

Design Strategy of Collector-Distributor Lanes in Urban Interchanges

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Abstract: Based on the functions and characteristics of the interchange collector-distributor lanes, with Harbin as an example, it is proposed in this paper that the local characteristics and traffic flow characteristics should be considered in the design of the interchange collector-distributor lanes, which includes the analysis of function, location, and many other aspects, in hopes to provide reference for the design of collector-distributor lanes in other regions of our country.

Keywords: Interchange; Collector-distributor lane; Design strategy

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1. Introduction

Urban interchange collector-distributor lane is an important part of urban road network system, in which it plays an important role in relieving urban road traffic congestion and promoting the coordinated development of urban traffic, society, economy, and the environment. With the rapid development of our country's economy, many large and medium-sized cities have begun to form dense traffic networks. As a key node in the urban road network, the interchange is responsible for the collection, distribution, and transfer of incoming and transiting vehicles from all directions. Large-scale reconstruction of collector-distributor lanes in the city will significantly alleviate the problem of insufficient traffic capacity of the existing road network, and lay the foundation for the coordinated development of the road network within and around the region in the future. The design of the collector-distributor lane of urban interchanges should follow the principle of "design speed of collector-distributor lane" in the "Design Regulations for Urban Road Intersections" (CJJ152-2010), while considering the actual service level of the interchanges to reasonably determine the length of the collector-distributor lanes. In order to meet different traffic needs, different forms of interchanges have been constructed: full interchange with expressways as the main part and some dedicated lanes as the auxiliary; semi-interchangeable interchange that is based on urban expressways and supplemented by some bus-only lanes^[1-4].

2. Research overview

Collector-distributor lanes are set up when the connecting roads (including traffic signal control system) on both sides of the inner ramp of the interchange intersect with the main line or diverge to different directions; and they are auxiliary lanes for vehicles to decelerate, stop, or turn when driving out of the main line or entering the ramp.

2.1. Features of urban layout

An urban internal road network is generally composed of three parts: main line (expressway, expressway), branch line (secondary road, branch road and laneway), and auxiliary lanes. Among them, the main line mainly connects the central urban area and the peripheral area, as well as the sub-arterial road. The grades of roads in the city are finely divided, mainly including expressways, main lines, sub-arterial roads, and branch roads, so the location of the collector-distributor lanes is also different. Taking Harbin as an example, the main lines in the city's internal road network intersect with Haxi Expressway (West Fourth Ring Road) and Hadong Expressway (Hatong Expressway) and extend to the main group nodes. Its entrance and exit are mainly located between the main line and the sub-arterial road. This type of road has a large scale and a wide range, but bears a small amount of traffic, while some sub-arterial roads are small in scale, but connect each group node, and bear a large amount of traffic ^[5-7].

2.2. Traffic characteristics

In terms of traffic flow, due to the unique position of the collector-distributor lanes within the interchange, it forms an interwoven traffic flow with the main line, and at the same time intersects with the main line to form a horizontal collector-distributor lane. When designing the width of the collector-distributor lanes, it is necessary to consider factors such as the weaving length between the sections inside the interchange, the direction of traffic flow, and the volume of traffic, so as to ensure the safe and orderly operation of the traffic flow in the collector-distributor lanes. At the same time, factors such as the speed of vehicles on the ramp, road alignment conditions, and the degree of mutual interference between vehicles on the ramp and vehicles on the main line must be considered to meet the traffic capacity and service level of the distribution lanes. From the perspective of traffic control, the collector-distributor lanes are relatively independent operating systems, which to a certain extent are the result of the coordination between the internal traffic control system of the interchange and the external road traffic control system. Therefore, it should be set according to the specific situation, comprehensively considering the impact of the surrounding roads on the traffic flow of the collector-distributor lanes and the layout of the urban road network. On this basis, the collector-distributor should be designed by rationally dividing the interweaving area and range between the various road sections inside the interchange; at the same time, the degree of mutual interference between vehicles on the ramp and the main line should be reasonably divided in consideration of the characteristics of the section along the road and the traffic capacity.

2.3. Function positioning

The functions of the collector-distributor lanes mainly include the following aspects:

- (1) Collecting, distribution, and diverting urban traffic
Collector-distributor lanes increase the traffic capacity of intersections by increasing the speed of vehicles entering and leaving the road, thus diverting the traffic at the bottleneck of traffic flow.
- (2) Ensuring driving safety
Collector-distributor lanes provide a place to stop and give way during heavy traffic and to vehicles that are moving fast, so as to reduce traffic accidents and delays, and ensure driving safety.
- (3) Other functions
Collector-distributor lanes shorten stopping time, reduce driving delays, reduce traffic accidents, ensure driving safety, improve traffic capacity, improve landscape quality and environmental quality, relieve traffic congestion, reduce pollution from motor vehicle exhaust emissions, and improves the city's image ^[8-11].

