Abstract

The diamond interchange is one of the common forms of road intersection. The design of most of the existing diamond interchanges is based on unsaturated traffic conditions, and transit operation shows its unique properties when traffic tends to reach saturation. In view of this, we analyzed the traffic organization of diamond interchange, studied the improvement of scheme and focused on the import and export of massive diamond interchange traffic organization. VISSIM software was used to simulate the adjustment effect of import and export of the massive in saturated traffic conditions with the specific parameters such as average delay time, average queue length and the times of the average parking. Import and export traffic organization before and after adjustment was also evaluated based on entropy of the congestion of intersection to make objectively assessment more effective.

Keywords: Diamond interchange traffic organization; Massive traffic import and export; Saturated conditions; Crowded degree evaluation.

1. Introduction

Recently, more and more interchanges were built in our cities. With the increase of traffic volume, many interchanges become "bottleneck" and traffic jams were caused, which restrict the role of counseling through traffic of the interchange.

Diamond interchange traffic organization is divided into three aspects: diamond interchange main entrance and exit traffic organization and the bridge traffic organization, cohesion section of the interchange traffic organization, and the main road of interchange traffic organization. This paper analyses from the aspects of the diamond interchange traffic organization.
At present, for the diamond interchange design are generally based on unsaturated traffic conditions. In the condition of traffic tends to be saturated, the original design has shortcomings. Therefore, it should be aimed at the situation of traffic organization. In the face of this kind problem, we can transform ideas, solve it from the main entrance and exit flow angle. From this perspective, the main entrance and exit transportation organization is an important aspect of diamond interchange traffic organization.

Making a study of the interchange traffic organization is of important significance to resolve the current problems of interchange traffic congestion. This paper focuses on the research of diamond interchange traffic organization operation features, puts forward the existing problems and improvement scheme.

2. Diamond Interchange Problems

As the vehicle has access to the main road, entrance and exit must be established. Due to the high density and small area of the interchange, it is difficult to build completely interchange all, which set special orientation ramp for steering vehicle. So in many crossroads, the vehicles also need to put off the main road in advance and into service road to finish the steering. Vehicles on the service road drive into the main road through the entrance and exit, which result in shunt, convergence and interweave in the road section nearby and differently influence the capacity in the entrance and exit. They are mainly displayed in the following aspects:

2.1. Vehicle Queue near the Export of the Main and Service Road

In most of the exit, additional lane can be set on the service road, which provides the right opportunity and neutral to search into service road. Some additional lane is short and the traffic is very large on the service road, which result in the vehicle left the main road can't timely into the service lane and drive slow in the additional lane. It can also wait in line, line up has been extended to be the main cause of vehicles on main disturbance and traffic jams. The vehicles waiting for the long time from the main road force into the service road and cause the service traffic chaos, which causes the whole export area traffic flow disorder.

2.2. Traffic Security Problems

Survey shows that most of the traffic accidents happened in the upper reaches of the interchange export and the connection position of exports in the weaving area and the service road. The main reason is shown as follows: in the weaving lane inside, the vehicles need to change lanes. Due to the speed of vehicles, appearance size, acceleration and deceleration capability, driving behavior, weather and road condition difference, different traffic behavior are often presented, which is easy to cause the traffic accident; And when the main and service road are connected without additional lane, vehicles on the main road drive into the service road and service vehicles avoid not timely, which is more easy to cause the traffic accident.

(1) Poor Ride Comfort

The main functions of the urban rapid road are the traffic corridor between city groups and it provides safe, comfortable, fast service for through traffic. Diamond interchange exports are often set on the road between interchanges. But because of small interchange spacing, in addition to other road phase contact, a lot of entrance and exits are located in the bridge crossing and road connect point downstream nearby, some even at the end of the bridge structure. This design causes the deceleration of vehicles on the main road, which makes passengers very uncomfortable. Road linear cohesion and other aspects are not rational. It also easy to cause the vehicles' frequent acceleration and deceleration, seriously influence passengers' comfort, and at the same time, it is the underlying cause of traffic accidents.
(2) influence the whole road system capacity and service level

The node of the urban road is the bottleneck of the whole road system. If the entrance and exits do not passage free, it will definitely affect the whole urban expressway system capacity and service level.

