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Discussion on Traffic Organization Design for the Expansion and Reconstruction of Highway Interchanges

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Abstract: As a critically important transportation infrastructure in China, highways play a significant role in supporting socio-economic development. However, due to the rapid growth of the current socio-economic landscape and the dramatic increase in the number of cars, many early-built highways have experienced a surge in traffic volume, making it difficult to meet the growing traffic demand. This has led to various issues such as traffic congestion and inefficient operation. Therefore, it is necessary to expand and reconstruct the highway interchanges, effectively optimizing traffic organization design and significantly improving the overall service level of the highway. This article provides a detailed analysis of the principles and key points of traffic organization design for the expansion and reconstruction of highway interchanges. Additionally, it delves into the design scheme for the traffic organization of these interchanges.

Keywords: Highway; Expansion and reconstruction; Interchange; Traffic organization design

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1. Introduction

Vehicles traveling on highways must strictly adhere to relevant standards and actual road conditions for lane changing. However, this process may be complicated by various factors such as insufficient roadside space and obstructed vision, increasing driving difficulty, and lead to significant fluctuations in driving speed [1]. Thus, only by expanding and reconstructing corresponding sections of the highway can we minimize traffic conflicts and reduce interference with transportation, thereby further improving the application and operational efficiency of the highway. Nevertheless, China has been late in applying highway expansion and reconstruction, and there are currently no specific standards and norms for traffic organization in this regard [2]. Consequently, relevant personnel must ensure effective road organization and management to enhance the practical application efficiency of highways and improve road service quality and performance.

2. Principles of traffic organization design for highway expansion and reconstruction of interchanges

2.1. Environmental protection principle

Highway expansion and reconstruction projects will inevitably have some impact on the surrounding environment. Therefore, it is imperative to implement the principle of environmental protection in the traffic organization design process. For instance, measures should be taken to minimize noise, dust, and other pollution during the construction phase, and targeted protective and remedial measures should be adopted to effectively protect the living environment and quality of life of surrounding residents [3]. Additionally, the route alignment should be reasonably planned in the design of interchange traffic organization to avoid damaging environmentally sensitive areas. Relevant staff should also focus on green design, planting suitable vegetation around interchanges and in the central median, which can not only enhance the aesthetic appeal of the environment but also contribute to noise reduction, dust prevention, and air purification [4].

2.2. Safety principle

Safety is a key principle in the traffic organization design process for the expansion and reconstruction of highway interchanges. At the same time, traffic safety during construction and after operation must be fully considered. For example, safety facilities such as traffic signs, markings, and guardrails can be reasonably set up to guide vehicles to drive in an orderly manner, thereby minimizing the probability of traffic accidents. Additionally, prominent warning signs and isolation facilities should be installed in the construction area to ensure the safety of construction workers and passing vehicles [5]. Furthermore, careful design should be given to key areas such as ramps and acceleration/deceleration lanes of the interchange to ensure that vehicles can safely accelerate, decelerate, and turn. The relevant staff should also fully consider the driving characteristics of different vehicle types to clarify the lane width and turning radius, thereby effectively avoiding scratches and collisions between vehicles.

2.3. Economic principle

The cost of traffic organization design and implementation should be minimized while meeting traffic demand. On the one hand, existing road facilities and resources should be reasonably utilized to reduce unnecessary demolition and reconstruction work. For example, roads with good structural conditions can be modified and reinforced to meet new traffic demands, avoiding large-scale demolition and reconstruction. On the other hand, the construction plan and traffic organization design should be continuously optimized and improved to reduce construction duration and traffic control time, thereby lowering construction costs and socioeconomic losses. Additionally, when selecting traffic facilities and equipment, cost-effective products should be chosen through comparison [6].

2.4. Smoothness principle

Maintaining traffic smoothness is an important aspect of traffic organization design. Therefore, during the design process, efforts should be made to minimize the interference and impact of construction on traffic, ensuring smooth traffic during construction. Clear planning of the construction situation, sequence, and traffic diversion routes can reduce traffic congestion. Additionally, in the traffic organization design process for the expansion and reconstruction of highway interchanges, not only should the traffic flow be effectively optimized and improved, but also conflicts between vehicles should be minimized to improve driving efficiency [7]. For example, reasonable traffic organization design measures can be adopted to effectively separate vehicles traveling in different directions. At the same time, the change in traffic flow should be fully considered, and the number of lanes should be reasonably set to ensure that traffic demand can be fully met during peak hours.

