The Intelligent Application of IoT and 3D Visualization Technology in a Road Maintenance Base

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Abstract. In the field of "new infrastructure" intelligent management and control, the Internet of Things and 3D visualization of these two technologies are developing more and more rapidly, and complement each other, which has also aroused the keen attention of road maintenance base managers. This paper will take a road maintenance base as the research object, to explore the practical application of Internet of Things 3D visualization technology in this particular scene. According to the needs of the whole project, through real-time monitoring and data collection of each business data in the intelligent road maintenance base, we analyze the different operational efficiency, energy consumption and output analysis under the traditional mode and the new mode of applying IoT 3D visualization technology, so as to provide a new solution for the intelligent operation and control of the road maintenance base in the future by using IoT 3D visualization technology.

Keywords: IoT and 3D Visualization · Road maintenance base · Intelligent application

1 Introduction

Internet of Things 3D Visualization is a technology that combines Internet of Things (IoT) and 3D Visualization (3D Visualization). The former collects, transmits and shares information in real time through a variety of devices connected to the Internet; the latter presents data in graphical form through BIM (Building Information Modeling) modeling technology and 3D graphic technology, enabling people to understand and analyze the data more intuitively and clearly. IoT 3D visualization technology, it is the integration of the advantages of the above two, the data collected by the Internet of Things, attached to the structure of the main body of the three-dimensional graphic display, so that users can better understand the meaning and relevance of the data represented by the application is very broad, in architectural design, transportation, urban planning, industrial manufacturing and other fields play a role. This technology can integrate real-time data from

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sensors, equipment, people, etc. with 3D models to form an interactive visualization interface that achieves a sense of realism in the observation and simulation of objects, scenes, and processes, which can help users better plan and make decisions, improve efficiency, reduce errors, and provide a better user experience.

With the rapid development of transportation roads and the growth of demand, how to improve the efficiency of road material production and provide road safety and stable quality has become an urgent issue. The central control room of the road maintenance base, as the core of the base production system, plays an important role in monitoring, controlling and managing the whole process of road material production. The central control room of the base is an information-intensive environment that involves the monitoring and control of many parameters, such as temperature, humidity and light.

However, there are some problems in the traditional control of road maintenance bases, such as the difficulty of data acquisition, inconvenient control operation, and untimely fault detection in hardware, while in the software platform, most of the 2.5D oblique view + dynamic picture display technology is used to realize low-cost pseudo three-dimensional stereoscopic graphic interface, which is not intuitive enough for easy use as a whole.The 2.5D technology adopts a multi-level superposition of planar images and transformations in order to create a visual effect that approximates a three-dimensional effect[1]. Unlike traditional flat images, 2.5D technology makes flat images look more three-dimensional and deep by processing the perspective, shadow and lighting of the image, but actually still consists of flat images. This technology can be used to create a more realistic sense of space and dynamics by adding layers, projection effects, motion effects and other means.

In order to solve these problems, IoT 3D visualization technology has emerged, bringing new applications and improvement possibilities to the road maintenance base [2].

IoT technology, as a derivative of Internet technology, through data collection, information processing and finally big data analysis can make things and objects further extend under the connection of Internet platform [3]. Its main features include extensive connectivity, real-time, intelligence and automation, etc. [4]. 3D technology refers to a technology based on three-dimensional spatial modeling and image processing technology for creating, displaying, manipulating and interacting with three-dimensional images and scenes. It uses advanced graphics rendering techniques by simulating real-world objects and environments so that observers can feel a realistic sense of three-dimensionality in virtual environments and be able to interact with them [5].

IoT 3D visualization technology enables the road maintenance base to realize real-time monitoring and management, automated operation and maintenance, data analysis and optimization, environmental protection and energy saving, as well as providing intelligent services and decision support. With the support of IoT 3D visualization technology, the whole of the maintenance base can present the real operation and control situation in multiple dimensions, and it is more conducive to the subsequent access of other contents.

In this paper, we will analyze the issues around how to select the IoT 3D visualization technology, the advantages and disadvantages in the application of the case study and the challenges and opportunities that the technology will face, and the research can play a certain role in guiding similar projects in the future.

