Research and evaluation of one-way traffic setting method

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Abstract. As an effective means of traffic organization, one-way traffic plays an important role in easing traffic congestion. However, the reality is often a one-way traffic organization based on experience, and new traffic problems have emerged during the implementation process. Based on the discussion of one-way traffic setting conditions, this paper models and evaluates the one-way traffic organization scheme that meets the conditions. The fuzzy distribution-analytic hierarchy process is used to evaluate the traffic patency, safety, economy, comfort and environmental impact of the organization scheme. Then, the setting condition-evaluation method is applied to the actual case in combination with VISSIM simulation for inspection. Finally, the experimental results show that the setting conditions-evaluation method can provide a scientific basis for the design and comparison process of one-way traffic organization.

1. Introduction

Compared with the emerging urban areas, the old urban areas have the characteristics of concentrated social public resources, dense road network and obsolete transportation facilities[1], which directly leads to the serious imbalance between traffic demand and supply. Therefore, according to the characteristics of traffic operation in the old urban areas, it is very necessary to find a reasonable way of organization to improve the quality of traffic operation. One-way traffic organization is a measure taken to solve traffic congestion. It is an effective measure taken to improve road transport efficiency or ensure road traffic safety on the premise of no road reconstruction and expansion[2]. At present, the implementation of domestic one-way traffic has largely alleviated the problem of road congestion.

The research on one-way traffic at home and abroad is reflected in three aspects. First, in terms of traffic characteristics, William[3] mainly studied the impact of one-way traffic implementation on traffic safety and regional economy; Liang[4] and Du[5] analyzed in detail the characteristics of one-way traffic, such as road network shape design, road section design and traffic sign design and so on. Second, in terms of organizational scheme optimization, Gao[6] put forward an optimization model combining the optimized site selection of information board with the single-line traffic organization; Jiang[7] focused on the application of one-way traffic in urban traffic microcirculation system, and designed a two-layer planning model for traffic microcirculation network organization optimization. Thirdly, in terms of effect evaluation, Cheng[8] combined the example to analyze the traffic conflict points and complexity of two-way traffic and one-way traffic intersections; Guo[9] used the Processor module in the Q-paramics software to generate an analysis report to compare the traffic conditions of the one-way traffic section; Zhuo[10] developed a specific method for scheme comparison and simulation evaluation of road one-way traffic system by using VISSIM.

In the existing research, the setting method for one-way traffic often relies on empirical analysis and lacks theoretical support. For the evaluation of one-way traffic, or staying in qualitative analysis,
or selecting indicators are not perfect, most do not combine the actual operating state of the road network. Based on this, the verified setting method and evaluation model proposed in this paper can effectively solve the problems in the current one-way traffic implementation process.

2. Setting conditions

2.1. Road network conditions
(1) Chessboard road network. The setting method is that two adjacent roads are paired into one-way traffic. (2) Strip-shaped road network. The setting method is to select a road that may be paired locally to form a one-way traffic system. (3) Other road networks. Two adjacent radioactive roads; When there are two adjacent loops in the road network and the length of the road section is short.

2.2. Road conditions
In special cases, when two roads are parallel and not at the same level, consider setting a low-grade road segment as one-way traffic while the other road is still two-way traffic.

2.3. Intersection conditions
The distance between intersections is less than 400 meters, the number of intersecting roads is five or more, and there are many left-turning vehicles, or roads with more difficult arterial coordination control should adopt one-way traffic organization.

2.4. Traffic flow conditions
(1) When the traffic composition is more complicated, it can be set as a one-way traffic type;
(2) Roads with obvious tidal traffic characteristics may be set as reversible one-way traffic;
(3) One-way traffic is implemented by the surveyed traffic that exceeds the road design capacity.

2.5. Other conditions
(1) Environmental conditions: When the two-way traffic road widening is difficult to ensure important buildings, monuments and greening on the road side; When parking space is required on the road but cannot be satisfied. (2) Terrain conditions: One-way traffic can be set up when complicated terrain or on-street traffic will cause great danger on steep slopes. (3) Legal conditions: Must comply with legal requirements such as "Road Traffic Safety Law of the People's Republic of China" and "The administrative licensing law of the People's Republic of China".

3. Evaluation method

3.1. Evaluation necessity and principle
The scientific construction of the evaluation system enables real-time tracking and feedback of the one-way traffic implementation plan in the city, and provides an improvement direction for the next step of the one-way traffic planning plan. The evaluation should follow the following principles: scientific principles, dynamic principles and practical principles.

