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# EXPLORING THE ROLE OF INTELLIGENT HIGHWAY INSPECTION VEHICLES IN VEHICLE-ROAD COLLABORATION SYSTEMS

RenJun Yang[1], JiaYing Zhang[1], NingBo Zhao[2], JianFei Wang[3*]
[1]*Yunnan Infrastructure Investment Co. Ltd, Kunming 650500, Yunnan, China.*
[2]*Qujing Xuanfu Highway Investment and Construction Development Co. Ltd, Qujing 655000, Yunnan, China.*
[3]*Yunnan Construction and Investment Holding Group Co. Ltd, Kunming 650500, Yunnan, China.*
*Corresponding Author: JianFei Wang, Email:17665719586@163.com*

**Abstract:** With the development of intelligent transportation systems (ITS), intelligent highway inspection vehicles and vehicle-road collaboration (V2X) systems have gradually become key tools for enhancing road safety and efficiency. This paper reviews and explores the current status and application scenarios of intelligent highway inspection vehicles and V2X systems both domestically and internationally. It summarizes the core technical modules of these systems, as well as the challenges they face. Through practical case analysis, the paper proposes reasonable technical solutions and implementation strategies. Finally, the future development directions of intelligent inspection vehicles and V2X systems are outlined, providing theoretical foundations and practical experiences for the intelligent management and operation of highways, thus promoting the transformation and upgrading of the highway industry.
**Keywords:** Highway; Intelligent inspection; Vehicle-road collaboration system; Intelligent management

## 1 INTRODUCTION

With the continuous expansion of China's highway network and the increasing frequency of urban road usage, road surfaces are increasingly subjected to the impacts of natural disasters and human damage. This results in a variety of defects, such as cracks, potholes, and deformations on the road surfaces. The safe operation and management of highways have become critical issues in the transportation sector. As a major transportation artery, the operational status of highways directly affects the healthy development of the national economy and social stability. In highway operation and management, the intelligent highway inspection vehicle and vehicle-road collaboration system, as an emerging technology, holds significant research and application value. This study aims to explore the application scenarios of the intelligent highway inspection vehicle and vehicle-road collaboration system. Through case analysis, reasonable technical solutions and implementation strategies are proposed to provide technical support for the intelligent management and operation of highways [1].

Internationally, the research on intelligent vehicle-road collaboration systems has a long history, especially in developed countries like the United States and Europe, where significant achievements in research and experiments have been made. For instance, the Intelligent Vehicle-Highway Cooperative System (IVCSS) in the United States is dedicated to enhancing road transport safety, efficiency, and environmental performance through vehicle-road collaboration technology. This project has successfully completed multiple tests, including vehicle platooning, automatic cruising, and intersection collision warning. The European "eTruck Platooning Challenge" project aims to enhance freight efficiency through autonomous driving platoons, while also reducing energy consumption and emissions. This initiative involves several truck manufacturers and logistics companies from various European countries. Japan has also achieved many successes in Intelligent Transportation Systems (ITS), having successfully implemented key technologies such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, and conducted application testing on actual roadways.

China has also made significant progress in intelligent vehicle-road collaboration (V2X) technology, with several research projects and experiments advancing steadily. The national project on "Key Technologies for Intelligent Vehicle-Road Collaboration" has conducted autonomous driving tests and vehicle-road-cloud collaboration experiments in the Xiong'an New Area, completing over 500 kilometers of autonomous driving tests. The research team from Tsinghua University's Department of Automation has explored vehicle platooning autonomous driving technology and conducted practical tests on the Jingxiong Expressway, successfully achieving fuel savings by reducing vehicle spacing. Qianfang Technology has also heavily invested in technologies such as the Internet of Things (IoT) and vehicle networking, providing technical support for the research on intelligent vehicle-road collaboration systems, which are widely applied in smart transportation infrastructure and intelligent driving fields [2].

Globally, vehicle-road collaboration technology is developing towards standardization and regulation. As the technical research deepens in various countries, an increasing number of standards are being formulated to ensure consistency and compatibility of the technology. At the same time, the application scenarios of vehicle-road collaboration systems are gradually expanding, covering not only highways but also urban roads, freight logistics, and other fields [3]. The integration of vehicle-road collaboration technology with other intelligent transportation technologies, such as autonomous driving, vehicle-to-everything (V2X), and big data, is expected to further enhance road transport safety, efficiency, and environmental performance. Moreover, strengthened policy support and industry cooperation have become key driving forces behind technological advancement. The high attention and support from managements around the world will accelerate the practical application and promotion of intelligent vehicle-road collaboration systems.