Literature [6] in the previous summary predicted that the development of the Internet of Things will go through four stages, through the development of these years at present the Internet of Things has entered the stage of full intelligence, the Internet of Things technology will also face many serious challenges. Literature [7] applies IoT technology to building construction from attendance, alarms, hazard monitoring and other aspects of the systematic elaboration of the role of building safety management. Literature [8] analyzes the necessity of intelligent transportation construction based on IoT technology, describes the key technology of IoT application in intelligent transportation, and discusses the specific application of IoT technology in intelligent transportation from the aspects of vehicle speed, traffic flow, and urban public transportation. Literature [9] realized the IoT interoperability of vehicles by applying intelligent technology to the monitoring of railroads. Literature [10] applies IoT technology to the management automation of agriculture, and investigates in detail the control model of the measurement components related to the control algorithm of IoT technology and the processing algorithm of sensor indication. The application and promotion of the above technology provides technical support for the application of IoT technology in the intelligent road maintenance base, but at present the application of IoT technology in the intelligent road maintenance base is still imperfect, and there are still many difficulties, this paper aims to provide technical support for the future when there are similar projects.

2 Application Case Analysis

This paper analyzes and discusses the practical application of 3D visualization technology of Internet of Things based on a road maintenance base construction intelligence engineering project in Jiangsu Province. The base is located in Yancheng City, Jiangsu Province, and undertakes the maintenance and protection work of part of the highway network in Jiangsu Province. This project will weighbridge area, production area, mixing area, tank area, material area, relay warehouse and other monitoring data of each plant area through the wisdom of the base center control room large screen system display, and provide alarm information on this.

2.1 Engineering Requirements Analysis

The original user requirements collected for this engineering project are as follows:

(1) Display real-time animation of work in various factory areas through 2.5D technology;
(2) Monitor the real-time production situation of each factory area and achieve timely reporting;
(3) Connect the data monitored by various sub business systems;
(4) Enter each subsystem to query detailed data through unified permissions.

Now based on customer demand, the project site visits, found that when using 2.5D technology output of the animation model as well as the screen can only show the object in a single angle of the model rendering effect, to see the full range of civil structures, the distribution of Internet of Things equipment, and not conducive to the reading and comparison of the various plants of the multiple sets of data, the overall intuition is poor. Compared to the effect of 2.5D picture rendering, 3D model can not only more intuitively express the full picture of the object in all angles, but also in the performance of graphic dynamics is very advantageous [11].

The use of Internet of Things 3D visualization technology, can be more intelligent and scientific management of the maintenance base, so as to enhance the production of raw materials out of the quality. For example: the use of RFID equipment, the realization of the stone into the field without personnel guarding, different specifications of the stone transported to the maintenance base by dump trucks, dump trucks with cargo specification information of the radio frequency card, unattended weighbridge is equipped with vehicle number identification and card reading equipment, can automatically save the vehicle information and weighing information to the system. Dust concentration monitoring and automatic spraying system are established in the stockpile area, and the spraying system is automatically turned on when the dust concentration exceeds the set value. Temperature, humidity and environmental data are collected in the lab through DTU devices. Using AI edge boxes with algorithms, behaviors of not wearing safety

