0.00146373220811012	0.052912379245838
13	113.120941, 23.0507930000001	6.96067258611717	0.051805367494...	0.00146096528974119	0.052812358058036
14	113.073265, 23.0384710000001	6.52141513869012	0.048536158490753	0.001394812059707	0.050420988395...

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Fig.3 Computed result

The Kriging space interpolation calculation. After the shortest travel time normalized into the accessibility coefficient, the interpolation result is as follows (Fig.4).

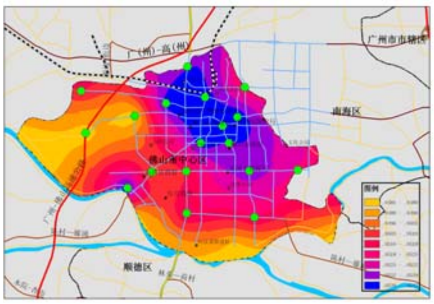

Fig. 4 Shortest travel time value interpolation chart

After the weighted average travel time normalized into the accessibility coefficient, the interpolation result is as follows(Fig.5).

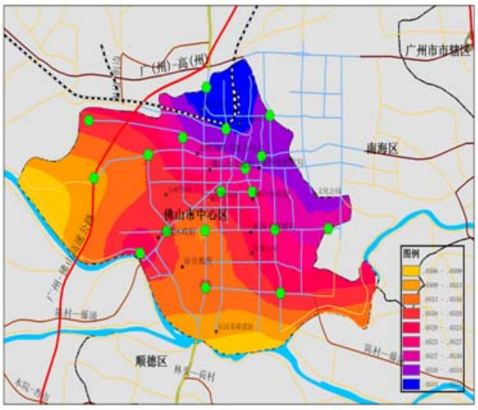

Fig.5 Weighted average travel time value interpolation chart

3.3 Discussion of the results

In Figure 4 and Figure 5, two assessment methods obtain the similar results. From North-east to the South-west, the Foshan central region's accessibility value decreases gradually.

In Figure 4, it mainly indicates the node's shortest general time. The central region of Foshan has relatively higher value of accessibility.

In Figure 5, on the one hand, the accessibility value displays the node shortest travel time characteristic. On the other hand, as the node has joined the weights on centricity and transportation rank, the northern region with a railroad, a national highway and provincial highway and so on, then it has a higher accessibility value.

In Figure 4 and Figure 5, the western region has relatively lower value of accessibility.

4. SUMMARY

Based on GIS spatial analysis methods, using ESRI Corporation's ArcGIS Engine components and Microsoft Corporation .Net Framework, we built a weighted and normalized index to value the accessibility of road nodes. In the sample test of Foshan city, the results show that the index can explain the true situation of road network's accessibility.

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