## 2 DEFINITION AND FUNCTIONS OF THE INTELLIGENT INSPECTION VEHICLE AND VEHICLE-ROAD COLLABORATION SYSTEM

### 2.1 Introduction to Intelligent Highway Inspection Vehicles

Intelligent highway inspection vehicles are advanced vehicles equipped with sensors, control systems, and communication technologies to perform real-time monitoring and diagnostics of highway facilities, road conditions, and the surrounding environment. The main functions of these vehicles include real-time monitoring, defect diagnosis, early warning and scheduling, data sharing and collaborative operations, as well as environmental monitoring and assessment. Equipped with high-resolution cameras, LiDAR, and other devices, intelligent inspection vehicles can detect road surface damage, traffic facility malfunctions, and vegetation conditions, providing essential data for maintenance and management. Additionally, these vehicles can identify emergency situations in real-time, send warning information, and optimize inspection routes to improve operational efficiency.

### 2.2 Introduction to Vehicle-Road Collaboration System

The vehicle-road collaboration (V2X) system integrates communication, perception, and control technologies to enable information exchange and collaborative control between vehicles and roads, as well as between vehicles themselves. By sharing road and vehicle data in real-time, this system helps enhance traffic safety, efficiency, and comfort. The system consists of several components: the vehicle end, roadside infrastructure, communication network, and data processing and analysis center. The vehicle collects information through sensors and communicates with roadside devices, while the communication network transmits the data. The data center analyzes the information in real-time to support decision-making processes.Key technological features of the vehicle-road collaboration system include information sharing, collaborative control, intelligent decision-making, and real-time updates.

In China, the vehicle-road collaboration system has already been applied in highway inspection. The widespread use of drones and intelligent inspection vehicles has made highway inspections more efficient, while the establishment of data-sharing mechanisms has enhanced emergency response times. Furthermore, intelligent analysis technologies are helping accurately detect road surface defects, providing scientific data for maintenance decisions. In the future, the vehicle-road collaboration system is expected to play an even larger role in highway management.

### 2.3 Integration of Intelligent Highway Inspection Vehicles with the Vehicle-Road Collaboration System

**Table 1** Relationship between Intelligent Inspection and Vehicle-road Collaboration Systems

| Intelligent Inspection System | Vehicle-to-Infrastructure (V2I) System | Relationship Description |
|---|---|---|
| Automated Inspection | Integration of Onboard Sensors and Roadside Equipment | The V2I system provides data support from onboard sensors and roadside devices, enabling automated operation of the inspection vehicle. |
| Real-time Data Collection and Transmission | Real-time Data Sharing and Transmission | The inspection system collects and shares real-time data (e.g., road conditions, traffic flow, weather) via the V2I system, providing decision-making support for the inspection process. |
| Road and Infrastructure Condition Monitoring | Road Information and Traffic Signal Monitoring | The V2I system provides real-time monitoring of road conditions and traffic signals, ensuring smooth and safe inspection operations. |
| Inspection Route Planning | Path Optimization and Dynamic Adjustments | The V2I system supports the optimization and dynamic adjustment of inspection routes, helping the vehicle avoid congestion and incidents. |
| Early Warning and Emergency Response | Incident and Emergency Event Detection and Response | The V2I system helps the inspection vehicle detect potential issues or emergency events in real-time, triggering an emergency response. |
| Big Data Analysis and Decision Support | Cloud Computing and Big Data Platforms | The V2I system supports big data analysis for the inspection system via cloud computing platforms, providing deep insights and decision support, enhancing inspection efficiency and resource allocation. |
| Collaborative Multi-Vehicle Operations | Vehicle-to-Vehicle (V2V) Communication | The V2I system enables communication between inspection vehicles, fostering collaboration and improving overall inspection efficiency. |
| Intelligent Maintenance and Repair Suggestions | Infrastructure Status and Maintenance Information | The V2I system collects and transmits infrastructure condition data, aiding the intelligent inspection system in creating more scientific and effective maintenance and repair plans. |