3.2. Select evaluation indicators
On the basis of following the above criteria selection principle, this paper selects relevant evaluation indicators from three aspects: network benefit, bypass cost and environmental impact. In terms of network benefit, the three indicators of average running speed, intersection delay reduction rate and traffic capacity increase rate are selected. In terms of bypass cost, two indicators of bypass distance variation coefficient and node access reduction rate are selected. In terms of environmental impact, two indicators of the reduction rate of parking times and traffic noise pollution are selected. Therefore, this paper selects seven indicators to evaluate the one-way traffic plan.
3.3. *Fuzzy distribution method to determine evaluation criteria*

The fuzzy distribution method is used to establish the evaluation criteria for the indicators selected in this paper. The evaluation values are listed in Table 1 below.

| Index                              | A     | B     | C     | D     | E     |
|------------------------------------|-------|-------|-------|-------|-------|
| Average running speed \( P_1 \), km/h | >40   | 30-40 | 20-30 | 10-20 | <10   |
| Intersection delay decline rate \( P_2 \), % | >35   | 35-25 | 25-15 | 15-5  | <5    |
| Capacity increase rate \( P_3 \), % | >35   | 35-25 | 25-15 | 15-5  | <5    |
| Bypass distance variation coefficient \( P_4 \) | 0-0.5 | 0.5-1 | 1-1.5 | 1.5-2 | 2-2.5 |
| Node access reduction rate \( P_5 \), % | 0-20  | 20-40 | 40-60 | 60-80 | 80-100 |
| Stop reduction rate \( P_6 \), % | 80-100| 60-80 | 40-60 | 20-40 | 0-20  |
| Traffic noise pollution \( P_7 \), dB | <60   | 60-65 | 65-70 | 70-75 | >75   |

According to the evaluation criteria of the indicators, the values of the indicators are added up and averaged to obtain the overall evaluation criteria of the one-way transportation organization scheme.

3.4. *Analytic hierarchy process to determine the weight of evaluation indicators*

This paper uses the analytic hierarchy process to determine the weight. The steps to implement the one-way traffic organization scheme using the analytic hierarchy process are as follows:

1. **Clear questions**
   To clarify the scope of the problem, this article is to evaluate the single-line program benefits of a single-line area, including the overall goal, the criteria layer and the indicator layer.

2. **Establish a hierarchy**
   The hierarchical structure of constructing one-way traffic impact assessment is shown in Figure 1. The feature associations between the layers are connected by straight lines.

![Figure 1. Hierarchy chart](image-url)
3.4.1. Determining the benchmark. At present, the expert group often uses the nine-point judgment benchmark scale to obtain the ratio of the relative importance between the target criteria, and the judgment benchmark table is shown in Table 3.

Table 3. Determine the benchmark table

| Two-two comparison | Extremely important | Very important | Important | More important | Equally important | Counter comparison |
|--------------------|---------------------|----------------|----------|----------------|-------------------|-------------------|
| Scaling            | 9                   | 7              | 5        | 3              | 1                 | Reciprocal        |

3.4.2. Establish a judgment matrix. According to the hierarchical structure of Fig. 1, through the joint investigation and discussion of experts and decision makers, the ninth-rank judgment criterion is used to determine the relative importance of the two indicators and establish a judgment matrix. In the same way, the judgment matrix of the total target and criterion layer, U-C matrix is established, see Table 4 for details.

3.4.3. Calculate relative weight. The orthogonal method is generally used to calculate the orthogonal matrix. The calculation steps are as follows:

(1) Calculate the sum $V_i$ of each row element of the judgment matrix:

$$V_i = \sum_{j=1}^{n} a_{ij} \quad (i = 1, 2, \cdots, n) \quad (1)$$

(2) Normalize $V_i$, you can get the relative weight of each element under a single criterion $W_i$:

$$W_i = \frac{V_i}{\sum_{j=1}^{n} V_j} \quad (i = 1, 2, \cdots, n) \quad (2)$$

(3) Calculate the combined weight of the indicator layer for the total target:

$$W'_i = \sum_{j=1}^{n} b_{ij} \cdot W_{ij} \quad (3)$$

Where $W'_i$ is the combined weight of the indicator; $b_{ij}$ is the relative weight of the criteria layer to the target layer; $W_{ij}$ is the relative weight of the indicator layer to the criteria layer.

The calculation results are shown in Table 4.

