Study on Traffic Organization around Pivotal Tunnel Entrance/Exit

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Abstract: With increasing pressure on above ground space and surface traffic, more and more cities choose to construct underground transportation junction to speed up traffic and improve travel efficiency. This paper covers survey and VISSIM simulation of vehicles at the entrance and exit of an in-progress tunnel at Zengjiayan, Chongqing. The results show: during construction of the pivotal tunnel, the entry of trucks to the construction area near the "left-in left-out" entrance and exit will significantly affect traffic on the artery where the tunnel is located; the flow line scheme under which trucks change lanes in advance at the entrance to the construction area is optimal. In addition to optimization of entrance and exit points, traffic organization around the tunnel during construction should be optimized to mitigate traffic pressure on the artery where the tunnel is located.

1. Introduction
As the critical component of a route, the pivotal tunnel structure is complex. The importance of its entrance and exit is self-evident in optimization of road structure. Management of the entrance and exit started relatively late in China, focusing on analysis of road class and entrance/exit spacing. At current stage, codes for entrance/exit spacing on urban roads are not available\cite{1-3}.

Regarding the effect of entrance/exit on traffic operation, Zhao Haijuan et al. studied the connection of expressway exit ramp to surface road under connection management concept, compared the characteristics of existing ordinary level crossing and found a reasonable traffic flow guidance method from geometric safety design of expressway exit ramps \cite{4}. Wang Zhenbao et al. collected data on diamond interchange entrance/exit and performed simulation using VISSIM micro model to conclude that increased traffic speed and controlled traffic flow on side road are very helpful to improve traffic on the fast road\cite{5}.

Regarding traffic organization optimization during construction of expressways and urban roads, global researchers conducted in-depth research into traffic organization where construction activity occupies or blocks the road. However, a pivotal tunnel is usually an underpass beneath an existing artery which will be expanded prior to excavating the tunnel. Consequently, it is rare for such construction activity to occupy the road. During construction of the pivotal tunnel, the impact on the artery consists mainly of the interference with general vehicles by large trucks going in and out of the construction area\cite{6-7}. Combined with the unreasonable layout of vehicles at the entrance and exit of the Jialing River Bridge Project in Zengjiayan, through the VISSIM simulation, the simulated entrance...
and exit points of the tunnel and the optimization of the layout plan of the tunnel entrance and exit are of practical significance to relieve the traffic pressure.

2. Project Background
Zengjiayan Jialingjiang Bridge Project starts at Xingsheng Road in Yubei District, enters a tunnel near Tianjiang Dingcheng, goes out of the tunnel across Longhu Chunsen, crosses the Jialing River, runs beneath Zengjiayan, Zhongshan Road No. 4, Shangqing Temple and Lianglukou successively, goes out of the tunnel south to an interchange by which it connects to Caiyuanba Bridge and Changbin Road. In near term the entire line is provided with 5 link roads mainly in the form of tunnels to connect to Beicheng Tianjie, Huangguan Road (link road A and B), Jiabin Road (link road A), Renmin Road and Changbin Road interchange.

During construction of tunnels under the project, frequent passage of construction vehicles, improperly arranged entrance/exit, traffic organization and lane occupation by construction vehicles often result in congestion in entrance/exit sections.

The underpass tunnel is normally an opening in the center of existing road with "left-in left-out" entrance and exit, as illustrated in Fig. 1. However, existing researches concentrate on "right-in right-out" entrance/exit. In addition, during construction stage vehicles through the entrance/exit of construction area are all large trucks whose travel characteristics are quite different from ordinary cars. Therefore, it is necessary to study the selection of "left-in left-out" entrance/exit point during tunnel construction stage.