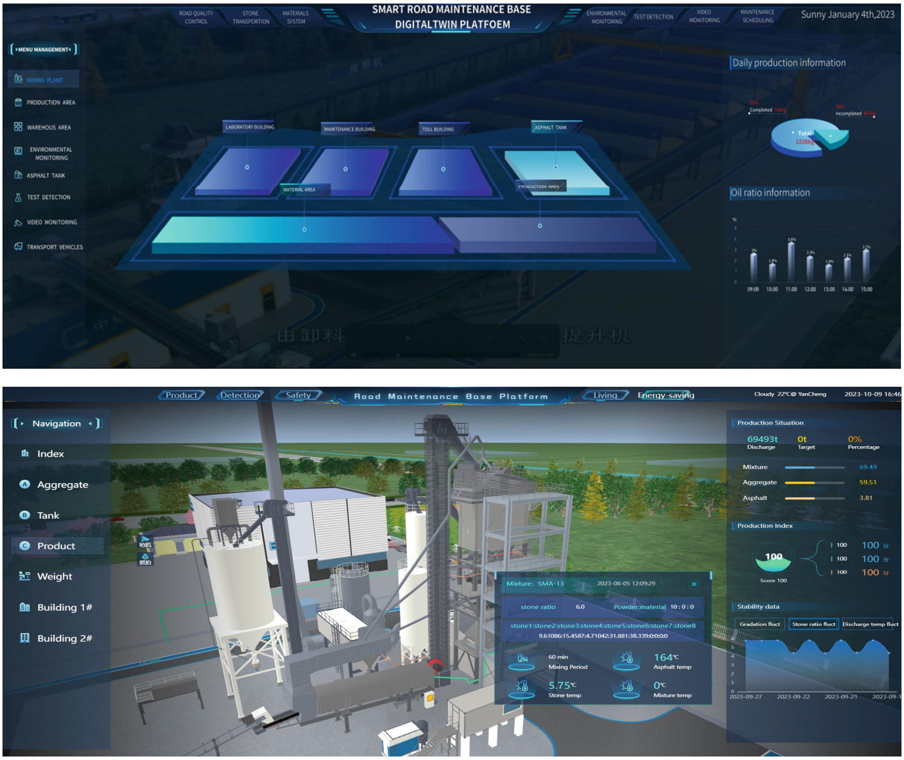

Fig. 1. Comparison of 2.5D and 3D model images

helmets and safety suits are identified and detected and warned. All of the above IoT devices can - in combination with 3D visualization technology - present location and data, while at the same time providing over-limit warnings through intuitive material changes.

Various equipment status, material management, production settings, and personnel flow information of the maintenance base are also synchronized and uploaded to the large screen platform in the control room of the base, which facilitates the overall management of the maintenance base. The 3D model of the road maintenance base can help decision makers make quick and accurate decisions in case of emergency. The following figure shows the difference between 2.5D and 3D in presentation (Fig. 1).

By clicking on the left side of the platform, you can quickly switch to the corresponding regional perspective, and then by clicking on the equipment in the model, you can get the current production and operation of the equipment. On the right hand side, you can visualize statistical information. In case of overrun or danger (e.g. edge box recognizes the phenomenon of not wearing a helmet), an alarm message will be popped up to remind the user to deal with it in time.

2.2 Engineering IoT Connection Implementation Requirements Change

In order to upgrade the 2.5D model display to 3D model display, we have to realize it through modeling technology and front-end WebGL programming technology. Firstly, we use conventional 3D modeling software (3dsMax software is used in this project) to establish 3D models and model animations that match the real structure and equipment, and at the same time, in the process of modeling, we carry out UV mapping and reduce the surface of some unnecessary surface positions; secondly, we bind the IoT devices (e.g., cameras) with the structure of the main body for the subordination of multiple information, and introduce dynamic data of the parsing interface from the background; then, we partition and cut the model file and sequentially implement it with front-end WebGL programming technology. Secondly, the model files are partitioned and cut into multiple files sequentially exported from the modeling software, and unified lightweight processing and compression is carried out to generate suitable loadable formats such as glb/fbx for loading on web pages.

At the software development level, the project interface is based on the VUE framework as a whole, while the open-source Three.js 3D engine library is introduced. The official raw script is used to load the 3D file format of glb/fbx, and the appropriate scene and camera viewpoints and lighting are created, which are rendered on the web page using the WebGL renderer. Subsequently, loop functions are created and local animation effects are realized by modifying parameters such as the rotation angle and position of the mesh, playing keyframes, and calling the renderer's render() method to render the scene and camera to achieve the effect of displaying 3D (Fig. 2).

