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Research on Traffic Guidance and Safety Management in Municipal Road Construction

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Abstract: This article focuses on the safety management of traffic guidance in the construction of municipal roads, Bridges and open-cut tunnels. An in-depth analysis was conducted on the interference and influence of road and bridge construction and open-cut tunnel construction on traffic, and corresponding traffic diversion countermeasures were proposed specifically. The management framework based on safety system engineering and the application of information management technology therein are systematically introduced. Through the elaboration of traffic organization schemes in multiple actual engineering cases, the existing problems at present are clarified, and the application prospects of new technologies are prospected.

Keywords: Municipal road and bridge; Traffic guidance; Safety management

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1. Introduction

With the acceleration of urban construction, municipal road and bridge construction is becoming increasingly frequent, and its traffic diversion and safety management are crucial. The “Several Opinions on Strengthening Urban Infrastructure Construction” released in 2022 emphasizes the importance of ensuring smooth and safe urban transportation. Common construction methods such as road and bridge construction, as well as open cut tunnel construction, will inevitably cause varying degrees of interference to surrounding traffic during the construction process. How to efficiently carry out traffic diversion and safety management to reduce the impact of construction on traffic, ensure smooth and safe traffic, has become an urgent problem to be solved. In recent years, BIM technology, the Internet of Things (IoT) and other emerging technologies have emerged in the field of traffic facilitation. Although there are still problems such as poor fusion of monitoring data and low efficiency of cross sectoral collaboration, the application prospects of new technologies such as 5G vehicle road collaboration and edge computing are highly anticipated, which is expected to open up a new path for the safety management of traffic facilitation in the construction of municipal roads and bridges.

2. Analysis of traffic diversion characteristics in municipal road and bridge construction

2.1. Characteristics of traffic organization in road and bridge construction

During the construction of roads and bridges, traffic organization faces many complex situations. The layout of the construction area is intertwined with the traffic flow, especially when the construction site is located on a main urban road. The traffic flow is large and diverse, and a slight mistake can lead to widespread traffic congestion [1,2]. During bridge construction, due to the need to occupy part of the bridge deck or set up temporary support structures, the traffic space will be directly reduced. This requires advance planning of vehicle diversion routes and pedestrian passages, reasonable setting of traffic signs and isolation facilities, guiding vehicles and pedestrians to safely and orderly navigate around the construction area, in order to maintain basic smooth traffic.

2.2. Difficulties in traffic relief in the construction area of open cut tunnels

There are many difficulties in traffic evacuation in the construction area of open cut tunnels. On the one hand, the in-situ protection of pipelines limits the layout of work surfaces. There are often numerous important underground pipelines distributed in the construction area. In order to avoid damage to the pipelines during construction, the work area must avoid these pipelines, which further limits the already limited construction space and brings great inconvenience to the formulation and implementation of traffic diversion plans, as well as hindering the progress of construction [3]. On the other hand, the dynamic adjustment of construction fences needs to be closely coordinated with traffic signals. With the continuous deepening of open cut tunnel construction, the position of the fence needs to be adjusted in a timely manner according to the construction process. Each change in the fence may affect the distribution and direction of traffic flow. If it cannot be coordinated with the setting of traffic signals, it is easy to cause traffic chaos and increase the difficulty of traffic diversion.

3. Typical construction scene safety management practices

3.1. Road and bridge construction cases

3.1.1. Traffic organization plan design

This project is the G205 national highway overpass renovation project, with a total construction length of 1.2km. As the core main road of the city, the daily average traffic volume before construction reached 18000 vehicles, of which the morning peak traffic volume was as high as 6000 vehicles per hour. The project involves the construction of continuous variable cross-section box girders with cast-in-place bridge supports, which requires occupying half of the roadway for a continuous period of 6 months. In the first week of construction, due to the lack of a detailed diversion plan, the congestion duration during the morning rush hour increased from 40 minutes before construction to 1.5 hours, and the average speed of the road section decreased from 35km/h to 12km/h (**Table 1**).

