Research on traffic organization improvement scheme of highway opposite side weaving area based on VISSIM simulation

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Abstract. Under the premise of configuration and length limitation, how to optimize the weaving area based on the existing basic conditions of the road is an important issue. In this paper, a case study of one interchange was presented to explore a traffic organization improvement scheme in opposite side weaving area with limited length. Based on VISSIM simulation, the traffic operation of the current scheme and the improvement scheme in the weaving area were analysed in the coming years. The results showed that before the "Forward 4" with a small flow, there was no significant comparison between the parameters of the current scheme and the improvement scheme. However, after "Forward 4" under the impact of large traffic flow, the section volume in the weaving area increased by 10%-26%, the running speed increased by 2.1-2.6 times, the number of vehicle lane changes decreased by 43-58%. Compared with the current scheme, the traffic efficiency of the improvement scheme was significantly improved. The research results could provide guidance and reference for this study case and similar projects.

1. Introduction
As an accident-prone area of highway interchange, the main reason is that the vehicle operation has changed from smooth and stable on the basic section to chaotic operation of confluence crossing and diverging on the weaving area. According to the configuration of the weaving area, the weaving area can be divided into same side weaving area and opposite side weaving area [1], as shown in Figure 1. Compared with the same side weaving area, the driver needs more lane changes and higher concentration when driving to the opposite side weaving area. Therefore, the traffic safety level and traffic efficiency are lower in the opposite side weaving area.

The length of the weaving area (Lw) has an important influence on the intensity of vehicle lane change. When other conditions are the same, the longer the length of the weaving area is, the more time and space the interleaving vehicles have for lane change, which is helpful to reduce the degree of traffic disorder, and improve the capacity of the weaving area. However, limited by such factors as investment, land use scale and terrain conditions, the length of the weaving area of some interchanges cannot be guaranteed. If the vehicle cannot change the lane in advance, it is easy to appear hesitation, sudden braking, emergency lane changing, stop and wait and other unsafe driving behavior at the interchange exit, which leads to the occurrence of traffic accidents.
The research fields of interchange weaving area were mainly about capacity and traffic safety. The highway weaving area was specified in “Highway Capacity Manual” of the United States [2]. On the basis of the above, China combined with national conditions and design experience to formulate the corresponding standard, such as "Guidelines for Design of Highway Grade-separated Intersections"[3], "highway engineering technical standards"[4] and so on. In terms of the length of the weaving area, the “national cooperative highway research project (NCHRP)” of United States showed that the minimum length was related to the type of interchange, the form of ramp, and the presence or absence of collection lanes [5]. Chinese scholars had also carried out relevant research on the minimum distance of weaving area [6-7], and at the same time conducted traffic safety evaluation on highway weaving area based on traffic conflict technology [8-9]. However, limited by investment, land use and other factors, there were still some problems such as too small intersections and serious traffic conflicts. Therefore, under the premise of configuration and length limitation, how to optimize the weaving area based on the existing basic conditions of the road was of great significance to improve the traffic safety of highway.

In this paper, a case study of one interchange was presented to explore a traffic organization improvement scheme in opposite side weaving area with limited length. Based on VISSIM simulation, the traffic operation of the current scheme and the improvement scheme in the weaving area were analyzed in the coming years. The research results could provide guidance and reference for similar projects.

2. Current and improvement traffic organization scheme
The opposite side weaving area in this study was the collinear sections of A highway and B highway, and the schematic diagram of weaving area was shown in Figure 2. The main line of highway A and highway B had 2 lanes, the weaving area had 4 lanes, and the length of weaving area was only 440m. In the current scheme, vehicles were free to change lanes in the weaving area because of the dotted white lines between lanes.

According to the 2019 survey, the current traffic volume of highway A and highway B was not large, and the data of the traffic survey was shown in Table 1. 30% of the traffic on each highway went in direction b and 70% in direction d. In addition, the weaving area in this study was an important transportation collector-distributor road which would be used by special type freight transportation (STFT) in the future. The peak hour volume of STFT was 200 veh/h, and the route was in the a-b direction.
### Table 1. The data of the traffic survey

| Highway | Peak hour volume (veh/h) | Diversion ratio | Vehicle type ratio |
|---------|--------------------------|-----------------|-------------------|
| A       | 474                      | 30%             | 70%               |
| B       | 170                      | 30%             | 70%               |

With the economic growth and the improvement of the surrounding road network, the traffic volume of this study would increase, so the safety risks caused by the short length of the weaving area and weaving on opposite side of the project became more prominent. On the premise of not changing road lines and optimal capital investment, the traffic organization improvement of weaving area was carried out in this study, and its main work was to improve the road traffic signs and markings of the weaving area and the upstream the weaving area.

