

# Drone Inspection and Management System for Railway Protection Zones

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**Abstract.** With the development of railways, the scope of protection for railway operators' security zones has expanded significantly, posing greater challenges to traditional manual inspection methods in terms of coverage, efficiency, and risk management. To address this challenge, an unmanned aerial vehicle-based monitoring and surveillance platform for railway security zones has been developed. This article discusses on the development of railway protection zone supervision and monitoring system based on how to use unmanned aerial vehicle and 3D Geographic Information System(GIS). It also talks about how to design and implement unmanned aerial vehicle (UAV) Inspection Management based on UAV Risk Identification Strategies. Finally, it introduces 6 modules of this platform and their functions. The platform features six core functions, task assignment, hazard information submission, hazard report confirmation, personnel evaluation, and analysis. Practical application demonstrates the value and effectiveness of the platform. By leveraging drones as the foundation, it establishes a human-machine collaborative platform to enhance oversight of railways.

**Keywords:** Railway, Protected Area Patrol, Control Platform, Drone Technology, Geographic Information System.

## 1. Introduction

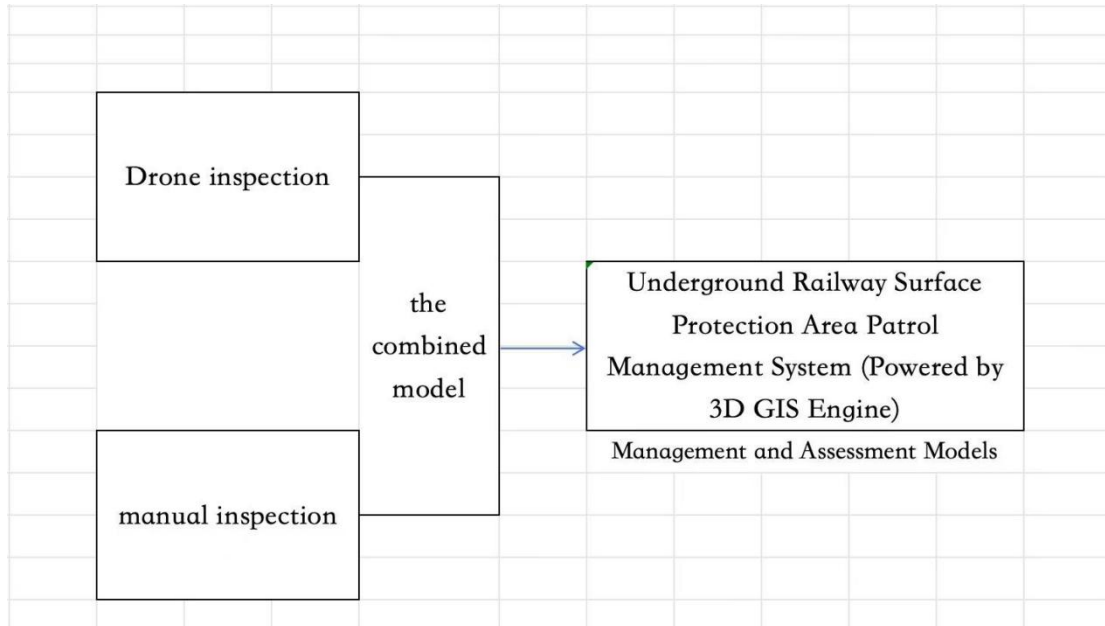
With the rapid development of railway construction in China, the total operational mileage of railways nationwide has surpassed 10,000 kilometers, presenting unprecedented challenges to railway safety operations. Particularly amid frequent construction activities near railways, incidents such as railway service suspensions and damage to line facilities caused by construction have become increasingly common, severely impacting operational safety and service quality. Against this backdrop, unmanned aerial vehicle (UAV) technology has emerged as an ideal solution to overcome the limitations of manual inspections and enhance safety management within railway protection zones. This is due to its advantages of rapid deployment, remote operation, high-definition imaging, and all-weather capability [1].

The introduction of drone technology provides a new way to solve this challenge. Drones has many distinct advantages such as mobility, rapid deployment, low cost, high precision, and multi-angle data acquisition, enabling them to perform extensive, all-weather patrols in complex environments [2]. When integrated with technologies like Geographic Information Systems (GIS), drones can capture real-time, high-resolution imagery of railway protection zones and accurately identify construction equipment, terrain changes, and potential risk. This significantly enhances the automation and informatization of inspections. In recent years, cities including Beijing, Shanghai, Guangzhou, Shenzhen, and Hangzhou have successively used drone monitoring systems for railway surface safety zones. These systems enable rapid detection, real-time reporting, and efficient oversight of illegal construction projects and set new benchmarks for railway security protection [3].