Through this approach, on the one hand, the platform can make the Internet of Things to realize the intelligent equipment to find and locate, on the other hand, also can make the Internet of Things platform real-time record of the dynamic information of the production of equipment, so that the whole project can achieve the refinement of the management. The combination of BIM model and Internet of Things equipment data can largely meet the needs after the change, not only realize the rendering effect

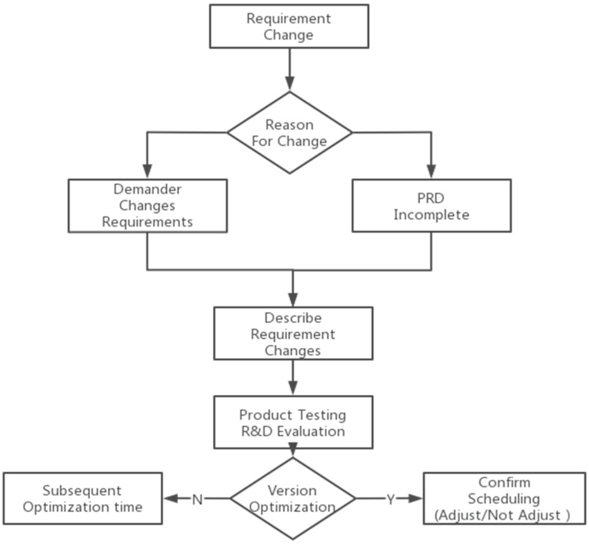

Fig. 2. Task flowchart for implementing requirement changes

of 3D stereo graphics, but also provide a very feasible solution for the overall project operation control and future development.

2.3 Application of IoT and 3D Visualization Technology

The application of Internet of Things (IoT) technology in the construction of road maintenance bases includes sensor-monitored data collection, remote control and operation, and fault detection and early warning. By installing suitable sensors and utilizing wireless networks to transmit data, base managers can monitor the operating status of equipment in real time and control it remotely. At the same time, based on sensor data analysis, the system can timely detect equipment failure and send early warning information to improve equipment reliability and operational efficiency.

Various types of sensors applied in the road maintenance base, including: temperature sensors, humidity sensors, smoke sensors, speed sensors, infrared sensors, weighbridge collection equipment and so on. Through the application of IoT technology, the air temperature, humidity, light intensity and other production-related information data and equipment operating speed can be collected in real time from each plant, and the data collected by the sensors are transmitted to the central entity server or cloud platform through wired and wireless networks for further background analysis.

Based on IoT technology, base managers can control and operate base equipment remotely from anywhere via the network. First, using wired and wireless communication networking technology, IoT devices can be seamlessly connected to the central server or cloud platform. Secondly, the cloud platform has the function of data storage and analysis, which provides users with an interface for remote management and control. Further, the remote control process should be parsed using specific protocols with corresponding message rules, such as HTTP(S), MQTT, Socket, etc., to ensure the safety and reliability of remote operation. Finally, user-friendly remote operation interfaces, such as Web interfaces and cell phone applications, provide an intuitive and convenient remote management and control experience.

The IoT technology detects the failure of equipment in the base in time based on data analysis and pattern recognition from sensors and sends early warning information to relevant personnel via SMS and email for timely handling. The technology utilizes sensors to collect the operating data of the equipment and analyze it in comparison with the pre-set indicator thresholds to detect the presence of anomalies. Once an abnormal state is detected, the system quickly sends out an early warning notification via a cloud platform or other forms so that appropriate maintenance and treatment measures can be taken in a timely manner. Such a fault detection and early warning system can improve the reliability and operational efficiency of the equipment, reduce the losses caused by failures, and has an important application value for road maintenance management and other intelligent emerging fields (Fig. 3).

