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Collaborative Governance Empowered by Digital Technology - Construction of Precision Intelligent Control and Early Warning Platform for Construction Solid Waste

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Abstract

With the continuous acceleration of China's urbanization process, construction solid waste, as an important component of urban solid waste, has caused pollution to the urban ecological environment to a certain extent through its utilization and disposal. The article established a precision intelligent control and early warning platform for construction solid waste, achieving precise supervision of the entire process of construction solid waste disposal, which is of great significance for promoting urban green development and improving urban ecological environment. The experimental results showed that the monitoring coverage rate of the intelligent control early warning platform based on digital technology reached up to 91.8%.

Keywords: Digital Technology, Collaborative Management, Construction Solid Waste, Precision Intelligent Control, Early Warning Platform

1. Introduction

With the acceleration of urbanization in China, there is an increasing amount of solid waste in urban household waste. However, in the current disposal process of solid waste from construction in China, there are generally problems such as arbitrary dumping and no covering, which have a significant impact on urban ecological

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environment and social security. Therefore, building a precision intelligent control and early warning platform for construction solid waste, achieving precise monitoring of solid waste throughout the process, is of great significance for promoting green development of Chinese cities and improving ecological environment quality.

The article intended to use digital technology to establish a precision intelligent control and early warning platform for construction waste, providing new ideas and methods for the refined management of construction waste. The article deeply analyzed the application of digital technology in the field of urban solid waste treatment, and explored the construction process of a refined intelligent warning system for construction solid waste based on intelligent control. Through the research in this article, it is aimed to provide new solutions to the problem of urban solid waste pollution, promote sustainable urban development, and protect the ecological environment.

2. Related Work

In recent years, there have been many studies on construction solid waste. Among them, Liu Qiong tested the electrochemical impedance spectra of different construction solid waste materials [1]. Kong Kunfeng conducted research on the cumulative deformation and critical dynamic stress test of recycled construction solid waste fillers [2]. Xie Jianwei studied the mechanical properties of cement stabilized construction solid waste recycled aggregates [3]. Nan Ning studied the preparation and performance of permeable bricks made from the mixing of building fixed waste and combustion sludge [4]. Ji Min analyzed the difficulties and improvement strategies of construction solid waste resource disposal technology [5]. The above content is very in-depth in the research of construction solid waste, but there are few studies related to solid waste treatment and control.

There are also many related studies on the application of digital technology. Azra F E A uses four spiral methods to study the application of digital technology in promoting women's entrepreneurship and empowerment [6]. Hughes M S conducted research on the application of digital technology in diabetes [7]. Davronovich A D studied the important advantages of digital technology in the process of organizing education [8]. Singh M N discussed digital technology in education [9]. Tsou H T try to use digital technology to improve the company's performance [10]. These studies have relatively good achievements in their respective fields, but they have not covered other fields and are not widely used.

3. Precision Intelligent Control Warning Platform for Construction Solid Waste

3.1. Current Situation and Existing Problems of Construction Solid Waste Disposal

With the continuous acceleration of China’s urbanization process, the generation of urban construction solid waste is also showing a rapid growth trend. The disposal methods of urban construction solid waste in China mainly include landfill, incineration, and resource utilization. Among them, landfill is the main disposal method for urban construction solid waste, and currently most cities in China adopt this disposal method. Compared to traditional landfill methods, resource utilization and disposal is the ultimate goal and fundamental way out of construction solid waste disposal, mainly including two aspects: resource regeneration and energy conversion and utilization.

There are several problems in the disposal process of solid waste from urban construction in China: the first is the environmental pollution and safety hazards caused by arbitrary dumping and uncovered areas; the second is the serious problems caused by illegal transportation and illegal disposal; the third issue is the lack of industry standards due to the inadequate government regulatory system. In addition, illegal transportation and disposal of construction solid waste can also bring serious safety hazards. For example, the waste muck and soil generated during illegal transportation and disposal can pollute soil and groundwater resources, while the construction waste generated during illegal transportation and disposal contains a large amount of non degradable components, which can cause serious environmental pollution and safety hazards. At the same time, there are still problems such as low utilization efficiency and substandard product quality in pilot areas for the resource utilization of construction waste in some cities. Therefore, it is necessary to achieve precise supervision of the entire process of construction solid waste disposal by building a precision intelligent control warning platform for construction solid waste.