3. Key points of traffic organization design for the expansion and reconstruction of highway interchanges

3.1. Understanding the current traffic situation

Before carrying out traffic organization design work, relevant staff must have a detailed understanding and investigation of the existing interchange traffic conditions. This mainly includes the setting of traffic signs and markings, the number and width of lanes, and the actual use of traffic facilities at the interchange. At the same time, the staff should also investigate the distribution of surrounding roads, traffic flow, and traffic capacity. Through investigation and understanding of the current traffic conditions, problems and deficiencies can be identified, and targeted solutions can be provided for traffic organization design work. For example, if it is found that a certain ramp of the existing interchange often experiences traffic congestion, it is necessary to analyze the actual reasons for the congestion, such as insufficient number of lanes, unreasonable setting of traffic signs, or other factors, so that corresponding measures can be taken to improve and optimize it, thereby reducing the probability of traffic congestion [8].

3.2. Reasonable setting of traffic facilities

The reasonable setting of traffic facilities is also the key to ensuring the effective implementation of the traffic organization design scheme. During the expansion and reconstruction of the interchange, traffic facilities such as traffic signs, markings, guardrails, and signal lights should be reasonably set according to the traffic organization design scheme. It is necessary to ensure that the location of traffic signs is reasonable and the information is clear, to correctly guide drivers. Additionally, the setting of markings must comply with national standards and be clear and eye-catching to standardize the driving trajectory of vehicles. Furthermore, relevant staff should pay attention to the maintenance and management of traffic facilities to ensure the normal operation of equipment [9].

4. Traffic organization design scheme for the expansion and reconstruction of highway interchanges

4.1. Subgrade construction

During the implementation of highway expansion and reconstruction projects, both unilateral and bilateral widening will directly affect and interfere with the normal operation of the highway. Moreover, the process of removing existing isolation belts will significantly reduce the control of horizontal traffic and lead to increased traffic chaos in the construction area, thereby increasing the risk and probability of traffic accidents to some extent. To ensure the safe and smooth operation of the highway, it is necessary to install isolation belts and prominent warning signs at key locations. Additionally, roadbed construction and road surface construction are mutually supporting and complementary links, and in highway expansion and reconstruction projects, the roadbed and road surface are typically the core focus. Therefore, unilateral roadbed widening without change and separate construction on both sides of the roadbed are two commonly used methods. During the actual construction process, the following strategies can be adopted for traffic organization design: Firstly, maintain the existing guardrail positions unchanged, reasonably adjust the isolation belt positions, and expand outwards, keeping the expansion area on both sides of the road to minimize interference and impact on the original road traffic. Secondly, during the splicing construction of the roadbed, it is necessary to use isolation fences to separate the roadbed on both sides and optimize and improve the corresponding traffic organization design to further enhance the operational efficiency of the highway.

4.2. Pavement construction

The most common practice during pavement construction on highways is to implement fully closed construction and divert traffic to other roads or use opposing lanes to effectively disperse traffic flow. However, such construction methods undoubtedly have a significant impact on the normal operation of the highway. Therefore, when carrying out pavement widening projects on both sides, pavement zoning and half-width construction measures can be applied. The specific construction measures are as follows: Firstly, relevant operators must follow the relevant norms and standards for highway expansion and reconstruction, and implement the construction of the expansion area step by step to ensure a deep understanding and control of the overall situation of the expansion and reconstruction section. This allows for accurate delineation of the specific locations and spacing of each construction area. Additionally, the application of half-width construction measures in highway expansion and reconstruction projects enables the rational use of opposing lanes to effectively transfer and disperse traffic flow. Vehicles return to their original lanes after passing through the construction area, and drivers must slow down to ensure safe driving. Furthermore, prominent protective fences and traffic indication signs should be set up in the construction area to ensure smooth traffic operation on the highway [10].