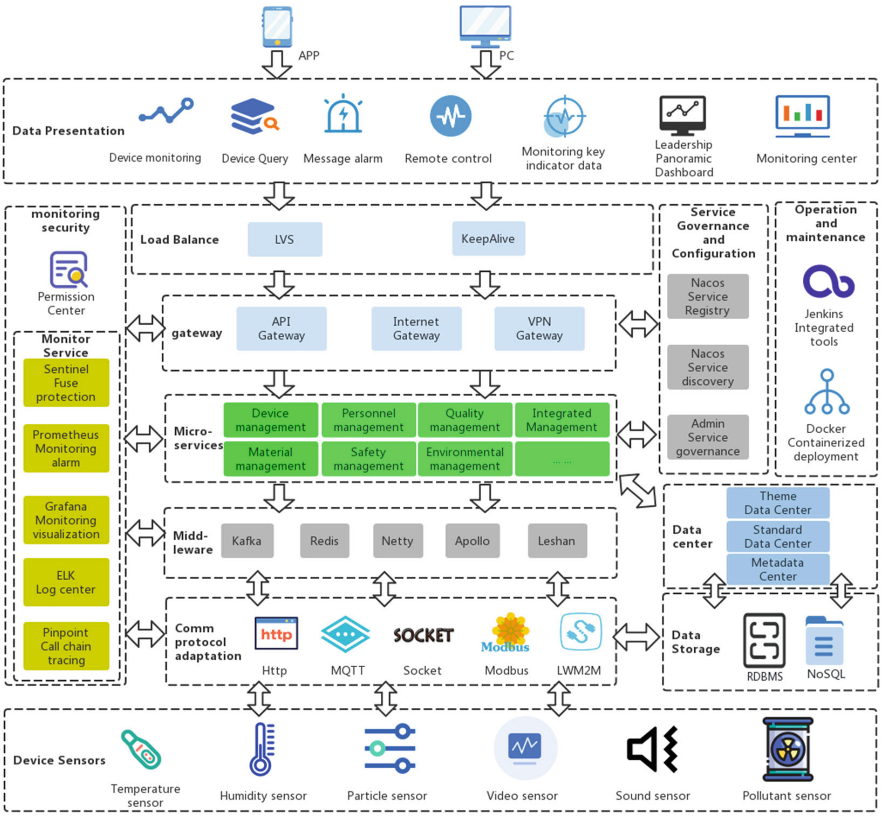

Fig. 3. Application Architecture of this Technology for Road Maintenance Base

3 Analysis and Evaluation of Application Effects

Through the application of IoT technology, the operational efficiency of the central control room of the intelligent road maintenance base can be improved, realizing the reduction of human input and the effective use of resources. In addition, through the Internet of Things technology to realize the early warning of failure and remote operation, can reduce the maintenance cost to a certain extent. At the same time, IoT technology can also enhance the security and monitoring reliability of the base center control room, and guarantee the stability and quality of road maintenance base production.

3.1 Efficiency Analysis

Evaluating the effectiveness of the IoT system in managing the road maintenance base provides a clear picture of the operational efficiency of the entire base. The figure below shows a flow chart of the value of operational efficiency between using the IoT system and traditional methods. The flowchart analyzes the work time spent, resource efficiency utilization, etc., which greatly improves the productivity of the entire base. A brief description and explanation of the IoT road maintenance base value flowchart is provided below (Fig. 4).

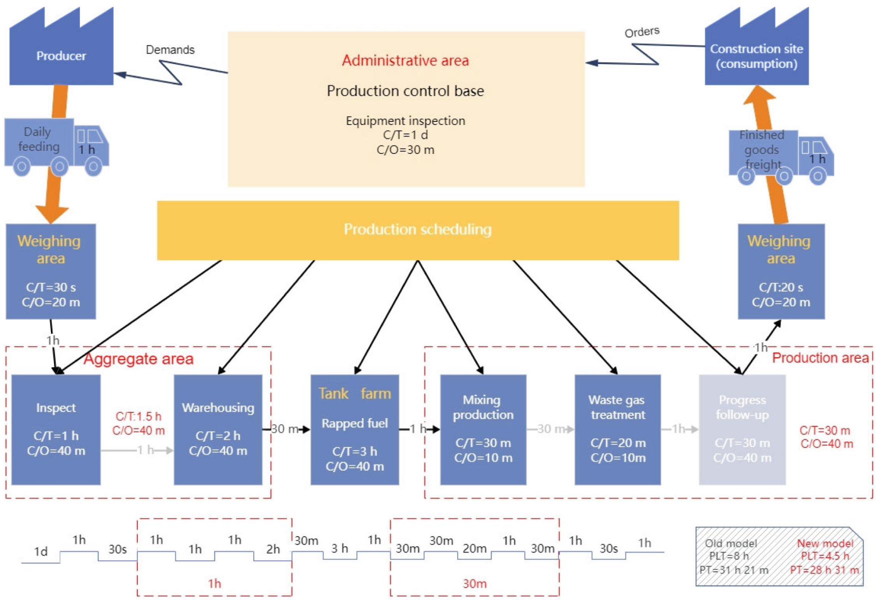

Fig. 4. Business Flow Value Transfer Process of Road Maintenance Base. **Note:** C/T (Cycle time): The time when the machine completes the task; C/O (Change time): Component change time; PLT (Product lead time): The delivery cycle time of a single product; PT (Process time): Production process time. Where 'h', 'm', and 's' represent time units of hours, minutes, and seconds.