This paper aims to study how to improve the safety and convenience of railways by unmanned aerial vehicle inspection, and explore the possibility of using UAVs to replace manual labor in railways, which can significantly improve work efficiency and reduce costs [4]. By building a human-machine interoperable management platform through 3D GIS engines, it can better show problems.

## 2. A Study of the Patrol and Control Platform in Railway Protection Areas

This article talks about using drone technology and GIS engines to construct the inspection and control platform of railway protection areas, and the specific research was shown in Figure 1.



**Figure 1.** the construction path of the patrol and control platform for the railway protection area

This paper uses unmanned aerial vehicle and 3D GIS engines to create a monitoring and management system for railway protection areas, and graphically shows the research steps of this method. Unmanned aerial vehicle is an important component of today's aviation science and technology and can be applied in multiple aspects such as military reconnaissance, terrain survey, environmental monitoring, and farmland spraying [5]. It can be divided into military applications and civilian applications. The former is mainly responsible for military tasks such as reconnaissance, surveillance and attack, while the latter is mainly responsible for work such as taking photos and keeping records, sending express packages and environmental monitoring. The advanced technology of drones provides us with another technical model for emergency monitoring or regular inspection, which can achieve real-time image collection of a certain area, high-altitude patrol and search and rescue, environmental monitoring, and high-altitude weather monitoring of toxic substances. Sure, the technical features of unmanned aerial vehicles are very distinct and can be analyzed in detail from two dimensions: their system composition and main capabilities. Overall, unmanned aerial vehicles are highly integrated technological platforms, and their characteristics are mainly reflected in intelligence, multi-purpose application, networking, and other aspects [6]. The high maneuverability and flexibility of unmanned aerial vehicles, especially multi-rotor UAVs, make them move freely forward, backward, left, right, up and down, rotate in place and hover, and perform tasks in complex environments. The powerful mission adaptability of unmanned aerial vehicles enables them to quickly switch roles by changing different mission payloads and be applied in various industries, achieving multi-purpose use on a single platform. The threshold for operating drones has been greatly reduced because of intelligent flight control. Ordinary people can operate them after simple learning, and the automation functions make complex tasks simple [7]. Drones have low usage costs and low risks. Compared with manned aircraft, their purchase, operation and maintenance costs are extremely low. At the same time, operations in dangerous areas (such as disaster sites, war zones, and near high-voltage lines) can be "unmanned", ensuring personnel safety to the greatest extent. Networking and cluster intelligence make multiple unmanned aerial vehicles be interconnected through data links, achieving coordinated formation flights. They can jointly complete complex tasks (such as light shows and collaborative searches) through cluster algorithms with efficiency far exceeding that of a single platform [8].

It does not require a designated take-off and landing site. Its start-up preheating time is short and the operation is simple. Secondly, there is the vastness of information collection. For instance, the high-speed camera it is equipped with can take pictures by tilting up and down. It can not only capture planar image information but also use low-altitude multi-angle pictures to take high-definition local images.

The proposal of unmanned operation platforms has truly solved the last mile of unmanned aerial vehicles. By using this unmanned operation platform, full coverage of unmanned drone patrols can be achieved.

## **2.1. Unmanned Aerial Vehicle (UAV) Risk Identification Solution**

### **2.1.1 Construction Equipment Identification**

High-resolution images can be used to identify whether there are construction activities, but the method of automatically detecting construction equipment can discover possible construction sites in a very short time. This paper uses the YOLO method for the automatic detection, labeling and classification of construction equipment. The YOLO method can directly detect and label construction equipment. If there are enough training samples, the YOLO method can distinguish different construction equipment just like a human, and it is fast and has wide coverage capabilities [9]. However, relying solely on the YOLO method can only determine the presence of construction equipment and the detected locations, but it is impossible to place different types of construction equipment within a single range. Moreover, machines cannot understand the diversity and dynamics of construction activities.

To address the above issues, this paper employs the already designated illegal engineering fields. It uses the method of first summarizing the illegal engineering fields known to the computer to assist the computer in summarizing the same type of engineering equipment, thereby achieving the effect of reducing the number of reported risks and avoiding duplicate reporting of deficiencies [10].