3.2. Construction of Precision Intelligent Control and Early Warning Platform for Construction Solid Waste

The precision intelligent control and early warning platform for construction solid waste is based on digital technologies such as the Internet of Things, cloud computing, and big data. It is constructed at multiple levels such as perception layer, network layer, platform layer, and application layer. Based on front-end perception devices, it integrates various resources through information technology, collects data, and transmits the data to the platform layer for data storage, processing, and analysis. Finally, it is applied to intelligent analysis, remote control, and other management. At the same time, in combination with the actual business scenarios of construction solid waste disposal, key data is monitored and warned in real-time. The precision intelligent control warning platform for construction solid waste is shown in Figure 1.

Fig 1. Precision intelligent control warning platform for construction solid waste

Figure 1 shows the platform layer of a precision intelligent control warning platform for construction solid waste in a certain city, which includes seven small sections: basic information, analysis and summary, personnel warning, vehicle warning, checkpoint analysis, joint monitoring, and abnormal enterprises. The middle part is the map of the city. In the process of building a precise intelligent control and early warning platform for construction solid waste. The multi-source perception data is accessed to the platform, and real-time calculation and analysis are carried out through edge computing technology. At the same time, all kinds of information are summarized to the data center for unified storage. In addition, different data analysis models are used for analysis and processing in different business scenarios to achieve precise supervision of the entire process of construction solid waste disposal. The perception layer of the precision intelligent control and early warning platform for construction solid waste includes a video monitoring system, an environmental monitoring system, and an intelligent management system. Through comprehensive perception equipment, real-time perception and intelligent analysis of the entire process of construction solid waste disposal are carried out, and environmental safety hazards are identified in a timely manner for environmental risk assessment and prediction. The perception layer of the precision intelligent control warning platform for construction solid waste is shown in Figure 2.

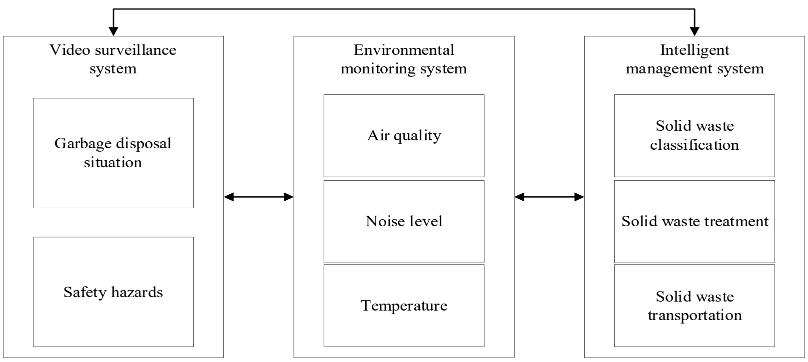

Fig 2. Perception layer

Figure 2 includes three major sections of the perception layer: video monitoring system, environmental monitoring system, and intelligent management system. Among them, the role of the video surveillance system is to monitor the situation of construction solid waste through cameras, including garbage disposal and potential safety hazards. The environmental monitoring system is used to monitor the environmental conditions around construction solid waste, including air quality, noise level, temperature, etc. The intelligent management system manages construction solid waste through an intelligent management system, including the classification, treatment, transportation, and other aspects of solid waste. The following formulas are used in the construction of a precision intelligent control warning platform for construction solid waste:

$$Q_a = \sum Q_i u_i k_i \tag{1}$$

In Formula (1), Q_a represents the total output of solid waste; Q_i represents the output of various types of solid waste; u_i represents the building utilization rate; k_i represents the building type coefficient.

$$E = \frac{Q_f}{Q_e} \times 100\% \times k_e \tag{2}$$

In Formula (2), E represents the efficiency of solid waste treatment; Q_f represents the amount of treated solid waste; Q_e represents the amount of solid waste before treatment; k_e represents the processing efficiency coefficient.

Real-time monitoring of the construction solid waste disposal site is carried out through video surveillance equipment, with no dead corners in all directions. Abnormal events are detected in a timely manner and early warnings are given. At the same time, dangerous areas, key areas, and major hazard sources during the disposal process can be monitored, and abnormal situations can be alerted. Real-time monitoring of environmental indicators such as temperature, humidity, noise, and dust at the construction solid waste disposal site is carried out through various sensors, and relevant data is analyzed and warned in a timely manner through a data analysis system to detect abnormal events and take corresponding measures.