As shown in the figure above demonstrates the operation of the entire base business. In the process can be seen from the construction side to provide orders to the production base as well as the production base and then through the supply side of the material transported to the base processing. The small rectangle in the figure shows the whole construction process of the traditional road maintenance base, and each link shows the machine completion time and part mold time, and the red dotted line shows the production link of the new model machine under the Internet of Things, and its completion time and part mold time. The stepped timeline at the bottom shows and counts the time needed in the whole processualization, with the machine completion time at the bottom of the steps and the time between machines at the top of the steps.

The time statistics in the graph show that the traditional model requires a total of 39 h and 21 min per production run, while the new model with IoT requires a total of 33 h and 1 min per production run, which is a reduction of 6 h of working time. The main reductions in time are the extra labor time and the time spent switching machines between sites before the IoT was used. The new model under IoT reduces the delivery cycle time by 3.5 h and the production process time by 3 h.

The value process map clearly shows the entire process chain, identifying and eliminating unnecessary links and wasted time in the original program using IoT technology. It helps managers better understand and grasp the entire production process, and improves the utilization of production resources and production efficiency.

3.2 Energy Consumption Management of IoT and 3D Visualization Devices

The widespread use of IoT technology in areas such as smart road maintenance bases gives us more opportunities to manage and optimize energy consumption. However, the energy consumption of IoT devices themselves has become one of the challenges that need to be addressed. Therefore, how to effectively manage and control the energy consumption of IoT devices, extend battery life, reduce energy consumption and minimize the impact on the environment has become one of the important issues we are facing. Next, we will have an in-depth discussion on the management of energy consumption of IoT technology in smart road maintenance bases, and analyze the advantages, challenges and related solutions. The following is a comparative analysis of the power and water energy consumption of the road maintenance base in two years under the old model and the new model in half a year each (Fig. 5).

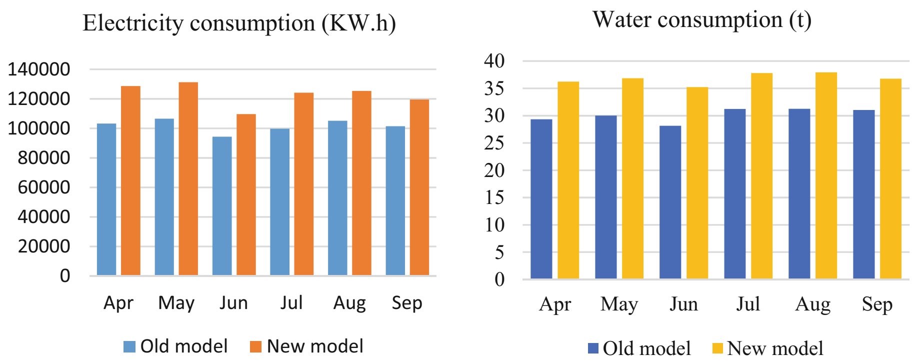

Fig. 5. Comparison and Analysis of Energy Sources between Electricity and Water Modes

The above figure shows that the energy consumption in the old model is lower than that in the new model, so the IoT technology increases the percentage of energy consumption when applied to the road maintenance base project. In road maintenance bases, the use of high-efficiency sensors, the selection of low-power communication methods and the adoption of intelligent energy management systems can improve the efficiency of system operation. However, large-scale deployments need to handle a large amount of data streams, and frequent device communication and data transmission may increase energy consumption. At the same time, keeping certain devices always on can further increase energy consumption. Therefore, overall energy management requires comprehensive consideration of the relationship between different devices and systems, and appropriate strategies, such as configuring device sleep/wake mechanisms, optimizing sensor operating modes, using energy-efficient devices, and optimizing data transmission methods. Effective energy management can only be achieved by comprehensively considering the relationship between balancing energy consumption and system requirements.