4.3. Interchange construction

Interchanges on highways are mainly divided into two types: interconnected interchanges and separated interchanges. Among them, separated interchanges can provide convenience for the diversion and transfer of traffic flow by setting up temporary passages. However, interconnected interchanges are more common on highways. They not only enable effective combination and connection of route networks in different directions but also allow reasonable distribution and merging of vehicles, thereby significantly improving vehicle operation efficiency. Additionally, during the implementation and construction of interconnected interchanges, it is necessary to ensure the smooth progress of construction work while minimizing the impact on the service quality of the interchanges. Therefore, construction managers need to reasonably divert vehicles upstream and downstream of the interchanges based on different vehicle types and speeds, thereby alleviating traffic pressure in the construction area.

Furthermore, specific measures for traffic organization design during the actual implementation of interchange expansion and reconstruction work include the following two aspects: Firstly, when performing unilateral widening of single-trumpet interconnected interchanges, the design should maintain the original trumpet shape of the interconnected interchange and expand on the outer side of the existing ramp. Half-width closure can be implemented on the original ramp to manage traffic flow using half-width lanes and temporary access roads. After construction is completed, fences should be removed promptly, and road markings and infrastructure should be reset for the interconnected interchange. Secondly, when performing bilateral widening of trumpet-shaped interconnected interchanges, it is necessary to complete the relevant construction work on the pavement, bridges, and other aspects on both sides of the original highway before the expansion and reconstruction work begins. Temporary access roads should then be built for vehicle traffic, thereby minimizing the impact of the expansion and reconstruction work on highway traffic.

4.4. Bridge construction

When designing the expansion and reconstruction of highway bridges, it typically involves various aspects such as culverts, bridges, and underground passages. Meanwhile, there is often a certain similarity and universality in the traffic organization design and traffic organization plans during the expansion of highway bridges. Moreover, during the actual expansion and reconstruction of highway bridges, uneven settlement easily occurs between the newly constructed parts and the existing bridges, which may cause stepped cracks at the junction of the old and new bridges. This issue is quite common in highway bridge expansion and reconstruction projects. Therefore,

during the expansion and reconstruction of highway bridges, construction activities at both ends of the bridge must be adjusted according to core data such as the actual bearing capacity of the bridge and vehicle traffic. Additionally, the construction plan must ensure coordination among various parts to guarantee a smooth connection between the bridge and the road. Furthermore, when constructing the substructure on both sides of the bridge, it is necessary to simultaneously construct the roadbed on both sides of the road. Road surface construction can only be carried out according to relevant standards and regulations after the completion of roadbed construction. During the construction process, relevant staff must base their work on the specific requirements and relevant specifications for roadbed and road surface construction, to maintain highway traffic order and promote the further development and construction of the transportation industry.

4.5. Service area construction

Although the expansion and reconstruction of highway service areas have a relatively minor impact on traffic, these service areas, as an important part of the highway, cannot be ignored. To ensure that vehicles can normally refuel and rest in the service area, it is necessary to carry out scientific and reasonable planning for the traffic organization of the service area during the expansion and reconstruction process. The traffic organization design for the construction of highway service areas can typically be divided into two stages. The first stage involves construction work on the roadbed and road surface on both sides of the road, while keeping the service area entrance and exit unchanged and ensuring its normal operation and application. Secondly, to expand the entrance and exit of the service area, vehicles are required to slowly queue on both sides of the road to enter or leave the service area. After the expansion of the entrance and exit is completed, the temporary fencing can be removed, and traffic signs, markings, and related traffic guidance facilities can be restored.

5. Conclusion

The traffic organization design for the expansion and reconstruction of highway interchanges is a relatively difficult engineering task, involving multiple fields such as traffic engineering, road engineering, and construction organization. During the design process, it is necessary to follow principles such as environmental protection, safety, economy, and smoothness, while adopting scientific design methods and combining actual situations to formulate reasonable traffic organization design plans. Additionally, through the analysis of common traffic organization design plans and case studies of engineering examples, it can be seen that reasonable traffic organization design can effectively solve the traffic problems of interchanges during the expansion and reconstruction of highways, ensure the safety and smoothness of traffic during construction, and significantly improve the operational efficiency of interchanges on expanded and reconstructed highways.

Disclosure statement

The author declares no conflict of interest.

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