Table 1 illustrates the connection between intelligent inspection and vehicle-road collaboration systems. Intelligent inspection vehicles share information with other vehicles and infrastructure through the vehicle-road collaboration system, enhancing road operation efficiency and reducing traffic accidents. Additionally, these vehicles monitor the surrounding environment, such as air quality and noise levels, providing a basis for environmental management. As technology continues to evolve, intelligent inspection vehicles will play an increasingly crucial role in highway maintenance and operations. In the context of highway intelligent inspection vehicles, the vehicle-road collaboration system is used for real-time traffic condition updates, abnormal event alerts, collaborative inspection, and vehicle-to-vehicle information sharing, all aimed at improving inspection efficiency and reducing risks. The key technologies of the system include onboard intelligent perception, onboard communication, onboard positioning, and control technologies, which together support the operation of the system and the functionality of inspection vehicles.

### 2.4 Definition of Intelligent Inspection Vehicle and Vehicle-Road Collaboration System

The intelligent inspection vehicle and vehicle-road collaboration technology refers to the real-time interaction between the inspection vehicle, highway infrastructure, and cloud data through vehicle-road communication technology. This system enables real-time monitoring of highway operational status, fault diagnosis, and early warning. Vehicle-road communication technology allows the inspection vehicles to exchange information in real-time with roadside infrastructure and other vehicles, ensuring the smooth flow of information and timely updates. Autonomous driving and collaborative control technologies enable the inspection vehicles to perform efficient inspection tasks without human intervention, while making decisions and adjustments based on real-time data.

In this system, the inspection vehicles use onboard sensors such as LiDAR, cameras, and millimeter-wave radar to sense real-time data about the road and surrounding environment, transmitting this data to the cloud platform for analysis. The cloud platform uses big data processing capabilities to evaluate the current road conditions and provide feedback to the inspection vehicles. This allows the vehicles to make autonomous decisions and, when necessary, collaborate with roadside facilities (e.g., traffic signals, road sensors, etc.). The goal of this technology is to enhance the efficiency, safety, and accuracy of highway inspections through real-time information sharing and collaborative work, closely linking the inspection vehicles, road infrastructure, and traffic management systems to ensure that inspection tasks are completed automatically, efficiently, and safely [4].

As seen in Figure 1, the intelligent roadside system gathers traffic environment information through various means, such as video detection, radar, laser, and loops, which include traffic flow, pedestrian density, intersection information, and road conditions. These data are then processed and analyzed by the RSU and transmitted to the vehicles through V2I (vehicle-to-infrastructure) communication. At the same time, traffic environment information is sent to other RSUs, and it receives information from OBU (onboard units) or other RSUs [5].

The intelligent onboard system collects vehicle's operational status and surrounding environment perception information, including positioning, acceleration, braking, steering wheel angle, heading angle, road alignment, road conditions, pedestrians, and target vehicles. These data are gathered via GPS, GIS, radar, visual sensors, infrared sensors, video detection, ABS systems, onboard gyroscopes, accelerometers, and steering sensors. Then, the OBU processes and analyzes this data, transmitting it to other vehicles through V2V (vehicle-to-vehicle) communication. It also receives information from roadside devices and other vehicles [6]. By synthesizing these data, the CVIS (Collaborative Vehicle Infrastructure System) provides driving guidance to the driver.

