

# Research on Key Technologies for Traffic Organization in the Reconstruction and Expansion of Complex Interchanges and Elevated Lifting Sections

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**Abstract:** Complex interchanges and elevated lifting sections represent critical nodes in the reconstruction and expansion projects of expressways and urban express roads, characterized by the most intricate structures, highest risks, and greatest traffic disruptions. Under conditions of heavy network traffic, limited construction space, frequent structural transitions, and interweaving multi-directional traffic flows, conventional traffic organization methods struggle to ensure both construction safety and network efficiency. To systematically address core challenges such as traffic dispersion, safety management, construction transitions, and network coordination faced during the reconstruction and expansion of complex interchanges and elevated lifting sections, this paper outlines the engineering characteristics and traffic pain points of these projects. It proposes key technologies for traffic organization in both complex interchange reconstruction and elevated lifting section reconstruction, aiming to provide technical references for similar complex node reconstruction projects. These technologies hold significant engineering value in enhancing traffic safety during construction, reducing congestion risks, and ensuring the smooth operation of the road network.

**Keywords:** Complex interchange; Elevated lifting section; Reconstruction and expansion; Traffic organization; Traffic transition; Safety management; Road network coordination

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## 1. Introduction

After years of operation, early-built expressways in China generally face issues such as saturated capacity, degraded service levels, and structural aging. Reconstruction and expansion have become the primary means to enhance the service capacity of the road network<sup>[1]</sup>. In reconstruction and expansion projects, complex interchanges and elevated lifting sections, due to their critical functions, dense structures, and strict alignment controls, have emerged as core nodes that constrain the overall project duration and safe operation. These

nodes are typically located at the heart of regional road networks, experiencing heavy traffic volumes and complex vehicle compositions. Moreover, construction must proceed under the condition of “traffic flowing while construction is ongoing,” making the traditional half-closure construction mode prone to causing long-distance congestion, traffic accidents, and construction safety hazards. With the advancement of regional integration, the functions of expressway interchanges are becoming increasingly complex, and the demand for elevated lifting reconstruction is on the rise. Traffic organization is no longer a simple road section management task, but requires coordinated linkage among mainlines, ramps, parallel road networks, and local roads. Based on the reconstruction and expansion project practice of the Wenzhou Nanbaixiang to Zhejiang-Fujian Border Section of the Yong-Tai-Wen Expressway, this paper systematically analyzes the engineering characteristics, traffic impacts, and risk sources of complex interchanges and elevated lifting sections. It refines key technologies for traffic organization, providing implementable and replicable technical solutions for similar projects.

## **2. Engineering characteristics and traffic impacts of reconstruction and expansion projects for complex interchanges and elevated lifting sections**

### **2.1. Engineering structural features**

Complex interchanges and elevated lifting sections exhibit distinct technical characteristics in reconstruction and expansion projects, which are also the fundamental reasons for the difficulty in traffic organization. Complex interchanges are mostly hub interchanges or composite interchanges, undertaking multi-directional conversion functions between expressways and expressways, as well as between expressways and urban express roads. The mainlines and ramps crisscross, with dense bridge structures and strict horizontal and vertical alignment indicators <sup>[2]</sup>. During the reconstruction and expansion process, it is often necessary to carry out demolition and reconstruction, in-situ splicing, off-site relocation, or synchronous implementation with the ongoing hub projects. The connection between old and new structures is complex, and construction procedures are highly overlapping. Elevated lifting sections are mainly constructed to meet clearance control, alignment optimization, or urban development needs. They involve raising the overall longitudinal profile of the existing subgrade or bridge, transforming the subgrade into an elevated structure. The construction process includes a series of procedures such as old bridge demolition, pile foundation construction, scaffold erection, beam and slab installation, and splicing of new and old bridge decks. The lifted sections are usually long, with a continuous construction period, and are closely adjacent to existing roads, resulting in extremely limited working space. Both types of nodes collectively present characteristics such as diverse structural forms, complex connections between old and new structures, narrow construction space, high demand for temporary works, and frequent overlapping of construction procedures. A fully closed construction mode cannot be adopted, and construction must proceed while ensuring traffic flow, highlighting the prominent contradiction between traffic and construction.