The Internet of Things (IoT) technology is being utilized to achieve remote monitoring and management of construction solid waste disposal facilities. Through the monitoring center and mobile application terminals, the operational status of disposal facilities can be seen in the remote monitoring center; through mobile application terminals, remote control and maintenance management of devices can be achieved, as well as supervision of the execution and execution of emergency plans. Remote monitoring and control of construction solid waste disposal facilities and equipment can be achieved through big data platforms. At the same time, data storage, processing, and analysis can also be achieved through cloud computing platforms, and information sharing can be achieved among multiple departments.

In the intelligent management system, it is possible to remotely monitor and control the construction solid waste disposal facilities. By real-time monitoring and analysis of environmental data at different time nodes, abnormal events can be detected in a timely manner and corresponding measures can be taken. At the same time, big data platforms are utilized to integrate and process data, and to analyze and predict the operational status of construction solid waste disposal facilities and equipment. In addition, it can also process, play, edit, edit, and edit video files stored in the video monitoring system. The precision intelligent control and early warning platform for construction solid waste collects various types of data in real-time through IoT devices to the data center, and cleans, fuses, analyzes, and processes the data to establish a data resource pool, providing support for the next step of data application. At the same time, the platform can aggregate data to regional cloud computing centers, building a data centered platform architecture, further improving the efficiency and stability of big data processing. After establishing a comprehensive data resource pool, the precision intelligent control and early warning platform for construction solid waste can integrate, analyze, and process various types of collected information. At the same time, it can construct corresponding models, algorithms, etc., based on various industry business scenarios, providing industry knowledge service capabilities to meet the specific business needs of different industries [11].

3.3. Digital Collaborative Governance of Construction Solid Waste Disposal

Digital collaborative governance of construction solid waste disposal refers to the use of digital technology to establish and improve collaborative governance mechanisms for various aspects of construction solid waste disposal, promoting the participation of multiple stakeholders. The government plays an important role, and relevant departments should strengthen their guiding role, establish information sharing and problem feedback mechanisms, and promote the participation of various entities in digital collaborative governance of construction solid waste disposal. The public and enterprises participate as supervisory and enforcement entities. In addition, the application of technology plays an important role in the disposal of construction solid waste.

The construction of digital collaborative governance requires the joint participation of government, enterprises, the public, and other non-governmental organizations, with the aim of improving the efficiency of construction solid waste disposal and reducing resource waste. Specifically, the digital collaborative governance system consists of four parts: top-level design led by the government, institutional guarantees organized by the government, technology and talent supply for enterprises, and public participation and supervision. Among them, third-party evaluation mechanisms and public participation mechanisms are introduced to improve the quality of governance.

The top-level design of government led digital collaborative governance promotes the digitization of construction solid waste disposal by improving policies and regulations, setting standards, and strengthening information sharing. The division of responsibilities, rules and regulations, and rights and obligations of each department are clearly defined to promote digital collaborative governance. A mechanism for information sharing and problem feedback is established to ensure the smooth flow of information, strengthen government coordination capacity building, and promote effective communication and coordination among all parties. It is necessary to strengthen public participation awareness and increase participation enthusiasm. A collaborative mechanism among enterprises is established to promote their participation in the disposal of construction solid waste and improve efficiency.

The use of digital collaborative governance models by relevant government departments can enhance the participation of enterprises and create a favorable environment for them, enabling enterprises to understand issues and shortcomings through information sharing and problem feedback mechanisms, and promoting active participation of the public in the disposal of construction solid waste through public participation mechanisms and corporate collaboration mechanisms. The information sharing mechanism is a key link in digital collaborative governance and needs to be established and improved. Insufficient information sharing and poor communication in the disposal of construction solid waste hinder digital collaborative governance. The government, enterprises, and the public are the main participants, and it is necessary to establish information sharing and problem feedback mechanisms, organically connect, and form a sound digital collaborative governance system. The government and enterprises should establish an information sharing mechanism, and government departments should guide enterprises to participate in digital collaborative governance, providing a good competitive environment. Government departments release information sharing and problem feedback channels to the public through Internet platforms, WeChat official account and other channels to guide public participation. The problem feedback mechanism and information sharing mechanism are improved, forming good communication and collaborative relationships.