Table 1. Comparison of traffic parameters on National Highway G205 before and after construction

Indicator	Before construction (morning peak)	Initial construction phase (unoptimized)	After plan optimization (morning peak)
Traffic volume (vehicles/hour)	6000	5800	5800
Average speed (km/h)	35	12	25
Congestion duration (minutes)	40	90	30

The number of complaints from citizens increased by 200% compared to before construction. To address the aforementioned issues and ensure that traffic does not become paralyzed during the construction period, the project has developed a comprehensive traffic organization plan. In the early stage of construction, conduct a comprehensive and in-depth analysis of the traffic flow, direction, peak hours, and other data of G205 National Highway, and determine a reasonable traffic diversion route based on the data. Clear and prominent signage should be set up on both sides of the bridge to guide vehicles to divert in advance and avoid traffic accumulation in the construction area. At the same time, assign a dedicated person to be responsible for traffic diversion, especially during peak traffic periods, to command vehicles to pass in an orderly manner in a timely manner. By optimizing the plan, the traffic parameters during the morning rush hour during the construction period have been significantly improved.

3.1.2. Implementation of temporary traffic control measures

The implementation of temporary traffic control measures is equally crucial during the construction of roads and bridges. Due to the influence of bridge design clearance on the installation of bridge supports, in order to ensure the safe passage of large vehicles through bridge supports, traffic control notices are issued through various channels such as official websites, traffic broadcasts, and on-site announcements before construction [4]. During the control period, warning posts, isolation belts and other facilities will be set up to block the construction area, and traffic police and construction personnel will be arranged to jointly guard and dissuade and guide vehicles attempting to enter. Through a series of measures, the control effect has been significant: the bypass rate of large vehicles has reached 95%, the number of vehicle intrusion incidents in the construction area has decreased from 3 takeoffs and landings per day to 0, and the incidence of bracket safety accidents is 0. This not only ensures construction safety but also minimizes interference with traffic.

3.2. Construction case of open cut tunnel

3.2.1. Coordination between pipeline protection and traffic organization

In the construction project of open cut tunnels in urban central areas, there is a challenge of coordinating in-situ protection and traffic diversion for numerous underground pipelines. Before construction, a detailed survey was conducted on the distribution of pipelines in the construction area. Personalized suspension protection plans were developed for municipal pipelines of different diameters and materials to ensure that the pipelines were not damaged during the construction process. On this basis, traffic organization was optimized by combining pipeline protection plans with construction area layout. We have adopted a partial enclosure and phased construction approach for the construction area near the pipeline, and reasonably planned the driving routes of vehicles to ensure that construction and traffic do not interfere with each other, guaranteeing construction safety and smooth traffic.

3.2.2. Optimization of traffic organization in restricted spaces

In response to the limited space and high traffic flow around the mountainous area on the north side of the western section of the open cut tunnel, traffic organization has been optimized. According to the traffic flow characteristics and construction process arrangement of the construction area, traffic control measures have been formulated for different time periods and road sections. During peak traffic hours, prioritize construction processes that have a significant impact on traffic. During peak traffic hours, construction activities should be minimized as much as

possible, and temporary traffic guidance signs and facilities should be added to guide vehicles and pedestrians to avoid the construction area and pass quickly. The use of staggered construction management methods avoids centralized operations during peak traffic periods, effectively alleviating the conflict between construction and traffic, and providing useful reference for traffic diversion and safety management in municipal road and bridge construction. In order to improve the efficiency of the passage of construction vehicles and social vehicles, a wharf slab is built in the open cut tunnel of the confined space section to provide passage for construction vehicles, increase the passage space for social vehicles, and achieve an increase in vehicle passage rate.