### **2.2. Main impacts of construction on traffic operations**

Reconstruction and expansion construction will alter the traffic operation state from multiple aspects such as traffic capacity, driving conditions, and road network distribution <sup>[3]</sup>. Firstly, there is a significant decline in traffic capacity. Construction occupies existing lanes, reduces the lateral clearance, and sets up long-term work zones, resulting in a decrease in the number of mainline lanes and a reduction in speed limits, leading

to an obvious reduction in overall traffic capacity. Moreover, driving conditions deteriorate. The alignment in the construction area is frequently adjusted, lanes become narrower, and visibility is limited. Vehicles need to change lanes, merge, and diverge multiple times, substantially increasing the driving workload. Meanwhile, the traffic disturbances caused by construction will quickly spread to the regional road network. Congestion on the mainline will directly lead to a sudden increase in traffic volume on parallel national and provincial roads, ring expressways, and connecting lines, causing local road sections to quickly reach saturation and resulting in road network-wide congestion. In addition, construction activities such as high slope excavation, bridge hoisting, and steel bar processing are adjacent to the driving lanes. Mechanical operations and personnel movement directly interfere with passing vehicles, further exacerbating the instability of traffic operations.

### **2.3. Main risk points in traffic operations**

Under the combined effects of high traffic volume, strong interference, and multiple conversions, traffic operations during the construction period of complex interchanges and elevated lifting sections exhibit obvious high-risk characteristics as follows:

- (1) There is the risk of multi-directional traffic flow intersection and conflict. In the interchange area, mainline traffic, ramp traffic, and turning traffic frequently converge in a narrow space. With insufficient acceleration and deceleration distances, rear-end and scraping accidents are prone to occur;
- (2) There are driving risks associated with sudden alignment changes. In traffic conversion sections, S-shaped transitions, mismatched cross slopes, and lane offsets are formed, making vehicles prone to deviating from their lanes, especially at night and in rainy weather;
- (3) Emergency rescue is difficult. With lane closures and insufficient emergency space in the construction area, it is challenging to quickly clear obstacles in case of an accident, which can easily lead to long-distance congestion and secondary accidents <sup>[4]</sup>;
- (4) There is the risk of wrong-way driving due to inadequate temporary facilities. Incomplete temporary signs, protections, and lighting, along with drivers' unfamiliarity with temporary routes, can lead to wrong-way and reverse driving;
- (5) There are risks associated with the management and control of large vehicles. The proportion of trucks in the project road section is high. With their long bodies, high centers of gravity, and long braking distances, their safety is significantly reduced in speed-restricted, lane-changing, and turning sections.

## **3. Key technologies for traffic organization in the reconstruction and extension of complex interchanges**

### **3.1. Staged traffic conversion organization technology**

Staged traffic conversion is the core aspect of reconstruction and extension projects for complex interchanges and is crucial for ensuring smooth traffic flow. During actual construction, the overall approach of “ensuring traffic flow first, then proceeding with construction; constructing new structures first, then demolishing old ones” is consistently followed. Based on the interchange type and traffic flow characteristics, the entire renovation process is clearly divided into four key stages: subgrade widening, ramp construction, structural demolition and reconstruction, and full-line conversion. The dynamic balance between construction areas and traffic flow at each stage is precisely controlled to avoid interference between construction and traffic movement.

For interchange nodes requiring demolition and reconstruction, priority is given to planning and constructing temporary bypass ramps or temporary passage structures before construction begins. Traffic is smoothly redirected from existing routes to temporary passages through guidance. Once traffic is fully diverted and stable, demolition of old structures can commence, minimizing the impact on mainline and ramp traffic and avoiding prolonged traffic interruptions. For complex hub interchanges with multiple connecting routes and concentrated traffic flows, an end-modification and phased construction approach is adopted. Normal traffic flow on the mainline and major ramps is prioritized, with temporary control measures implemented only in localized areas requiring renovation. This reduces the scope of control measures and minimizes the impact on the regional road network.

For continuous interchanges with close spacing, simultaneous construction can easily cause congestion in the regional road network. In practice, an alternating closure and staggered construction strategy is employed, reasonably staggering the closure times of adjacent interchanges to avoid simultaneous traffic interruptions and effectively reducing the diversion pressure on the regional road network. For key processes such as ramp bridge demolition and reconstruction and overpass mainline bridge modifications, which significantly impact traffic, a half-closure construction method is used, allowing two-way traffic on the other half. Reasonable transition zones and gradual lengths are set up, along with optimized traffic guidance signs, to ensure smooth and continuous traffic flow without sudden braking or lane-cutting, thereby eliminating safety hazards. Throughout the traffic conversion process, the principles of “uninterrupted traffic flow, minimal road closures, short closure durations, and rapid conversions” are upheld, achieving deep coordination between traffic and construction organizations and ensuring that both construction and traffic flow proceed smoothly without mutual interference.

