Application of Running Speed Coordination on the Analysis of Road Alignment Intelligent Recognition

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Abstract. For road alignment design, the design speed is the control basis of the current road design and determines the minimum index value of the route alignment design elements. The actual driving speed is important to measure and check the rationality of the route design index and whether the coordination is appropriate. According to the basis, the change range of its operating speed objectively reflects the balance of the linear index and the continuity of the road linear design. Based on the coordination of operating speeds, this paper analyzes the route of the reconstruction project of the 207 National Road (K3075+800—K3077+600) in the Guangdong-Guizhou County Economic and Industrial Cooperation Demonstration Zone (Xindu Industrial Zone), and takes the ratio of the operating speed difference between adjacent sections as the analysis indicators, the results show that the line shape of this section of the project is reasonable.

Keywords: Road design, Road alignment analysis, Running speed coordination.

1. Introduction
In the road design process, the linear design is an important part, which directly affects the safety of driving during the operation period, and ensuring the safety of the road during the operation period is also the ultimate goal of the linear design. At present, the main control index of road design is the design speed, which determines the minimum index value of each element in the linear design. However, the actual vehicle running speed is an important basis for measuring the rationality of the design index. The change state of the vehicle running speed can directly reflect the balance of the road alignment index and the continuity of the road alignment design. Statistical analysis shows that the road sections with large speed changes are usually road sections with discontinuous road alignment designs, which often present greater traffic safety hazards. Therefore, this paper takes the continuity index of the running speed as a parameter to test the safety of the road alignment, reflects the quality of the alignment with the coordination of the running speed, and uses actual engineering cases for engineering analysis.
2. Project Overview
The reconstruction project of 207 National Highway (K3075+800—K3077+600) in the Guangdong-Guizhou County Economic and Industrial Cooperation Demonstration Zone (Xindu Industrial Zone), starting at the intersection of National Highway G207 and Shankun Expressway (G78) Xindu Entrance (National Highway G207 Stake No. K3075+800), the terminal is located at K3077+600 on National Highway G207, and the total length of the route is 1.808 kilometers. There are three existing irrigation ditches and no planned rivers along the line. The start and end of the project are connected with the existing roads. The road grade is a first-class road, with a design speed of 60km/h, two-way four-lane, and a roadbed top width of 21.5m.

3. Linear indicator
This paper proposes to analyze the continuity of the road section with the ratio RV of the theoretical operating speed difference between adjacent road sections. The indicator is expressed as follows:

$$RV = \frac{|V_i - V_{i-1}|}{V_{i-1}}$$

RV —— the ratio of the theoretical operating speed difference between adjacent sections;
V_i —— theoretical operating speed of the current road section;
V_{i-1} —— Theoretical operating speed of the previous section.

4. Application of evaluation method of running speed coordination

4.1. Application of evaluation method of running speed coordination
According to the longitudinal section slope and the radius of the plane circular curve, the project is divided into 6 units, namely the short straight section of K0+000~K0+059.021, the straight section of K0+059.021~K0+416.665, the straight section of K0+416.665~K1+030.364, the straight section of K1+030.364~K1+398.942, the straight section of K1+398.942~K1+702.678, the short straight section of K1+702.678~K1+808.189.

4.2. Running speed calculation
(1) On a straight road section, since both small cars and large cars have expected driving speeds in straight-line driving, when the initial speed is less than the expected driving speed, the vehicle runs into a variable acceleration process, and no longer accelerates when the desired speed is reached. Drive at a constant speed at a constant speed. In the process of variable acceleration of the vehicle, the running speed of the vehicle on a certain road section is calculated according to the following formula:

$$V_s = \sqrt{V_0^2 + 2a_0S}$$

V_s —— the expected speed of the vehicle traveling on a straight line, m/s.
V_0 —— The initial speed of the vehicle in the road section, m/s.
a_0 —— The acceleration of the vehicle, m/s^2.
S —— The distance of the straight-line segment, m.

The recommended acceleration values are shown in Table 1. In this project, the acceleration of the small car in the straight line is 0.165 m/s^2, and the acceleration of the large car in the straight line is 0.2 m/s^2.
Table 1. Recommended acceleration values for various models

| Vehicle type | Small car | Large car |
|--------------|-----------|-----------|
| $a_t (m/s^2)$ | 0.15–0.50 | 0.20–0.25 |

(2) For the flat curve section, select the middle of the curve and the running speed at the exit of the curve for prediction. According to the entrance speed $V_{in}$ of the curve, the curve radius $R_{now}$ of the current section and the radius $R_{back}$ of the preceding curve, the middle speed $V_{middle}$ of the curve is predicted. Then according to the middle speed $V_{middle}$ of the curve, the curve radius $R_{now}$ of the current road section and the curve radius $R_{front}$ of the subsequent road section to predict the speed $V_{out}$ at the exit. The specific operating speed calculation refers to the prediction model in Table 4.