#### Figure 3. Schematic diagram of road marking improvement in weaving area

From reducing traffic conflicts point of view, white solid lines were set between 1/2 lane and 3/4 lane in the weaving area to prevent vehicles from changing lanes. After adopting such a scheme, the number of weave lanes was reduced from the 4 to 2 interleaved lanes, as shown in Figure 3. At the same time, indication signs were set in the interleaving area and its upstream to prompt vehicles to change lanes in advance, as shown in Figure 4. In the upstream 0-200m section of the weaving area, white solid lines were set in the ramp area of highway A and highway B, and lane change of vehicles were prohibited. In the upstream 200-1200m section of the weaving area, indication signs were set up, indicating that vehicles heading for direction b should drive on the inside lane, and vehicles heading for direction d should drive on the outside lane.

### 3. VISSIM simulation

The simulation road network of the weaving area was built based on the data of the road cross section and vertical section, and the arrangement diagram of road traffic signs and markings. Based on VISSIM simulation, the traffic operation of the current scheme and the improvement scheme in the weaving area were analyzed in the coming year. The following were the input data in VISSIM modeling.

#### 3.1. Background traffic volume

According to the predicted traffic volume of highway A and highway B, the traffic volume of 2025, 2030 and 2038 were calculated by referring to the ratio of diversion and vehicle types in 2019. At the same time, in order to test the vehicle operation in the weaving area under the impact of large traffic flow, a total of 7 groups of forward large flow data from "Forward 1" to "Forward 7" were given, as shown in the Table 2. Among them, restricted by the output of transport of goods, the peak hour volume and direction of STFT remained unchanged.
Table 2. Traffic volume in the coming year

| Year  | Highway | Peak hour volume (veh/h) | Highway | Peak hour volume (veh/h) |
|-------|---------|--------------------------|---------|--------------------------|
|       |         | a-b                      | a-d     | a-b (STFT)               |
|       |         | Section a                |         | Section c                |
|       |         |                           |         | c-b                      |
|       |         |                           |         | c-d                      |
| 2019  | Section a-b | 474 142 332 200 | Section a-b | 170 51 119 |
| 2025  | Section a-b | 593 178 415 200 | Section a-b | 240 72 168 |
| 2030  | Section a-b | 660 198 462 200 | Section a-b | 283 85 198 |
| 2038  | Section a-b | 766 230 536 200 | Section a-b | 344 103 241 |
| Forward 1 | A     | 900 270 630 200 | Section a-b | 400 120 280 |
| Forward 2 | A     | 1000 300 700 200 | Section a-b | 500 150 350 |
| Forward 3 | B     | 1200 360 840 200 | Section a-b | 600 180 420 |
| Forward 4 | A     | 1400 420 980 200 | Section a-b | 800 240 560 |
| Forward 5 | A     | 1400 420 980 200 | Section a-b | 1000 300 700 |
| Forward 6 | A     | 1400 420 980 200 | Section a-b | 1200 360 840 |
| Forward 7 | A     | 1400 420 980 200 | Section a-b | 1400 420 980 |

3.2. Traffic composition
The traffic composition of each coming year was the same as that of 2019, as shown in the Table 1.

3.3. Speed limit
The speed limit of the weaving area and the ramp area were 40km/h, so the expected speed was set as 35-40km/h in the VISSIM simulation.

Based on the above data, the simulation of the current scheme and the improvement scheme were carried out. After the vehicle operation of the simulation reached steady state, the data of section volume, running speed, lane change in the weaving area were collected. The data collection duration was 1h.

4. Simulation evaluation
The evaluation was carried out from the three parameters of section volume, running speed and lane change.

4.1. Volume
Compare the section volume of the current scheme and the improvement scheme in weaving area, as shown in Figure 5.

![Figure 5. Comparative analysis of section volume in weaving area](image1)

In the improvement scheme, with the increase of the background traffic volume, the volume of the weaving area increased, and was basically the same as the theoretical value in each year. This indicated that the road network of improvement scheme was relatively stable. However, in the current scheme,
the volume of the weaving area showed a decreasing trend from the "Forward 4" stage. This indicated that the capacity of the weaving area had reached saturation in "Forward 4" stage. In the later stages, any interference would make the traffic flow disorder or even traffic jam, and road running state had been unstable.