Table 4. Index combination weight calculation table

| Indicator layer $P$ | C1 (Traffic patency) | C2 (Traffic safety) | C3 (Traffic economy) | C4 (Traffic comfort) | C5 (Traffic environment) | Combination weight |
|---------------------|----------------------|----------------------|-----------------------|-----------------------|--------------------------|-------------------|
| Average running speed $P_1$ | 0.4000 | 0.4157 | 0.2079 | 0.0831 | 0.0854 | 0.3949 |
| Intersection delay decline rate $P_2$ | 0.4000 | 0.1618 | 0.0966 |
| Capacity increase rate $P_3$ | 0.2000 | 0.2500 | 0.1455 |
| Bypass distance variation coefficient $P_4$ | | 0.1618 | 0.0337 |
| Node access reduction rate $P_5$ | 0.3088 | 0.0642 | 0.1642 |
| Stop reduction rate $P_6$ | 0.5294 | 0.3333 | 0.1642 |
| Traffic noise pollution $P_7$ | 0.5294 | 0.6667 | 0.1009 |

Therefore, $W' = (0.3949, 0.0966, 0.1455, 0.0337, 0.0642, 0.1642, 0.1009)$.
3.5. Building a model
The final selection of the one-way traffic organization plan should be comprehensively calculated.

\[ N = \sum_{j=1}^{2} W_i r_j = W_1 r_1 + W_2 r_2 + \cdots + W_i r_i \]  

(4)

Where \( N \) is the total score of the one-way traffic organization plan; \( W_i \) is the weight of the i-th indicator; \( r_j \) is the score of the i-th indicator.

4. Instance verification

4.1. Case overview
This paper takes the Greenland Central area as an example. The Greenland Central is located in the north of the city center of Jinan city. It is adjacent to the historical old street Puli Street in the north, the Gongqingtuan Road in the south, and the Shunhe elevated in the west.

Gongqingtuan Road (Shunhe West Road - Yinhuchi Street) is 520 meters long, with dense commercial areas and heavy traffic. Puli Street is a “golden passage” between the old city and the commercial port. It is 450 meters long and has a very large traffic volume. This small area is suitable for setting one-way traffic conditions as follows: (1) Flow conditions: The area is located in the old city with heavy traffic pressure on road sections and intersections. (2) Road network conditions: the communist youth league road (Shunhe west road - Yinhuchi street section) and Puli street are two adjacent radioactive road. (3) Section conditions: the Gongqingtuan Road (Shunhe west road - Yinhuchi street section) is a slab road. Puli street is a three-board road. One-way traffic can reduce the lateral interference of vehicles and improve vehicle speed and road service level. (4) Intersections conditions: There are five intersecting roads and the distance between intersections is less than 400 meters.

4.2. Design
Gongqing Tuan Road (Shunhe West Street - Yinhuchi Street Section) implements one-way traffic from west to east, with two-way bus and special bus lanes. The Puli Street real motor vehicle runs from east to west in one direction, and the bus has two-way traffic with special bus lanes. After the design of the scheme, place relevant traffic signs and optimize the layout of bus stops.

![Figure 2. Scheme design drawing](image)

4.3. Scheme simulation
In VISSIM, the flow and signal timing are input into the road network simulation model. Place the detector and get the intersection and road data, such as delay, number of stops, travel speed, etc. Comparing the data with the current survey data, the error is within 8%, indicating that the VISSIM simulation model is well constructed. The resulting data can be used in the next step to calculate values in the evaluate model.
4.4. Scheme evaluation
The score of each evaluation index was obtained from the simulation effect data and membership function: the average running speed score is 0.82, the intersection delay decline rate is 0.80, the capacity increase rate is 0.91, the bypass distance variation coefficient is 0.55, the node access reduction rate is 0.81, the stop reduction rate is 0.75, the traffic noise pollution is 0.49. The one-way traffic plan score is the average value of each evaluation index score, which is 0.78. The evaluation level is B. The traffic effect is good, which proves that the one-way traffic scheme in this place is feasible, and the validity of the model is verified.

5. Conclusion
Aiming at the problems in the setting and evaluation method of one-way traffic, this paper uses VISSIM simulation software and fuzzy distribution-analytic hierarchy process to study the design and evaluation of one-way traffic in detail and establish an evaluation model. The model is applied to the one-way traffic system network in the Greenland Central of Jinan City, Shandong Province, which proves that the evaluation model is reasonable and effective.

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