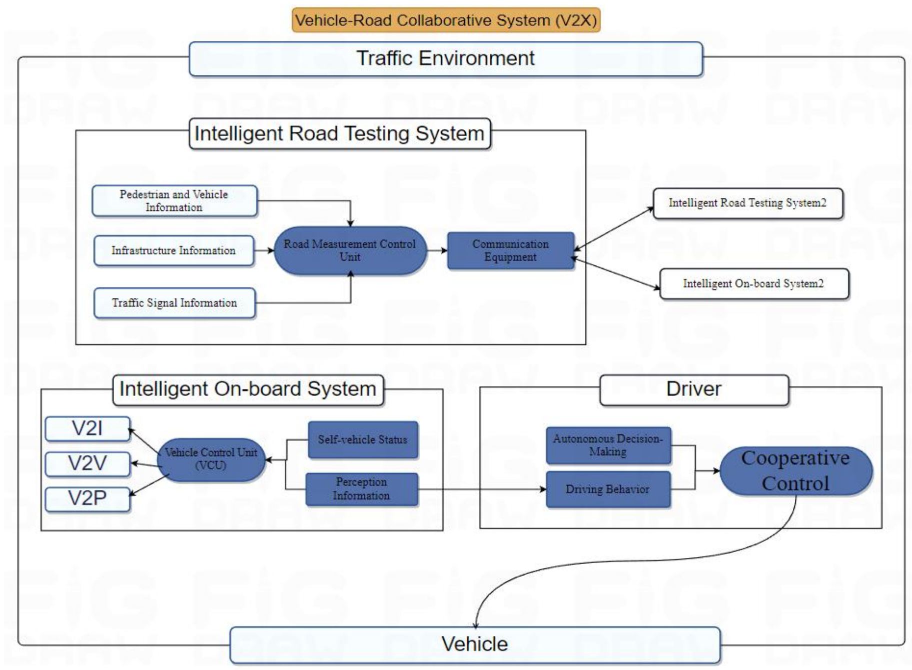


**Figure 1** Basic Structure of CVIS

## 3 EXPLORATION OF APPLICATION SCENARIOS FOR HIGHWAY INTELLIGENT INSPECTION VEHICLES AND VEHICLE-ROAD COLLABORATIVE SYSTEMS

As the highway network continues to expand, traditional road inspection methods are increasingly insufficient to meet the demands of efficient, safe, and intelligent management. The application of intelligent inspection vehicles and vehicle-road collaborative systems offers a new solution for the intelligent management of highways. The following explores the application scenarios of intelligent inspection vehicles and vehicle-road collaborative systems on highways:

### 3.1 Real-Time Road Condition Monitoring and Early Warning

Scenario Description: Intelligent inspection vehicles, equipped with vehicle-road collaborative systems, use onboard sensors, cameras, and other devices to collect real-time road condition information. This data is shared with roadside sensors and cloud data for interaction, enabling the monitoring of real-time highway conditions. Application Scenario: Real-time monitoring of abnormal conditions such as traffic congestion, accidents, and construction, and the timely release of early warning messages to enhance road safety. Automatic detection of road damage and infrastructure issues provides decision-making support for maintenance departments.

### 3.2 Intelligent Dispatching and Route Planning

Scenario Description: The intelligent inspection vehicle vehicle-road collaborative system uses real-time road conditions and vehicle demand information to provide optimal scheduling and route planning for inspection vehicles. Application Scenario: Ensuring the rational distribution of inspection vehicles to improve inspection efficiency; planning the optimal route for inspection vehicles based on road conditions, thereby reducing travel distance and time.

### 3.3 Autonomous Driving-Assisted Inspection

Scenario Description: Intelligent inspection vehicles are equipped with autonomous driving technology, enabling autonomous driving-assisted inspection that reduces the driver's burden and improves inspection efficiency. Application Scenario: Conducting autonomous driving inspections on highways to reduce the driver's workload; in special circumstances, the autonomous driving system automatically takes control of the vehicle to ensure driving safety.

### 3.4 Collision Avoidance in Emergency Situations

Scenario Description: The intelligent inspection vehicle vehicle-road collaborative system uses vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technologies to provide early warning of potential collision risks. Application Scenario: In complex scenarios such as intersections and junctions, the system can give early warnings of potential collisions to prevent accidents. It also enhances the driver's situational awareness under adverse weather conditions, reducing accident rates.

### 3.5 Unmanned Inspection and Remote Monitoring

Scenario Description: Utilizing unmanned devices such as drones and robots, combined with the vehicle-road collaborative system, enables unmanned inspection and remote monitoring. Application Scenario: Conducting unmanned inspections in hard-to-reach or hazardous areas, thus reducing safety risks. Real-time monitoring from a remote control center allows for the inspection data to be viewed and facilitates remote dispatch and coordination.

### 3.6 Digitalization and Management of Assets

Scenario Description: The intelligent inspection vehicle vehicle-road collaborative system facilitates the digital management of road infrastructure, enabling real-time updates and querying of asset information. Application Scenario: Digital encoding of road infrastructure for easier management and querying; using the vehicle-road collaborative system to provide real-time updates on the status of road infrastructure, offering decision-making support to maintenance departments.

In conclusion, the intelligent inspection vehicle vehicle-road collaborative system has a wide range of application scenarios, including real-time road condition monitoring, intelligent dispatching, autonomous driving-assisted inspection, collision risk warning, unmanned inspections, and digital asset management. These capabilities contribute to improved highway management and ensure road safety and smooth traffic flow [7].