3. Simulation of Tunnel Entrance/Exit Point
3.1. Simulation scheme
Due to the size and complexity of the transport system, it is impossible to build a completely true system to reproduce real events for testing and analysis of some problems. It is difficult to find a solution to many problems in the real world by means of analytical method alone. For study on traffic organization around pivotal tunnel entrance/exit, reference may be made to the above study on traffic organization during construction of expressways and urban roads. For micro study on traffic organization in the construction area, reference shall be made to the study method for urban road entrance/exit management. In this paper VISSIM simulation will be employed to compare and assess entrance/exit schemes during construction of the underpass tunnel beneath Xingsheng Road (see Fig. 1) from the perspective of the effect on surrounding traffic.

In this paper two schemes for entrance/exit layout will be discussed. Under Scheme 1, large trucks turn left into the construction area after passing the pedestrian crossing signal ahead of the construction area, and turn right into the artery before the pedestrian crossing signal in the opposite-direction street. Under Scheme 2, large trucks travel on the left side before the pedestrian crossing signal into the construction area, and turn right into the artery after the pedestrian crossing signal in the opposite-direction street.
As shown in Figure 2, for large trucks entering the construction area, scheme 2 makes the lane changing track more smooth and avoids secondary parking at the signal light. In scheme 1, although the lane change track is shorter, the lane change can be carried out with the help of the characteristics that social vehicles usually slow down at the signal lights. For large trucks leaving the construction area, there is little difference between scheme I and scheme II.

![Fig. 2 VISSIM road network under two entrance/exit layout schemes (Scheme 1 on the left side; Scheme 2 on the right side)](image)

3.2. Parameter selection
The simulation environment is created in the following order: set vehicle type group; build vehicle behavior model; set traffic flow composition; create road network; enter traffic flow OD and intensity; set vehicle travel route; add traffic lights; set bus stop and route; and select traffic efficiency indicators.

The artery traffic intensity is entered as follows: unidirectional traffic volume on the artery is 600, 1500, 3000, 4000 and 6000veh/h respectively; buses operate at a frequency of 1 bus/minute. Under this traffic environment, 100 parallel simulation tests are performed.

4. Result Analysis

4.1. Result of entrance/exit point selection
The output from 100 VISSIM parallel simulations under unidirectional traffic volume of 600, 1500, 3000, 4000 and 6000veh/h is the distribution of traffic efficiency indicators on the artery (in both directions) where the underpass tunnel is located. Medians are taken for the purpose of comparison. These indicators are average delay for cars (sec), average delay for buses (sec) and maximum queuing length on artery (m). The comparison of traffic efficiency indicators in both directions on the artery under the two schemes is displayed below.
Based on analysis of the above data, the impact on the artery is generally smaller under Scheme 2 than under Scheme 1, especially from north to south, i.e. the direction in which large trucks enter the construction area. The impact on the artery varies little under the two schemes from south to north, i.e. the direction in which large trucks leave the construction area.

However, in the case of excessively high section traffic volume the effects under the two schemes are similar, i.e. ineffective optimization of entrance/exit point. As a result, in order to prevent excessive traffic volumes on the artery where the tunnel is located from invalidating the construction area entrance/exit organization scheme, study is needed on how to divert traffic around the tunnel during its construction so as to relieve traffic pressure on the artery, in addition to entrance/exit point optimization.

5. Conclusions
The diversion strategy for traffic around the artery where the underpass tunnel is located is developed for the possible influence zone of tunnel construction. In actual applications, depending on the traffic influence zone of tunnel construction the following conclusions are drawn:

(1) During construction of the pivotal tunnel, the entry of trucks to the construction area near the "left-in left-out" entrance and exit will significantly affect traffic on the artery where the tunnel is located whereas exit of the trucks from the construction area will have an insignificant impact on the traffic on the artery.

(2) The flow line scheme under which trucks change lanes in advance at the entrance to the construction area is optimal. However, in the case of excessive artery traffic volumes, the construction area entrance/exit organization scheme will be invalidated. Therefore, traffic diversion is needed around the tunnel during its construction to relieve traffic pressure on the artery, in addition to entrance/exit point optimization.

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