4. Construction of traffic diversion safety management system

4.1. Management framework based on security system engineering

To establish a safety management system for traffic diversion in municipal road and bridge construction, a three-level management framework based on safety system engineering is required as follows:

(1) Comprehensively sorting out the potential impact of factors such as changes in traffic flow and construction process conversion on traffic in construction sections, and accurately identifying risk sources [5];

(2) Preparation of contingency plans, based on risk results, to develop scientifically reasonable diversion plans including temporary traffic control, diversion route planning, traffic signal adjustment, etc;

(3) Process monitoring, which utilizes advanced monitoring equipment and technology to real-time control traffic conditions and dynamically adjust diversion measures based on flow and congestion information;

(4) Integrating traffic impact assessment and construction progress management enables the traffic diversion plan to flexibly adapt to construction changes and minimize adverse interference.

4.2. Application of information management technology

BIM technology constructs a three-dimensional model that includes elements such as roads, bridges, and construction areas to achieve visual simulation of traffic evacuation plans. It intuitively presents the surrounding traffic environment and changes in traffic flow during the construction process, identifies potential problems in advance, and optimizes the plan. At the same time, the real-time monitoring and early warning system for traffic flow constructed by IoT technology deploys sensors in the construction area and surrounding areas to collect real-time data on traffic flow (warning threshold > 500 vehicles/hour), vehicle speed (warning threshold < 15km/h), queue length (warning threshold > 200m), etc. Through data analysis and processing, it quickly detects congestion trends and abnormal situations. The average response time of the system is within 5 minutes, and the risk resolution rate reaches 88–92%. Once traffic risks are detected, warning signals are automatically issued, prompting relevant departments to take timely measures to ensure the safety and smoothness of traffic during the construction period.

5. Research on optimization strategies for security control

5.1. Innovation of management mechanism

5.1.1. Dynamic risk assessment mechanism

It is crucial to establish a dynamic risk assessment mechanism in the safety management of traffic diversion during the construction of municipal roads, bridges, and open cut tunnels. There are different risks in different

construction stages, such as traffic congestion caused by frequent concrete transportation vehicles during the pouring stage of road and bridge foundations. During the excavation stage of the open cut tunnel foundation pit, accidents are prone to occur due to disputes between earthmoving vehicles and social vehicles. A dynamic risk assessment model should be constructed based on construction progress, changes in the on-site environment, and fluctuations in traffic flow to quantify risks at each stage [6]. Based on this, we will increase patrols and dispatch personnel to high-risk areas and time periods, allocate resources reasonably, improve the accuracy and effectiveness of safety control, and ensure the safety and smoothness of traffic diversion during the construction period.

5.1.2. Multi party collaborative decision-making platform

Building a collaborative decision-making platform that involves multiple stakeholders, such as construction entities, traffic management departments, and municipal authorities, is of significant importance for enhancing the efficiency of traffic diversion and safety management during municipal road and bridge construction. Construction entities possess detailed knowledge of construction progress and workflow, traffic management departments are responsible for understanding and implementing traffic flow regulations, and municipal authorities have a comprehensive awareness of surrounding road infrastructure and public spaces. Effective collaboration among these parties enables complementary advantages and resource sharing. Through an integrated information-sharing mechanism, stakeholders can access real-time critical data, including construction progress, traffic conditions, and facility maintenance status, thereby supporting scientific and informed decision-making. Furthermore, establishing a joint command center with clearly defined responsibilities and authority allows for rapid response and coordinated action during emergencies, facilitating the timely resolution of traffic congestion and incidents and ensuring the smooth implementation of municipal road and bridge construction projects.

5.2. Application of intelligent technology

5.2.1. Application of digital twin technology

A digital twin system for traffic operations in construction areas should be developed to provide robust support for traffic diversion and safety management during municipal road, bridge, and open-cut tunnel construction. The system employs high-precision digital modeling to accurately replicate the geometric characteristics, physical attributes, and operational states of roads, bridges, transportation facilities, and construction equipment within the construction zone. Real-time data, such as traffic flow, vehicle speed, and queue length, are collected through sensors to drive dynamic model operation, enabling the simulation of traffic flow variations under different control strategies. By evaluating the feasibility and effectiveness of proposed traffic management schemes in a virtual environment, the system can accurately identify potential congestion points and safety risks, including assessing the impacts of traffic control measures on surrounding road networks and optimizing traffic organization within construction areas. This approach provides a scientific and reliable basis for decision-making in traffic diversion and safety management during actual construction, thereby enhancing the foresight and precision of management decisions.