3. Traffic Organization Of The Diamond Interchange

3.1. Diamond Interchange Traffic Organization of Entrance and Exits on the Main Road and the Bridge

When the main and service roads are set, traffic organization mainly shows 2 aspects: the entrance and exit, and the bridge.

Entrance and exit arrangement whether to use first into then out type or first out then into type involve in the conflict on main or service road. For the entrance and exit on both sides of the interchange body, it is usually the first out then into type. This type is not suitable for bridge traffic saturation situation. It makes the weaving zone transfer to bridge, which has already been in saturation. It will increase the burden of the road under the bridge, especially for the insufficient weaving length, bridge traffic will be worse. Whether the main road in congestion or not, service road is the source. If we can dredge the service road and make it in normal operation, the phenomenon of not passing in and out is not able to happen because of the continuous saturated flow in the main entrance and exit.

Therefore break the traditional design concept of the interchange, the use of reverse thinking (saturated and unsaturated itself is a pair of mutual relationship) makes the original interchange exchange one direction, change the first out then into type to first into then out type, which can solve the congestion problem brings from saturated condition.

3.2. Traffic Organization in Taking of Road and Bridge on the Interchange

The entrance and exits on the main road should be designed standard. There is weaving lane on the service road, entrance acceleration lane and export deceleration lane on the main road. It makes vehicles completely weave on the service road, achieve the transition of the acceleration and deceleration on the main road.

The following issues should be notes in the settings of acceleration and deceleration lane:
(1) The two interchange with side variable lane can't be well versed on the main road, otherwise it will cause Five strands of traffic flow for three stranded lane situation;
(2) The inside and middle of the lane should be yellow shielded in the interchange. It not only avoids ramp Traffic influencing the import traffic, but also avoids the accidents in the bridge when doubling and changing;
(2) In order to reduce the number of conflict in the ramp inlet, all turning traffic is on the road outside, all Traffic on the bridge is on the two lanes in the road inside;
(3) According to the principle of laminar flow speed limit, small speed difference allow modified line place,

Vehicle lane line is rowed; Big speed difference sections are not allowed to change and double, yellow shielded wire is rowed.

If broaden variable lane is difficult, stop to give way control should be implemented in the expressway entrance ramp, namely the vehicles into the main road. No matter whether there is vehicle into the main road,
parking must be happened in the ramp inlet to confirm the main road free and drive into it. It is helpful to reduce the influence of the main traffic flow and prevent the occurrence of accidents.

3.3. Traffic Organization of the Interchange on the Main Road

Sections and interchange is a whole, road traffic organization is not good, certainly will put the contradictions are all squeezed to the interchange. On the other hand, interchange contradiction is too centralized, also be the scattered on the road to solve, simplify the interchange traffic organization.

For the main and service roads, there is a great relationship among main bus position setting, the main entrance and exit, pedestrians’ street facilities and main lane. Generally speaking, in order to facilitate the passengers pass and transfer, bus station should be located in pedestrian street facilities, such as street bridge, tunnel's stairway end.

(1) The first into then out type. Bus station is generally located in the upstream of the entrance to avoid the access of vehicles’ weaving; If it is between the entrance and exit, it is necessary to ensure the distance between the site and exit, which should meet the requirement of bus and the vehicle on the main road for the shortest weaving.

(2) The first out then into type. Bus station should be set in the exit downstream or the entrance upstream. The entrance and exit forms the natural harbor of bus stop, which makes full use of the main road, achieves the driving on the main road and does not affect the vehicles and bus stop.

4. VISSIM Simulation Verification

4.1. Investigation Object

The paper takes traffic organization improvement of urban diamond interchange in saturated condition as the research object. It verifies the saturated condition congestion of first out then into type diamond interchange, and then checks the decrease degree of taking the first into then out type traffic congestion organization form.