## 4 APPLICATION CASE ANALYSIS OF VEHICLE-ROAD COLLABORATIVE SYSTEM IN HIGHWAY INTELLIGENT INSPECTION VEHICLES

This section will analyze the application of the vehicle-road collaborative system in highway intelligent inspection vehicles based on practical cases.

### 4.1 Case 1

A 100-kilometer section of a highway, designed with four lanes in both directions, aims to improve safety performance and operational efficiency by introducing intelligent inspection vehicles for real-time monitoring. The vehicle-road collaborative system, as the core technology of the intelligent inspection vehicles, will be fully applied.

#### *4.1.1 Application case analysis of the vehicle-road collaborative system*

In this highway section, intelligent inspection vehicles use vehicle-road communication technology to achieve real-time information exchange with the infrastructure of the highway. The intelligent inspection vehicles can obtain real-time status information from infrastructure elements such as toll stations, cameras, and weather stations, providing accurate operational data for the inspection vehicles. The system enables seamless exchange of information between the vehicles and the infrastructure. In addition, the vehicles can receive real-time instructions from the road control system, such as speed limits and lane closures, ensuring safe operation of the inspection vehicles within the highway section [8].

Vehicle collaboration control technology can help intelligent inspection vehicles achieve coordinated operation with other vehicles. The specific application is as follows: intelligent inspection vehicles can automatically adjust their speed based on information such as the speed and inter-vehicle distance of the vehicle ahead, ensuring safe driving and controlling the distance between vehicles. Moreover, intelligent inspection vehicles can form a convoy with other inspection vehicles, enabling coordinated inspection and improving inspection efficiency.

Intelligent scheduling technology helps intelligent inspection vehicles optimize the allocation of inspection tasks. The specific application is as follows: the system automatically assigns inspection tasks to intelligent inspection vehicles based on the actual road conditions, improving inspection efficiency and completing task allocation. The system also plans the best inspection route for the vehicles based on road conditions, reducing operating costs and achieving optimal route planning.

The network architecture of the highway vehicle-road collaborative system is mainly divided into two parts: the aggregation network and the access network, as shown in Figure 2.

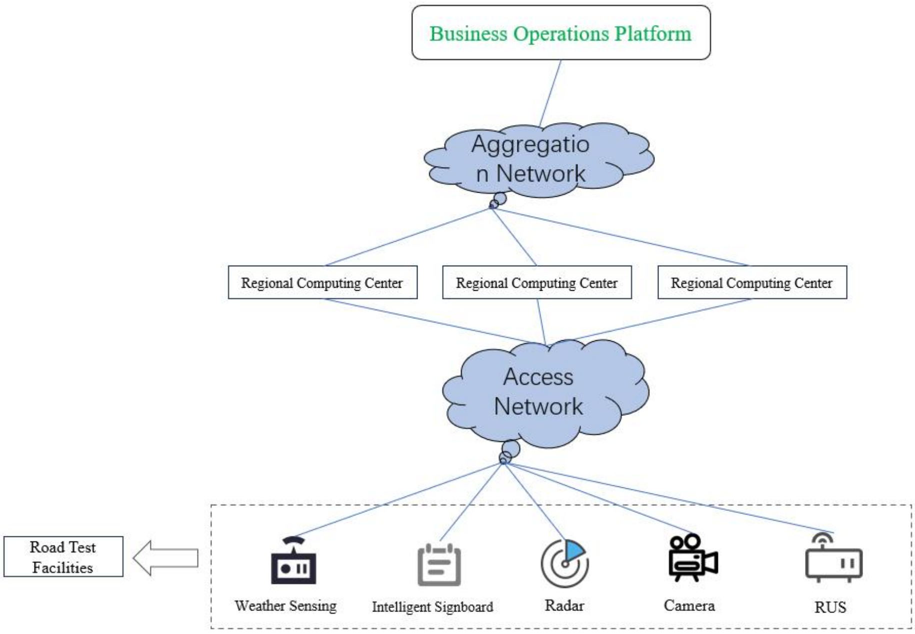


**Figure 2** Network Architecture of Highway Vehicle-Road Collaborative System

The aggregation network in Figure 2 connects the regional computing center with the municipal business management platform. Through the access network, it links the roadside equipment to the municipal business management platform, facilitating the aggregation, backup, and unified network management of vehicle-road collaborative business information, and supporting the aggregation networking of multiple vehicle-road collaborative regional computing centers.Each individual vehicle-road collaborative regional computing center is responsible for the real-time processing of V2X services and information within its region. The vehicle-road collaborative municipal computing center handles the global aggregation, management, and analysis of traffic data, as well as the global strategy management and configuration delivery. The access network is responsible for networking roadside equipment and roadside edge computing platforms, and for facilitating information exchange with vehicle-road collaborative regional computing centers.