### **3.2. Multi-directional traffic diversion and control technology**

The construction sites of complex interchange reconstruction and extension projects are characterized by a diverse range of traffic flows, including long-distance through traffic, interval traffic, and short-distance distribution traffic, with frequent crossings and interweaving, making them prone to congestion and safety hazards. Therefore, an integrated diversion system must be established, incorporating “source induction, road network diversion, hierarchical control, and vehicle-type restrictions” to achieve precise control and scientific diversion of various traffic flows.

In specific implementation, traffic induction points are set up at distant hub interchanges. Construction information is disseminated in advance through signs and electronic display screens, guiding long-distance through traffic to bypass parallel expressways such as the Yongguan Expressway and Wenzhou Ring Expressway, thereby reducing traffic pressure in the construction area from the source. At interchanges upstream of the project, diversion points are established with dedicated personnel on duty to forcibly divert traffic approaching the construction area and prevent a concentrated influx into the construction section. At the entrance of the construction interchange, control points are set up to implement real-time flow control and vehicle-type restrictions based on construction progress and on-site traffic capacity, ensuring that traffic in the construction area remains within controllable limits.

Based on regional road network conditions, different types of traffic flows are diverted accordingly: long-distance through traffic is prioritized for diversion to parallel expressways to ensure its efficiency; interval traffic relies on hub interchanges and connecting lines for rapid conversion, reducing detour

distances; and short-distance distribution traffic is diverted using national and provincial roads and urban roads for the convenience of the public. In terms of vehicle-type control, the principle of “prioritizing the diversion of trucks and the passage of passenger vehicles” is followed. Large trucks are diverted remotely to prevent them from entering the construction area, reducing safety pressures and traffic congestion. Meanwhile, dynamic entrance control measures are implemented, with intermittent release of traffic at local interchanges during peak hours to reasonably control mainline traffic density, prevent overflow congestion in the construction area, and ensure orderly traffic flow.

### **3.3. Safety protection and facility layout technology**

The construction sites of complex interchange reconstruction and extension projects feature dense work points, concentrated personnel and machinery, and interweaving traffic flows with construction areas, posing high safety risks. Therefore, a standardized and integrated safety protection system must be adopted to comprehensively prevent construction and traffic safety hazards and ensure the safety of construction personnel, equipment, and passing vehicles <sup>[5]</sup>.

According to traffic engineering construction specifications, warning zones, transition zones, buffer zones, work zones, and termination zones are uniformly set up in the construction area. The lengths of each zone are strictly controlled in accordance with standards, ensuring that gradual lengths, isolation facilities, and speed limits are mutually matched to form a complete safety protection chain. High-grade anti-collision movable barriers are used at the edges of work zones to achieve hard isolation between the construction area and the roadway, effectively preventing vehicles from accidentally entering the construction area and protecting construction personnel and machinery. For key areas with poor visibility and frequent traffic interweaving, such as ramp curves, downhill sections, and merging zones, additional deceleration markings, reflective warning facilities, and nighttime lighting equipment are installed to enhance visibility at night and in adverse weather conditions, guiding drivers to decelerate in advance and proceed with caution. Fully enclosed protection measures are adopted for high-risk work areas such as bridge edges and high slopes, prohibiting unauthorized personnel and vehicles from entering. During construction, blasting is strictly prohibited, and mechanical excavation methods are prioritized to avoid falling objects from blasting operations that could damage passing vehicles and interrupt traffic. Traffic monitoring equipment and information dissemination equipment are installed at key construction nodes to monitor traffic flow and road conditions in and around the construction area in real-time, promptly disseminate road condition information, speed limits, and congestion warnings, achieve proactive safety warnings, and guide drivers to reasonably adjust their driving speeds and routes, reducing safety risks caused by driver errors.

## **4. Key technologies for traffic organization in the reconstruction and extension of elevated sections**

### **4.1. Traffic conversion technology for elevated construction**

Traffic conversion for elevated construction must be tailored to local conditions, flexibly adopting differentiated modes such as bypass road diversion, outer-side super-widening and splicing, half-width alternating construction, and separation of new and old alignments based on the functional positioning of the road section, elevation height, and existing structural forms to achieve a dynamic balance between construction and traffic flow.