### **2.1.2 Elevation Change Detection**

By comparing the altitudes of different periods, the range of altitude changes in the railway protection area can be precisely identified. Based on the analysis of whether the altitude increases or decreases, it can be determined whether the risk lies in accumulation or excavation.

The operation of the railway is a long-term project. Therefore, when comparing elevation data, it is not only necessary to compare the data of the two periods before and after, but also to compare it with the initial data. In this way, the data can accurately reflect hazards caused by changes of ground elevation.

## **2.2. UAV Inspection Process**

The process of managing unmanned aerial vehicle inspection operation includes operation assignment, operation application, operation permit and operation evaluation.

### **2.2.1 Task Management**

Through the one-way notification management mode of unmanned aerial vehicle patrol tasks, the personnel conducting the UAV patrol complete the submission of relevant information. For instance, this month's work arrangements, updates on work content, and uploads of flight dynamic videos, etc., only need to be known by the railway company. They will not directly participate in the specific management of the execution of the work. All inspection tasks are submitted by the implementing agencies through third-party platforms. However, whether the tasks have been completed is determined by the computer, and the completion of flight tasks is one of the performance evaluation indicators for the implementing agencies [11].

According to the types of flight missions, they are mainly classified into four categories: pending execution, changes, unfinished types and completion.

### 2.2.2 Risk Reporting

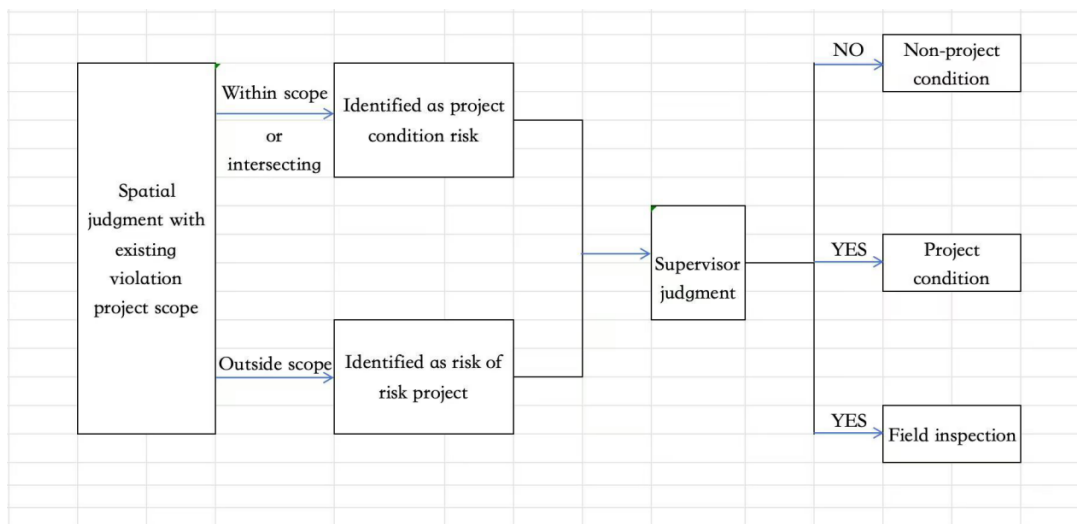
The potential risk of drones will be distinguished. If the risk of construction equipment are found, they should be reported to the relevant departments immediately and completed on the same day or the next day. If no problems with the equipment involved in this inspection are found, they can be reported in a zero-risk form. For highly variable risks, they can be reported a little later. It is sufficient to provide a summary once a month. At least one photo should be provided for each risk. The photo should clearly indicate the location of the risk, the location of height changes, railway structures, platform buildings, and the boundaries of the protection area. Each reported risk information should include the ID, path, area, risk description, spatial location, time of risk discovery, and the implementing unit. Among them, the ID is the unique information, and its composition can be the abbreviation of the executing unit + path + year + date + self-increasing number.

### 2.2.3 Risk Confirmation

Risk confirmation consists of two steps: automatic confirmation and manual confirmation. For the platform of system risk reporting, the computer crosses the risk latitude and longitude coordinates with the existing engineering violation scope in the platform. If the coordinates are within the project scope, the risk type will be automatically confirmed as the engineering operation status; if the coordinates are outside the project scope, the risk type will be engineering risk [12].