5.2.2. Intelligent traffic guidance system

The intelligent traffic guidance system plays a significant role in traffic diversion during the construction of municipal roads, bridges, and open cut tunnels. One of its core technologies is the linkage between variable

message boards and navigation apps [7]. Set up variable information boards around key road sections in the construction area to release real-time construction information, road condition changes, and traffic control measures; The navigation app synchronously pushes this information to the user terminal. With the help of intelligent algorithms, the system dynamically adjusts the guidance strategy based on real-time traffic flow, construction progress, and user preferences. The variable information board provides intuitive display to assist on-site drivers in making timely decisions, such as slowing down, changing lanes, or taking detours. Navigation apps allow travelers to plan their routes in advance, avoid congestion, and choose the optimal path. This online and offline linkage method significantly improves the accuracy and timeliness of traffic guidance, effectively alleviates traffic pressure during construction, and ensures traffic safety and smoothness.

5.3. Improvement of standard system

5.3.1. Development of grading control standards

In the safety management of traffic diversion during the construction of municipal roads, bridges, and open cut tunnels, the development of graded control standards is the key to achieving refined management. By comprehensively evaluating the importance of road grades, traffic flow and service functions, as well as construction scale, different safety control levels are classified. For example, the renovation of large bridges or the construction of long-distance open cut tunnels on urban main roads need to be classified as high-level control due to the wide range and long duration of traffic impact. Small bridge maintenance or short distance tunnel construction on branch roads can lower the level of control. Develop control standards for different levels, covering measures such as traffic sign installation, personnel allocation for traffic diversion, and monitoring equipment deployment, to form a comprehensive hierarchical control system and ensure scientific and orderly management of traffic diversion safety.

5.3.2. Optimization of emergency response procedures

It is crucial to optimize the emergency response regulations in the safety management of traffic diversion during the construction of municipal roads, bridges, and open cut tunnels as listed:

(1) Refine the process of handling sudden traffic accidents, clarify the operational norms and time limits for information reporting, on-site protection, personnel treatment, traffic control, accident investigation, traffic recovery, and other links, to ensure efficient and orderly emergency response [8];

(2) Establish standards for the construction of specialized emergency rescue teams, standardize the selection, training, and assessment of team members, as well as team structure, equipment allocation, and exercise mechanisms;

(3) Require team members to possess rich experience and professional skills, and regularly conduct practical exercises and training to enhance emergency response speed and disposal capabilities;

(4) Strengthen coordination and cooperation with other emergency departments such as fire, medical, and environmental sanitation, establish a linkage mechanism, form a joint force, quickly and effectively carry out emergency rescue, minimize the impact of accidents on traffic and personnel safety, and ensure traffic safety during the construction period.

6. Conclusion

Although there have been achievements in traffic diversion safety management during the construction of

municipal roads, bridges, and open cut tunnels, there are still problems such as insufficient integration of monitoring data and the need to improve cross departmental collaboration efficiency. In the future, emerging technologies such as 5G vehicle road collaboration and edge computing will help dynamic traffic control. 5G vehicle road collaboration can achieve low latency and high bandwidth communication between vehicles and road facilities, making traffic information transmission more real-time and accurate. Vehicles can obtain traffic conditions and warning information in the construction area in advance and respond in a timely manner. Edge computing can quickly process massive traffic data on the spot, shorten the decision-making cycle, and improve the efficiency and accuracy of traffic evacuation decisions. These technological integrations are expected to make up for the shortcomings and promote the development of intelligent, efficient, and precise management of municipal construction traffic diversion safety, ensuring smooth and safe urban traffic.

Disclosure statement

The author declares no conflict of interest.

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