The public participation mechanism strengthens communication and interaction with the public by establishing participation platforms and channels, and encourages participation in the supervision and implementation of construction solid waste disposal. The public is guided to establish a green lifestyle concept through publicity and education, and improve their participation enthusiasm. The collaborative mechanism of enterprises encourages participation in supervision and execution by establishing internal management mechanisms and regulatory efforts. The supervision of enterprises is strengthened, and digital technology is utilized to achieve data exchange and technology sharing, forming a sound digital collaborative governance system. Digital collaborative governance requires strengthening the collaborative capacity building and supervision of all parties, as well as enhancing communication and coordination. Regular communication and problem feedback mechanisms are established to promptly resolve issues. An assessment and evaluation mechanism is established to strengthen the supervision of various entities and improve their participation enthusiasm [12].

4. Test Results and Discussion of the Precision Intelligent Control Warning Platform for Construction Solid Waste

The article studied the construction scheme of a precision intelligent control and early warning platform for construction solid waste, aiming to achieve intelligent and precise management of the construction solid waste treatment process through digital technology empowerment. In order to verify the effectiveness and feasibility of the scheme, a series of experiments and data analysis were conducted to evaluate the performance and effectiveness of the platform in construction solid waste treatment. The experiment first collected data on the production, treatment efficiency, and resource utilization of construction solid waste. The performance of the precision intelligent control warning platform for construction solid waste was evaluated through actual measurement and analysis of intelligent monitoring coverage, warning accuracy, and intelligent control system response time. The results of the production, treatment efficiency, and resource utilization of construction solid waste are shown in Tables 1, 2, and 3. The experimental results of intelligent monitoring coverage, warning accuracy, and intelligent control system response time are shown in Figures 3, 4, and 5.

Table 1. Production of construction solid waste (unit: 100 million tons)

	2021	2022	2023
Project under construction	9.74	11.12	7.82
Demolition project	18.89	18.06	22.59
Decoration project	3.4	3.55	3.42
Total	32.03	32.73	33.83

In Table 1, the production of construction solid waste in 2021, 2022, and 2023 was 3.203 billion tons, 3.273 billion tons, and 3.383 billion tons, respectively. Among them, the amount of solid waste generated during construction in construction projects was 974 million tons, 1.112 billion tons, and 782 million tons, respectively. The amount of solid waste generated during demolition projects was 1.889 billion tons, 1.806 billion tons, and 2.259 billion tons, respectively. The amount of solid waste generated during decoration projects was 340 million tons, 355 million tons, and 342 million tons, respectively.

Table 2. Efficiency of construction solid waste treatment

	2021	2022	2023
Residential building	63.8%	66.8%	67.8%
Office Building	61.5%	62.5%	63.5%
Business district	61.5%	64.5%	66.5%
Decoration project	64.9%	67.9%	69.9%

Table 2 showed that the solid waste treatment rate of different types of buildings increased between 2021 and 2023. Among them, the solid waste treatment rate of residential buildings increased from 63.8% to 67.8%, and the solid waste treatment rate of office buildings and business districts also showed a similar growth trend. In addition, the solid waste treatment rate of decoration projects was constantly increasing, from 64.9% to 69.9%. These data show the overall improvement trend of solid waste treatment rate in different types of buildings and projects, indicating that the work of solid waste treatment and resource recovery has been improved to a certain extent.

Table 3. Resource utilization rate

	2021	2022	2023
Stone	46.7%	48.9%	50.2%
Metal	47.6%	49.5%	52.3%
Wood	48.1%	50.4%	52.1%
Other	48.5%	50.6%	52.5%

According to Table 3, it can be seen that the resource utilization rate of construction solid waste with different materials has increased in recent years. Among them, the resource utilization rate of stone solid waste has increased from 46.7% to 50.2%, and the resource utilization rates of wood and metal solid waste were also increasing year by year. Meanwhile, the resource utilization rate of other types of solid waste was also constantly improving, increasing from 48.5% to 52.5%.