If there are many non-compliant items stored on the platform, they need to be compared one by one, which increases the computer operation time. To improve the operation efficiency, the non-compliant items in this interval and adjacent intervals should be screened based on the interval information of the risk, and then compared again. This can greatly improve the operation efficiency.

Manual processing of tasks is determined by the team leader - the inspection team leader - to automatically identify potential issues and execute batch tasks. If the inspection system identifies a list that may have problems, the team leader will conduct random checks on it, view the problem descriptions and pictures of the problematic items on the platform, and complete the status confirmation, rejection or on-site survey of the problem through this platform. In addition, if a project identified as a significant issue is found, the team leader will review it one by one, generate a patrol work order on this platform, and hand it over to the lower-level staff for on-site survey. The process is specifically shown in Figure 2 below [13].



**Figure 2.** UAV Risk Confirmation Process

### 2.2.4 Assessment of Mission Effectiveness

The ultimate goal of the railway company is to replace manual patrols with drones. In the future, it is hoped that manual inspections will be transformed into regional tours. Inspectors only need to complete risk assessments within their jurisdiction and no longer have to undertake the job responsibilities of daily inspections. This will significantly reduce the cost input of inspection

personnel. However, in order to achieve this, strong evidence is needed to show that the use of drones for inspection can fully and thoroughly detect illegal construction activities in the railway protection areas.

### **3. Platform Construction**

This study has constructed a monitoring and management system for the railway safety zone by integrating unmanned aircraft technology and 3DGIS engines. It combines aircraft monitoring methods with manual inspection methods, covering six major parts: workspaces, task organization, engineering management, ground-air collaboration, staff assessment, and data statistics and analysis. Among them, the workroom is a centralized entrance workroom. Potential hazards are comprehensively calculated based on variables such as the completion time of inspection tasks, new tasks, the tracking status of tasks, the response of regulatory offices, and the frequency of path repetition, facilitating quick retrieval and repair. Task organization can plan the inspection tasks for people and mechanical equipment and support algorithmic review of inspection frequency to prevent the phenomenon of insufficient task volume. The key point of engineering management is the all-round management of non-compliant items. The scope and condition can be judged by observing the high-definition images of drones. The ground-air collaboration section encompasses the safety management of unmanned aerial vehicles and the management of railway boundaries, enabling the retrieval of potential hazard maps, mission organization, and actual operational status. The staff can do assessment based on the submitted qualification level by setting scoring rules, summarize the total by year, quarter and different stages, and then output reports. The data statistics and analysis section conducts summary, cumulative analysis and output based on different levels, lines, regions and types of work. The system aims to achieve overall intelligence and digitalization in inspection management [14].

### **4. Conclusion**

The safety monitoring system for railway protection areas studied in this paper relies on two key technologies: unmanned aerial vehicles and 3DGIS engines. It breaks through the limitations of traditional monitoring that depends on manual labor and has distributed technologies. It builds a core framework that is technologically advanced and has a solid foundation for the field of safety monitoring in railway protection areas. It fundamentally enhances the technical starting point and reliability of monitoring work. This system is not a single-function tool but deeply integrates multiple capabilities such as human-machine collaboration and active scanning. It can operate in a high-precision and high-efficiency mode, fully covering the entire process of risk working conditions, including rapid identification, risk early warning, task planning, project implementation, risk collaboration, personnel performance, and statistical analysis. It has effectively addressed the problems such as low efficiency, process disruption and data lag that existed in past monitoring. This can transform risk control from "passive response" to "active prevention".

More importantly, the system, through the in-depth interaction of multiple modules, provides managers with comprehensive decision-making and management support. Not only can it monitor the overall inspection situation in real time, rationally allocate resources and deploy inspection tasks, but it can also precisely locate violation incidents, assist scientific decision-making with data analysis, and even enhance the professional capabilities of the inspection team through personnel rating mechanisms and strengthen management tracking with statistical data. This has completely changed the predicament of information asymmetry and decision-making relying on experience in traditional management. It has significantly enhanced the refinement and scientific level of management in the railway protection area. The core value of this paper is that it provides a solution with replicable and easily scalable data. This solution not only directly provides stable and efficient technical support for the current safety monitoring of railway protection zones, but also, due to its strong adaptability and

controllable promotion cost, has the prospect of being widely applied in the monitoring work of railway protection zones in different cities across the country. It has important practical implications and offers significance reference value for the industry on promoting the technological upgrading and standardization development of the entire railway safety monitoring industry.

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