In the study, many traffic flow parameters are involved, such as the vehicle constitute, expect the speed, the exit flow, main road flow, service road flow, the distribution characteristics of vehicles in the lane, we must have a clear definition, then quantitatively analyze all kinds of factors on the influence of export capacity. This study needs to adopt collection data including export geometry data, traffic flow data and environmental data. Geometric data: main and service lane number, lane width, service lane length, canalization length, etc. Traffic flow data: expressway main road, service road and export traffic flow, vehicle type composition, speed. Environmental data: road conditions of the investigation location, the weather and traffic organization and management, and so on.

The following principles are mainly considered in the process of survey site selection:

① The weaving area length is 150-300 m on the main export;
② Expressway diamond interchange exit upstream is far away from the intersection, at least fifty meters, best in the 100 meters and above:
③ Expressway entrance should be located in the longitudinal slope gentle straight sections;
④ Diamond interchange main road takes traffic organization mode of first out then into type. So choose Beijing third ring expressway as survey section, the intersection between Jinsong Bridge and Shuangjing Bridge diamond interchange as the research object.
4.2. Data Acquisition

The diamond interchange is two-way eight lanes on the main road, three lanes on the service import. There is also an additional lane, whose length is sixty m. And there are three lanes come from wide channel imports. Canalization length is twenty m. The intersection adopts four phase signal timings, specific timing parameters are shown in the list below.

![Signal Timing Plan](image)

Peak hour volume statistics are shown in table 1. By actual survey calculation, average delay time, average queue length and average parking times are shown in table 2.

Table 1. Peak Hour Volume Statistics on Each Lane of the Road

| Intersection (pcu/h) | East entrance (1042) | West entrance (1125) | South entrance (826) | North entrance (781) |
|----------------------|----------------------|----------------------|----------------------|----------------------|
|                      | Left | Straight | Right | Left | Straight | Right | Left | Straight | Right | Left | Straight | Right | Left | Straight | Right | Left | Straight | Right |
|                      | 260  | 417      | 365   | 168  | 338      | 619   | 256  | 487      | 83    | 226  | 469      | 86    |

| Main road (pcu/h)   | South entrance (1740) | North entrance (2251) | East entrance (328) | West entrance (416) |
|---------------------|----------------------|----------------------|---------------------|---------------------|
|                      | Straight | Right | Straight | Right | Left | Straight | Right | Left | Straight | Right | Left | Straight | Right | Left | Straight | Right |
|                      | 1566     | 174   | 2026     | 225   | 195  | 280      | 53    | 107  | 245      | 104   |

Table 2. Intersection Congestion Parameters

| Average delay timed (s) | Average queue length L (m) | Average parking times h |
|-------------------------|----------------------------|-------------------------|
| 38.7                    | 23.4                       | 45.75                   |

4.3. Simulation Test Research

Because the service road in the diamond interchange is crowded, and then affect the operating status on the main road. So take first into then out traffic organization form to verify the congestion situation is improving or not by
carrying on the simulation. VISSIM simulation establishes the network structure of the actual intersection firstly, the main vehicle's line take first into then out. Then the road geometry characteristics, the peak hour traffic flow, signal timing data input to traffic simulation software VISSIM in operation. The input model scale: car 0.8, truck 0.1, bus 0.1. Lane width is 3.25 m. Expect speed interval, car 45 to 55 km/h, bus 30km/h, Truck 30 km/h. The simulation running status is shown in figure 2:

![Fig. 2. VISSIM Simulation Operating Status](image)

The simulation results are as follows:

Table 3. Simulation Results

| Average delay timed (s) | Average queue length L (m) | Average parking times h |
|-------------------------|-----------------------------|-------------------------|
| 17.9                    | 12                          | 29.25                   |

5. Verification Method—The Intersection Traffic Congestion Degree Evaluation Method Based On Entropy

The attributes of average delay, average queue length, average parking times which can be used to evaluate the intersection congestion degree quantify the comprehensive indexes of the congestion level based on entropy. So the specific data of the average delay, average queue length and average parking times can be made to evaluate the congestion degree.