For long-distance overall elevation of main road sections with high traffic density and demand, priority is given to constructing solid temporary bypass roads on both sides of the mainline. Vehicles are guided to bypass the construction area through complete signs and markings, allowing for full closure of the mainline for construction. This approach completely separates the construction area from traffic flow, avoiding cross-interference and creating a safe environment for high-precision elevation operations. For medium-length elevated sections, an “outer-side super-wide splicing” scheme is adopted. The outer-side newly added bridge structure is constructed and opened first. Once it meets traffic conditions, the inner-side old bridge is gradually demolished and elevated and renovated. Traffic flows bidirectionally in the splicing section, effectively reducing the closure scope and minimizing the impact on the surrounding road network. For general road sections with open terrain, a conventional “two-side widening and half-width alternating” traffic maintenance mode is adopted. Half of the lanes maintain normal bidirectional traffic flow, while the other half is used for bridge elevation construction, progressing segment by segment and restoring traffic segment by segment to ensure that the overall road network continuously meets basic traffic capacity requirements. At nodes where new and old alignments overlap and construction space is extremely limited, a two-way two-lane traffic maintenance standard is adopted, significantly reducing the traffic section and strengthening segmented control to prioritize meeting the public’s traffic needs. All traffic conversion links must strictly adhere to the technical standards of “advance notice, smooth transition, opposite-direction hard isolation, and unified speed limits.” The alignment of transition sections must be continuous and smooth, and central isolation facilities must be sturdy and reliable to eliminate safety hazards caused by opposite-direction collisions and lane changes from the source.

#### **4.2. Safety protection technology for elevated work zones**

Elevated construction is a typical high-altitude edge work, and safety protection must focus on “preventing falls, preventing overturning, and preventing intrusion” to build a comprehensive and multi-layered protection system. High-strength, high-toughness protective railings must be set up on the side of the work bridge deck, with dense mesh safety nets fully hung to form a closed physical barrier. Key facilities such as scaffolding, formwork, and large lifting equipment must be equipped with sufficient anti-overturning devices to ensure structural stability. Construction materials are subject to zoned centralized stacking and enclosed management to eliminate the risk of falling objects from high altitudes. When roads are still in use below the elevated section, a sturdy anti-fall protection shed must be erected across the entire section to achieve absolute physical isolation between the construction area and ground traffic. In terms of traffic control, a unified speed limit is implemented across the entire line. The conventional speed limit is 80 km/h, which is further reduced in key sections such as bridge elevation, traffic conversion nodes, and tunnel transitions. Large vehicles are mandated to keep to the right and are prohibited from overtaking to reduce lateral traffic interference with the construction area. Nighttime construction requires full-coverage continuous lighting, strobe warning lights, and delineators to enhance nighttime visibility. In case of severe rain, strong winds, or other adverse weather conditions, high-altitude work must be immediately suspended, and the work zone must be closed to guide vehicles to bypass, ensuring absolute safety.

#### **4.3. Integrated traffic organization technology for upper and lower layers**

Elevated sections are mostly grade-separated projects, and their construction organization must be integrated with the lower-level ground roads and urban main roads to achieve upper-lower coordination

and simultaneous diversion. The construction of the upper elevated section and the diversion routes of the lower roads must be uniformly planned and implemented simultaneously, strictly avoiding simultaneous bottlenecks for upper and lower traffic during the same period. For key processes such as beam installation and large-volume concrete pouring, which occupy a long time and have a wide impact range, construction plans must be carefully arranged to avoid peak ground traffic hours as much as possible, minimizing interference with public travel. Meanwhile, an upper-lower traffic emergency linkage mechanism must be established. Emergency rescue channels must be uniformly planned and reserved to enable rapid linkage and obstacle clearance in case of traffic accidents, preventing concurrent congestion on upper and lower sections and regional road network paralysis. Additionally, parallel expressways, national and provincial roads, and surrounding urban road networks must be fully utilized as diversion channels to implement balanced diversion and avoid excessive concentration of traffic flow in the construction section. Through scientific regulation, the load on the regional road network can be evenly distributed, comprehensively improving overall traffic reliability and risk resistance.

## 5. Conclusion

Complex interchanges and elevated sections are the most complex and safety-risk-prone key nodes in expressway reconstruction and extension projects. The core conflicts lie in the spatial conflict between high-intensity construction and high-volume traffic flow and the temporal conflict between frequent structural conversions and continuous traffic flow. Practice has shown that adopting systematic traffic organization technologies can achieve the goals of uninterrupted mainline traffic, reduced congestion, lower accident rates, and orderly construction progress, thereby ensuring the smooth implementation of reconstruction and extension projects while minimizing the impact on social traffic. This technology system is applicable to the reconstruction and extension of complex nodes on coastal high-volume expressways and can provide reliable references for similar domestic projects. With the development of intelligent transportation and vehicle-road coordination technologies, future traffic organization during construction periods will upgrade towards dynamic perception, real-time regulation, and global coordination, further enhancing safety levels and traffic efficiency.

## Disclosure statement

The authors declare no conflict of interest.

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