The roadside equipment includes RSUs, intelligent roadside perception devices, dynamic traffic information boards, roadside meteorological stations, etc. Edge computing can fuse and process the raw data output from these roadside devices to extract structured road and target object status information, enabling data analysis and processing to support various vehicle network applications. Many vehicle-road collaborative services are completed within the roadside network, which requires high real-time performance and bandwidth. The access network architecture will adopt multiple models to support various deployment scenarios, such as fully distributed or relatively centralized edge computing. The access network can be subdivided into two components: the access roadside network and the backhaul network for the regional computing center. In scenarios where MEC and regional computing centers are co-located, the access roadside network and the access backhaul network are integrated, with communication latency aligned to meet the delay requirements of the access roadside network.

#### *4.1.2 Case effect evaluation*

By introducing the vehicle-road collaboration system, the intelligent inspection vehicles on this highway section achieved the following results:

1.Increased inspection efficiency and reduced labor costs;

2.Improved road safety performance, reducing the risk of traffic accidents;

3.Optimized resource utilization, improving operational efficiency.

In summary, the application of the vehicle-road collaboration system in intelligent highway inspection vehicles has provided strong support for the intelligent management of highways in China, showing great potential for future applications.

### 4.2 Case 2

In order to improve highway inspection efficiency and reduce labor costs, a highway management department decided to introduce the intelligent inspection vehicle vehicle-road collaboration system to enhance the level of automation in inspection tasks. The following is a detailed analysis of this case.

#### *4.2.1 Composition of the intelligent inspection vehicle vehicle-road collaboration system*

The intelligent inspection vehicle is the core of the vehicle-road collaboration system, equipped with functions such as autonomous driving, automatic road condition recognition, and data collection. The vehicle is equipped with various sensors, such as LiDAR, cameras, and millimeter-wave radar, to monitor road conditions and the surrounding environment in real time.

The vehicle-road collaboration system consists of the following components:

1. Onboard Terminal: Responsible for transmitting data collected by the vehicle to the cloud and receiving instructions from the cloud to control the vehicle's operations.
2. Roadside Unit: Installed on the sides of the road, used for communication with the onboard terminal, collecting vehicle data, and transmitting road information to the cloud.
3. Cloud Platform: Responsible for processing and analyzing the collected data, providing path planning, fault diagnosis, and other services for the inspection vehicles.

#### *4.2.2 Application scenarios*

Road Condition Monitoring: During inspections, intelligent inspection vehicles use sensors to monitor road conditions in real time, such as surface damage, obstacles, and traffic signs. If abnormalities are detected, the onboard terminal transmits the data to the cloud, where the cloud platform processes it, generates an inspection report, and notifies relevant departments for timely action.

Vehicle Fault Diagnosis: During inspections, the intelligent inspection vehicle can monitor vehicle conditions in real time, such as engine temperature and battery levels, via the onboard terminal. When a fault occurs, the onboard terminal transmits the fault information to the cloud, where the cloud platform analyzes it and provides diagnostic information and solutions for the driver.

Path Planning and Navigation: Before inspections, the cloud platform generates the optimal inspection route for the vehicle based on road conditions, vehicle status, and other factors. During the inspection, the onboard terminal adjusts the vehicle's route according to real-time data to ensure the inspection proceeds smoothly [9].

Real-time Communication and Collaborative Operations: During inspections, the intelligent inspection vehicle can use the vehicle-road collaboration system to communicate in real-time with other inspection vehicles for collaborative operations. For example, when one vehicle detects road congestion, it can promptly notify other vehicles to adjust their routes, improving inspection efficiency.