Table 2. Speed prediction model on horizontal curve

| Curve continuous form | Entrance line—curve | Entrance curve—curve | Export curve—line | Export curve—curve |
|-----------------------|---------------------|----------------------|-------------------|-------------------|
| Small car             |                     |                      |                   |                   |
| V_{middle}            | $V_{middle} = -24.212+0.834V_{in}+5.729\ln R_{now}$ | $V_{middle} = 1.277+0.924 V_{in}+6.191\ln R_{now}-5.959\ln R_{back}$ | $V_{out} = 11.946+0.908 V_{middle}$ | $V_{out} = -11.299+0.936 V_{middle}-2.0601\ln R_{now}+5.203\ln R_{front}$ |
| Large car             |                     |                      |                   |                   |
| V_{middle}            | $V_{middle} = -9.432+0.963 V_{in}+1.522\ln R_{now}$ | $V_{middle} = -24.472+0.990 V_{in}+3.629\ln R_{now}$ | $V_{out} = 5.217+0.926 V_{middle}$ | $V_{out} = 5.899+0.925 V_{middle}-1.005\ln R_{now}+0.329\ln R_{front}$ |

4.3. Running speed prediction

The operating speed prediction of this project is based on the operating speed calculation method proposed in Appendix B of the "Highway Project Safety Evaluation Specification". In order to make the predicted result closer to the actual situation, it needs to be adjusted. The specific method is as follows:

According to the terrain characteristics and the design of the project, two typical models of small cars and large cars are used for speed measurement. The design speed $V_d$ for the whole line of the project is 60km/h, the initial speed $V_0$ in the up and down directions: 60km/h for small cars, 50km/h for large cars, and expected speed $V_e$: 90km/h for small cars and 75km/h for large cars. According to the curve radius and the longitudinal gradient, the entire route is divided into straight, flat and short straight sections, divided according to the speed measurement standards of small cars and large cars, and evaluated the running speed of the road section according to the model method provided by the specification Measure and calculate the running speed of the whole line section, and get the running speed of small passenger cars and large trucks in the upward and downward directions of the section, as shown in Figure 1. From the perspective of vehicle operating speed distribution, the operating speed of small vehicles is basically maintained at 63km/h to 86km/h, and the operating speed of large vehicles is basically maintained at 52 to 70km/h, which meets the regulations and driving requirements.
5. Analysis of running speed coordination

This paper uses the RV index to analyze the coordination of operating speeds, and reflects the continuity of the project's linear design by analyzing the speed changes of adjacent units. The RV value distribution of small and large vehicles in the upward and downward directions is shown in Figure 2.

Figure 1. The running speed distribution diagram of the vehicle in the upward and downward directions

Figure 2. Distribution of RV values of vehicles in the upstream and downstream directions
(1) Analysis of the coordination of running speed in the upstream direction

From the RV value distribution diagram in the upward direction, it can be seen that the maximum RV value of small cars on the whole line is 0.1294, and the RV value of most road sections is below 0.1, indicating that the adjacent road sections along the line are well coordinated and the linear design is reasonable.

The RV values of large vehicles are all below 1.0, and the running speed is well coordinated, meeting the standards of linear continuity design and design element compatibility.

(2) Analysis of speed coordination in the downward direction

From the RV value distribution diagram in the downward direction, it can be seen that the maximum RV value of small cars on the whole line is 0.1075, and the RV value of most road sections is below 0.1, indicating that the adjacent road sections along the line have good coordination and reasonable linear design.

The maximum RV value of large vehicles is 0.1094, and the RV value of most road sections is below 0.1, and the running speed is coordinated well, meeting the standards of linear continuity design and design element compatibility.

6. Conclusion

In summary, the design of road alignment is directly related to the safety of vehicle operation. The RV index proposed in this paper can effectively analyze the coordination of vehicle operating speeds, thereby objectively reflecting the rationality of road alignment design. This method is verified by actual engineering cases. It can be seen that the route design of the project has good continuity and reasonable linear design. The driver can drive at a faster speed during the driving process, and the risk of traffic accidents caused by the linear shape is low. In the subsequent operation and management, it is recommended to consider the cooperation between protective facilities and the main body of the highway, reduce the mutual influence between various types of vehicles, and improve traffic efficiency.

References

[1] Qu Qiang. Discussion on highway alignment design method from the road geometry allowable speed and limit speed coordination [J]. Highway, 2020, 65(04): 238-242.
[2] Yin Bing. Application and discussion of design method of running speed route in engineering practice [J]. Guangdong Civil Engineering and Architecture, 2020, 27(05): 53-56.
[3] Yan Cunming. Research on speed coordination of expressway reconstruction[J]. Traffic and Transportation, 2020, 33(S1): 97-100.