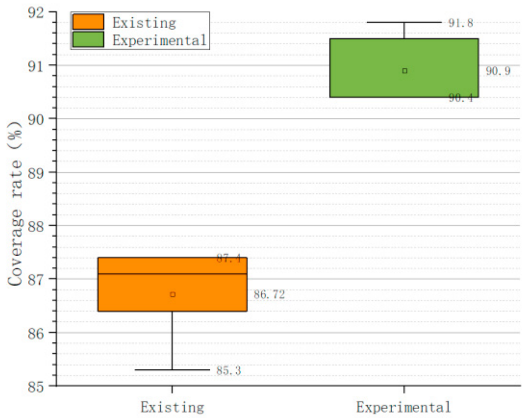

Fig 3. Intelligent monitoring coverage

In Figure 3, the monitoring coverage rate of the existing intelligent control early warning platform was the highest at 87.4% and the lowest at 85.3%, with a calculated average coverage rate of 86.72%; the monitoring coverage of the digital technology-based intelligent control early warning platform in the experimental study reached a maximum of 91.8% and a minimum of 90.4%, and the calculated average coverage rate was 90.9%. Therefore, the precision intelligent control and early warning platform for construction solid waste based on digital technology has a wider monitoring coverage.

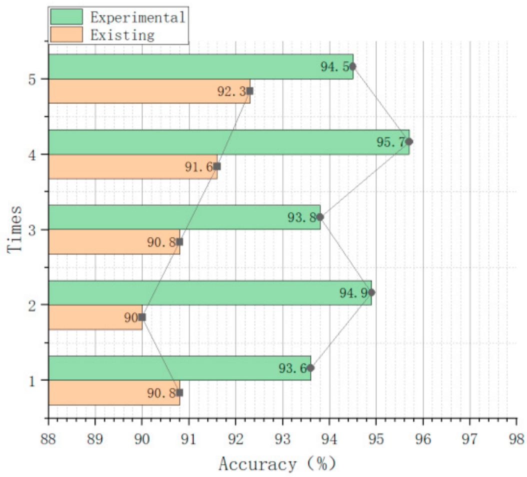

Fig 4. Warning accuracy

In Figure 4, the existing intelligent control warning platform had the highest warning accuracy of 92.3% and the lowest of 90%, with a calculated average accuracy of 91.1%; the experimental research on the intelligent control early warning platform based on digital technology achieved the highest warning accuracy of 95.7% and the lowest of 93.6%, with a calculated average accuracy of 94.5%. Therefore, the accuracy of the precision intelligent control warning platform for construction solid waste based on digital technology is higher than that of existing intelligent control warning platforms.

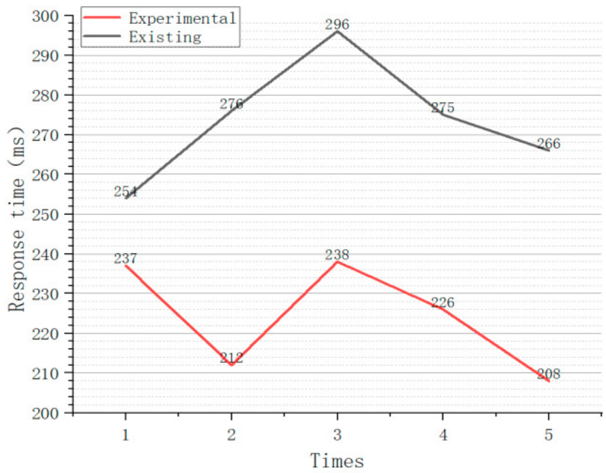

Fig 5. System response time

In Figure 5, the response time of the existing intelligent control warning platform was the longest at 296ms and the shortest at 254ms, with a calculated average time of 273.4ms; the response time of the digital technology-based intelligent control early warning platform in the experimental study was 238ms at the longest and 208ms at the shortest, and the calculated average time was 224.2ms. Therefore, the precision intelligent control and early warning platform for construction solid waste based on digital technology has a shorter system response time.

5. Conclusions

The construction of a precision intelligent control warning platform for construction solid waste provides strong support for improving the level of urban construction solid waste management, and helps to promote green development and improve the urban ecological environment. From the perspective of platform operation, the authenticity, accuracy, and real-time performance of the data are good, effectively ensuring the integrity and effectiveness of the data. From the perspective of application, the precision intelligent control warning platform for construction solid waste can effectively improve the standardization and refinement level of the construction solid waste disposal process, and provide efficient and convenient business support services for construction solid waste disposal enterprises. However, there are still some shortcomings in the actual application process of the platform, such as data sharing, standard specifications, and technological innovation. Therefore, the construction of a precision intelligent control and early warning platform for construction solid waste should continuously improve its data processing and sharing capabilities while ensuring the authenticity, reliability, and real-time sharing of data. Furthermore, the platform's functional modules should be continuously improved to enhance its application effectiveness.

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