Algorithm steps:

1. Each congestion degree is considered as a decision scheme with three attributes, respectively the average delay time $d$, average queue length $L$, average parking times $h$.

2. Determining the standard value of the evaluation indexes. The standards are obtained by clustering analysis through various different congestion degrees of the history data in the intersections, as table 4 shows:

Table 4. Standards of Evaluation Attributes

| Standards Attributes | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_7$ | $V_8$ | $V_9$ |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Average delay timed (s) | 5     | 17    | 23    | 48    | 64    | 125   | 160   | 180   | 200   |
| Average queue length L (m) | 5     | 25    | 50    | 80    | 100   | 125   | 250   | 350   | 400   |
| Average parking times h | 6     | 12    | 24    | 36    | 48    | 60    | 84    | 108   | 120   |
(3) The basic weight coefficient is determined based on the information entropy method.

Assume that decision matrix D for 9*3 matrices, 9 for program (congestion), 3 is the number of attributes. Then the element \( x_{ij} \) is the \( j \) attribute value of the program \( i \), the program (congestion) about attribute \( j \) evaluation type are defined as follows:

\[
p_i = \frac{x_{ij}}{\sum x_{ij}}
\]

The entropy of the program about attributes \( j \) is:

\[
E_j = -K \sum_{i=1}^{9} p_{ij} \cdot \ln p_{ij}
\]

\( K \) is constant:

\[
K = \frac{1}{\ln 9}
\]

Define information deviation degree for:

\[
d_j = 1 - E_j
\]

Define weight coefficient of the attribute \( j \) as:

\[
w_j = \frac{d_j}{\sum_{j=1}^{3} d_j}
\]

(4) Simply by weighting method to make a decision, compute comprehensive congestion indexes. Use simple weighted method to calculate each program (congestion degree) comprehensive congestion indexes.

\[
Q_i = \sum_{j=1}^{3} w_j \cdot x_{ij}
\]

(5) Output result

| Table 5. Weight Coefficient |
|-----------------------------|
| Average delay timed (s) | Average queue length L (m) | Average parking times (h) |
| 0.340 | 0.397 | 0.263 |

| Table 6. Congestion Comprehensive Indexes |
|------------------------------------------|
| Unblocked | Congested |
| Level 1 | Level 2 | Level 3 | Level 1 | Level 2 | Level 3 |
| [0,5.3) | [5.3,18.9) | [18.9,34.0) | [34.0,57.6) | [57.6,74.1) | [74.1,107.9) |

Congested

| Level 1 | Level 2 | Level 3 |
|--------|--------|--------|
| [107.9,175.8) | [175.8,228.6) | [228.6,258.5) |
Table 7. Congestion Degree Evaluation

| Entrance and exit mode | Average delay timed (s) | Average queue length L (m) | Average parking times h | Comprehensive congestion index | Congestion degree |
|------------------------|-------------------------|----------------------------|-------------------------|-------------------------------|------------------|
| First out and then into type | 38.7                    | 23.4                       | 45.75                   | 34.47                         | Congested level1 |
| First into and then out type | 17.9                    | 12                         | 29.25                   | 18.54                         | Unblocked level 2 |

Through the simulation test and congestion degree evaluation, congestion degree is improved to unblocked level 2 from congested level 1.

6. Conclusion

This paper made a study on diamond interchange traffic organization, respectively from the entrance and exit traffic organization and the bridge of the diamond interchange traffic organization, the interchange bridge and the main road and the interchange the traffic organization. But on the background of unsaturated traffic condition transition to saturated traffic conditions, it is particularly important to make a research for diamond interchange main entrance and exit traffic organization. Through the actual diamond interchange research and VISSIM simulation, it is verified that the main entrance and exit transportation organization form to the first into then out type is necessary and effective when the first out then into type unsaturated traffic design diamond interchange happened on crowded and affect main traffic operation.

But when diamond interchange is close to the intersection, contradictions will likely focus on its distance, not on export itself. Therefore, the suitable distance of the diamond interchange export needs a further research in different traffic demand situation.

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