### 4.3 Case Summary

Through these two cases, it is evident that vehicle-road collaboration technology has broad application prospects in the field of highway inspections. In the future, as technology continues to advance, the vehicle-road collaboration system will better serve highway operation and maintenance management, contributing to the sustainable development of China's highway network.

## 5 CHALLENGES AND COUNTERMEASURES IN THE APPLICATION OF INTELLIGENT INSPECTION VEHICLE VEHICLE-ROAD COLLABORATION SYSTEM

## 5.1 Problems and Challenges Encountered

### *5.1.1 Performance issues with sensors and communication equipment*

The vehicle-road collaboration system relies on various sensors and communication devices, such as cameras, radar, LiDAR, and communication between vehicles and between vehicles and infrastructure. In practical applications, performance issues with these sensors and communication devices can lead to inaccurate data collection and processing, which in turn affects the judgment and behavior of intelligent inspection vehicles.

### *5.1.2 Data security issues*

The vehicle-road collaboration system involves a large amount of sensitive data, such as vehicle location and speed. Ensuring data security, preventing data breaches, and protecting against malicious attacks is a significant challenge faced today.

### *5.1.3 System compatibility and standardization issues*

The vehicle-road collaboration system involves multiple technologies, devices, and platforms. Ensuring compatibility and standardization between different systems to ensure the efficient operation of the entire system is a key issue that needs to be addressed.

### *5.1.4 Legal, Regulatory, and Ethical Issues*

The practical application of the vehicle-road collaboration system may raise legal, regulatory, and ethical concerns, such as privacy violations during vehicle operation, accountability issues, and more.

## 5.2 Countermeasure Suggestions

### *5.2.1 Improve the performance of sensors and communication devices*

To enhance the accuracy of the vehicle-road collaboration system, the following measures can be taken:
1.Select high-performance sensors and communication devices;
2.Implement multi-sensor fusion technology to improve the comprehensiveness and accuracy of data collection;
3.Optimize data processing algorithms to improve the timeliness and accuracy of data processing.

### *5.2.2 Strengthen data security protection*

To ensure data security in the vehicle-road collaboration system, the following measures are recommended:
1.Use encryption technology to ensure the security of data transmission;
2.Establish comprehensive data security management systems to prevent data leakage;
3.Enhance system security protections to improve resistance to attacks.

### *5.2.3 Promote system compatibility and standardization*

To address the compatibility and standardization issues, the following actions can be taken:
1.Develop unified technical standards and interface specifications;
2.Strengthen industry cooperation to encourage upstream and downstream companies to promote system compatibility and standardization collectively;
3.Actively participate in the formulation of international standards to align China's vehicle-road collaboration systems with global standards.

### *5.2.4 Improve legal, regulatory, and ethical guidelines*

To address legal, regulatory, and ethical concerns, the following measures should be implemented:
1.Formulate and improve relevant laws and regulations to define the scope of application and accountability for the vehicle-road collaboration system in intelligent highway inspection vehicles;
2.Strengthen ethical education to raise the professional ethics of personnel involved;
3.Establish a sound supervision and evaluation mechanism to ensure the compliant application of the vehicle-road collaboration system [10].

# 6 CONCLUSION AND OUTLOOK

This paper presents an in-depth study of the application scenarios of the intelligent highway inspection vehicle vehicle-road collaboration system. By analyzing the pain points and challenges of existing highway inspection tasks, a solution based on the vehicle-road collaboration system is proposed. This solution leverages onboard equipment, roadside devices, and cloud platforms to enable real-time information exchange and collaborative control between vehicles and roads. Through practical case studies, the significant advantages of the vehicle-road collaboration system in highway inspection work have been demonstrated, such as improving inspection efficiency, reducing labor costs, and enhancing road safety.

In the future, the intelligent highway inspection vehicle vehicle-road collaboration system will have a broad development prospect. On the technological front, advances in autonomous driving, the Internet of Things (IoT), and big data will strengthen the system's support capabilities, improving the accuracy of data collection and processing. On the application front, the system will be further optimized and expanded in areas such as highway maintenance, rescue, and tolling, leading to a fully intelligent operational management system. Managements should increase support for relevant technologies, introduce policies to ensure the application of vehicle-road collaboration systems, and strengthen safety supervision. On the industry front, cooperation between relevant enterprises and research institutions will promote the implementation of technologies, drive the development of the intelligent transportation industry chain, and create more economic value.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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