4.2. Speed
The comparison of the running speed of the current scheme and the improvement scheme in each stage was shown in Figure 6. According to the simulation design, the expected speed of the weaving area was 35-40km/h. Before the "Forward 1" stage, the running speed of the weaving area in the current scheme and the improvement scheme in each stage was above 35km/h, and there was no obvious difference between the two schemes. The service level of the weaving area could basically reach level 2 or above.

After the "Forward 1" stage, the running speed of the weaving area decreased with the increase of traffic volume. In the improvement scheme, the speed reduction was not significant. Even under the impact of large traffic flow in the "Forward 7" stage, the running speed could reach 30.9km/h. However, in the current scheme, after the capacity of the weaving area reached saturation (after "Forward 4" stage), the running speed of the weaving area decreased greatly with the increase of traffic volume. Under the impact of large traffic flow in the "Forward 7" stage, the running speed could was only 8.5km/h.

4.3. Lane changes
Lane change behavior was the direct factor that causes the traffic flow to affect each other. The research showed that lane change times could better reflect the comprehensive traffic conflict risk index [8]. Frequent lane changes of vehicles in the weaving area not only affected the operation of surrounding vehicles, but also posed certain safety risks.

Figure 7 was the comparison diagram of the average number of lane changes per vehicle and total number of lane changes in the weaving area under the current scheme and the improvement scheme. In the improvement scheme, with the increase of the background traffic volume, total number of lane changes in the weaving area increased steadily, and the average number of lane changes per vehicle remained around 0.5 times per vehicle.

![Figure 7. Comparative analysis of lane changes numbers in weaving area](image)

However, in the current scheme, the average number of lane changes was more than 0.8 times per vehicle in each year, and even reached 1.19 times per vehicle in the "Forward 5" stage. The reason for the above results was that the vehicles did not drive in separate lanes in advance. With the increase of vehicle lane change times, the vehicle conflict caused by lane change behavior increased, and the risk of operation increased at the same time. In the large traffic flow, vehicles those had not completed lane change in advance could only stop at the end of the weaving area and wait for the gap acceptance, as shown in Figure 8. This also disrupted the traffic flow of the downstream vehicles, resulting in the queuing of vehicles in the weaving area.

It should be noted that after "Forward 5", the average number of lane changes per vehicle and total number of lane changes tended to decrease, because lane changes were more difficult when the traffic volume was oversaturated.
Figure 8. Lane change behavior at the end of weaving area (“Forward 5" stage)

5. Conclusion
In this paper, a case study of highway interchange was taken to explore the improvement scheme of traffic organization in opposite side weaving area with limited length. Based on VISSIM simulation, the traffic operation of the current scheme and the improvement scheme in the weaving area were analysed in the coming years.

The results showed that in the current scheme, the capacity of the weaving area was saturated in the "Forward 4" stage. After "Forward 4" stage, the traffic operation condition was very unstable in each coming year, and the section volume in the weaving area showed a decreasing trend, the running speed was reduced to about 10km/h, and the maximum number of lane changes of vehicles was 1.19 times per vehicle. In the improvement scheme, with the increase of the background traffic volume, the volume of the weaving area increased, and was basically the same as the theoretical value. The running speed of the weaving area could keep above 31.6km/h, the number of lane change was maintained at about 0.5 times per vehicle. The traffic operation condition was relatively stable in each coming year.

Therefore, after traffic organization improvement scheme was adopted for the opposite side weaving area with limited length, the road capacity was significantly improved. Before the "Forward 4" with a small flow, there was no significant comparison between the parameters of the current scheme and the improvement scheme. However, after "Forward 4" under the impact of large traffic flow, the section volume in the weaving area increased by 10%-26%, the running speed increased by 2.1-2.6 times, the number of vehicle lane changes decreased by 43-58%. Compared with the current scheme, the traffic efficiency of the improvement scheme was significantly improved.

In conclusion, the traffic organization improvement scheme was more conducive to improving the traffic efficiency and road safety in the weaving area. The research results could provide guidance and reference for this study case and similar projects. In the future work, the optimization scheme of traffic organization in highway opposite side weaving area with different lengths could be considered.

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