3. Problems existing in urban interchange collector-distributor lanes

3.1. The length of the collector-distributor lane is too short

In the design of interchanges, the length of the collector-distributor lanes is often too short. There are many reasons why the collector-distributor lanes of urban interchanges are too short. For example, many roads in the city belong to expressways, or the nature of the surrounding land makes it impossible to build a long collector-distributor lane. In order to meet the needs of intercommunication, traffic signs and markings are set up at road intersections. For example, when the main line west to south intersects with other roads, some right-turning traffic needs to turn left at the west entrance of the main line. At the same time, the interchange also has four ramps (two of which are left-turning ramps): the first one is a right-turning ramp when the expressway intersects with the main line; the second one is a right-turning ramp when the expressway intersects with the ground-level road; the third is a left-turn ramp when the expressway intersects with the ground-level road. When the length of the collector-distributor lane is too short, several problems will occur, which are explained below.

(1) Unable to meet one-way multi-entry single-exit or two-way single-entry double-exit

If the length of the collector-distributor lane is too short, it will cause disorganized traffic, and requirements such as one-way multi-entry single-exit or two-way single-entry double-exit cannot be met. Besides, ground-level crossing traffic capacity at the intersection will be decreased and traffic safety near the intersection will be affected.

(2) Significantly affecting the existing traffic facilities

Collector-distributor lanes that are too short will inevitably reduce the traffic capacity of surrounding intersections or affect the use of existing traffic facilities.

3.2. Collector-distributor lanes mixed with straight vehicles

The design speed of the collector-distributor lanes of urban interchanges is generally not lower than 60 km/h. In general, short collector-distributor lanes can be used, but in order to meet the needs of traffic, the short collector-distributor lanes are mixed with straight vehicles.

3.3. Problems caused by long collector-distributor lanes

The length of the collector-distributor lanes should be determined according to the length of the main line and ramps, the number of ramps, and the traffic conditions within the interchange. In general, since the main lines and the ramps have different lengths, the length of the collector-distributor lane can be calculated by using the ratio of the minimum bending radius of the main line to the minimum circular curve radius, and the main line is usually represented by "1." In addition, to connect the main line to the collector-distributor lane, the collector-distributor lane can be set on the main line, and a certain turning radius can be set along the direction of the main line. In order to facilitate motorists to enter or exit the collector-distributor lane, lanes to "2," "3," "4," and can be constructed. The "Technical Standards for Highway Engineering" states that "ramp spacing of interchanges should not be greater than 200 m" ^[12]. Therefore, the ramp spacing should not be more than 200 m. However, according to the "Highway Route Design Code," the minimum value of the ramp spacing in the should not be less than 40 m, and the length of the collector-distributor lanes should not be less than 200 m in general ^[13]. The length of the collector-distributor lanes can be increased when the traffic volume and service level are high, and if there are multiple main lines and ramps within the interchange range. If necessary, a left-turn lane, a right-turn lane or a reverse entry ramp can also be created on the ramp.

4. Design of collector-distributor lanes for urban interchanges

4.1. Design principles

The design of collector-distributor lanes should be based on the “Code for Design of Urban Roads” (CJJ36-95) [14], comprehensively considering factors such as traffic volume, vehicle speed and direction, combined with local urban planning and traffic needs, to ensure that it is compatible with interchanges. The collector-distributor lanes are mainly used for vehicle deceleration, parking, and turning, and shall comply with the relevant regulations on expressway collector-distributor lanes in the “Technical Standards for Highway Engineering” (JTGB01-2014) [12]. In addition to expressways, collector-distributor lanes can also be used for non-vehicular traffic flow. In the design of collector-distributor lanes, two or more auxiliary lanes should be provided for vehicles coming from different directions. If there is a lesser demand, a single auxiliary lane can be used; when the requirements are met and the construction conditions permit, the connecting road (including the traffic signal control system) and the main line shall be arranged in the same direction with the traffic flow; when same-section control cannot be realized, the separated-lane control may be adopted.

4.2. Position determination

The location of the collector-distributor lanes of interchanges should be selected according to the structure of the urban road network, and on the basis of factors such as urban road planning, existing road conditions, traffic flow, and facility layout. Since collector-distributor lanes are mainly set up to alleviate traffic congestion of the forks, the traffic capacity of the forks should be fully considered when selecting the position of the lanes, as shown in **Figure 1**.



Figure 1. Interchange collector-distributor lanes

4.3. The length of the collector-distributor lane of the interchange

The length of the collector-distributor lanes of urban interchanges should be reasonably determined according to their service levels. It should be noted that after the length of the collector-distributor lanes is determined, other design indicators in each scheme should also be determined, such as the minimum short straight distance, the minimum turning length, and many more. After the length of the collector-distributor

lanes is determined, the signal timing in each scheme should also be reasonably set. In terms of type of interchange, if the combination of expressway and special lane is adopted, the combination of expressway and dedicated lane should be preferred; and for a full interchange, if the combination of urban expressway and some dedicated lanes is adopted, the combination of expressway and some dedicated lanes should be preferred. According to Article 6.2.5 of the “Code for Design of Urban Road Intersections” (CJJ152-2010) [3], the length of the collector-distributor lanes in urban road engineering is generally 60–80 m, it can be seen that the recommended length of the collector-distributor lanes is 60–80 m, as shown in **Figure 2** show.



Figure 2. Design drawing of collector-distributor lanes

4.4. Lane number

Starting from the composition structure of the interchange system, the vehicles on the collector-distributor lanes should be in an ideal position in the interchange system, so as to maintain the consistency of the main line speed; at the same time, the traffic volume undertaken by the collector-distributor lanes should be within a reasonable range, and the interference to the main line and the traffic flow along the line network should be minimized to ensure smooth traffic on the main line and the surrounding road network. (1) According to the traffic volume requirements of expressways for collector-distributor lanes in China, full cloverleaf-type interchanges, when the intersection road is an expressway or a first-class trunk road, or the weaving traffic volume is greater than 600 pcn/h, a collector-distributor lane should be set up to isolate the weaving area between the two circular ramps from the straight-going vehicles on the crossroad [3]. Therefore, in the design of urban interchanges, two or more collector-distributor lanes can be created according to the actual situation. In addition, for cities where interchanges are needed because there are multiple main lines in different directions (or at least two ramps in different directions), the interchange should avoid directing vehicles to the same direction. If a turn cannot be avoided, a left-turn lane should be set up. For urban interchanges with level crossings, the number of collector-distributor lanes generally ranges from 1 to 3. (2) The number of collector-distributor lanes should be determined according to the length of the entrance and exit of the urban interchange, the length of the main line, and the traffic volume undertaken. Generally, when the length of the exit ramp and the main line is less than 1000 m, or the length of the entrance and exit ramp is greater than 150 m and the length of the main line is greater than 3500 m, a collector-distributor lane should be created. (3) The number of collector-distributor lanes should be determined according to the distance between the ramp and the main line, and the distance between the on-ramp and the main line.

4.5. Lane width

The width of the collector-distributor lane is related to the vehicle speed of the ramp, road conditions, charging standards, and many more. The selection of the lane width should take into account the influence of various aspects and ensure the safe driving of vehicles. In general, in order to ensure vehicle safety and avoid traffic accidents caused by speeding, the speed limit should be set between 50 km/h and 80 km/h, depending on the direction of the lane and ramp width. The collector-distributor lanes can be in the form of single or double lanes, and the width of each lane should be 3.5 m. The lane allocation should be the same from the entrance to the exit of the main line, there is no specific requirement for the number of collector-distributor lanes. A divider should be set between the collector-distributor lane and the main line, the width of the divider should not be less than 2.0 m, and the original hard shoulder width should be maintained.

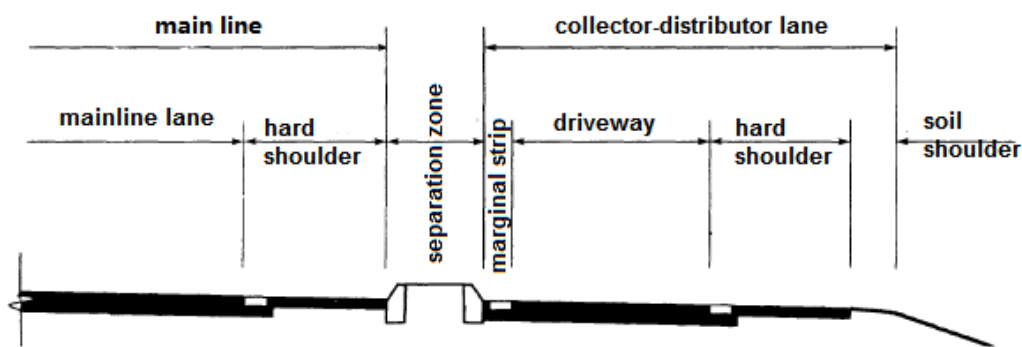


Figure 3. Cross-sectional diagram of collector-distributor lanes

5. Position of forks

The function of the forks is to set a deceleration lane or an advance notice lane at the exit or entrance of the ramp. When there are many ramps, it can be installed at the exit of the ramp, so that the driver can choose the route in advance; when there are few ramps or there is no deceleration lane, the fork can be set at an appropriate position before the exit or entrance.

6. Conclusion

The design of urban interchange collector-distributor lanes is a complex system engineering, in which factors such location, traffic flow, and function needs to be considered and analyzed. For example, the Harbin interchange collector-distributor lanes are located in the peripheral areas of the city, where the traffic flow is high and concentrated, and at the node where the main line and the ramp intersect. Considering the existing engineering projects in China, it is proposed that factors such as location, traffic volume, functional positioning and traffic flow of interchanges should be considered in the design of collector-distributor lanes, and suggestions are made for the planning of distribution lanes in corresponding areas. For example, increase the number of exit lanes of the exit ramp can be increased or auxiliary diversion roads can be set for the entrance ramp. With the rapid development of our country's urban road network, the reconstruction of collector-distributor lanes will be inevitable.

Disclosure statement

The author declares no conflict of interest.

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