However, whether the application of IoT technology in smart road maintenance bases is reasonable or not also requires a comparison of the efficacy of the outputs in order to arrive at a rationalization, and the capacity of the road maintenance bases in these two modes will be further analyzed in the following.

3.3 Capacity Analysis

As one of the important fields of the application of Internet of Things (IoT) technology, the intelligent road maintenance base realizes the intelligent management and control of road maintenance equipment and infrastructure through the integration of sensors, communication networks and data analysis and other technical means. However, while promoting the development of intelligent road maintenance base, we need to pay attention not only to its energy consumption but also to the effect of its output. Therefore,

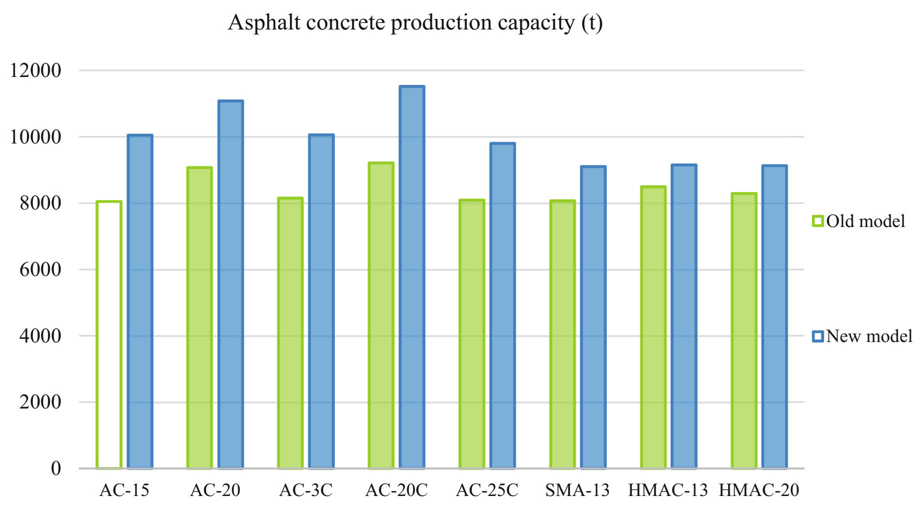

Fig. 6. Comparison of Asphalt concrete Production

the following will be targeted to analyze the capacity. A comprehensive assessment of the output effect of IoT technology in smart road maintenance bases can provide strong support and guidance for improving energy efficiency, optimizing operation and management, and promoting application. The following figure compares the output of different types of concrete for one month in the road maintenance base under the old model with the output of different types of concrete for one month under the application of IoT technology (Fig. 6).

The above figure shows that the output of concrete in the intelligent road maintenance base with the application of IoT technology is more than the output of concrete in the road base of the traditional model, and it can also be seen from the value flow chart that the intelligent road maintenance base with the application of IoT technology has a lower mold change time than the traditional one, so it can also produce more different types of soil mixing materials in the same time. The results of capacity analysis show that it can significantly improve the production efficiency and product quality. Not only that, the intelligent road maintenance base applying IoT technology is also able to realize the base's highly automated and precisely regulated production process through real-time monitoring of the raw material supply status, intelligent proportioning and process control, as well as remote monitoring of the equipment operation status and failure warning. This helps to increase production and reduce downtime, as well as ensure product consistency and stability, meet customer demand and enhance competitiveness.

Through the above evaluation of efficiency analysis, energy consumption management, capacity analysis and other indicators, we can get a comprehensive understanding of the effect of the engineering application of IOT technology in the intelligent road maintenance base. In terms of efficiency, it improves the utilization of production resources and productivity, in terms of energy consumption, it can achieve the balance of energy consumption through the formulation of appropriate strategies, and in terms of capacity analysis, it improves the output of products, improves the management ability and reduces the input of human resources. This will help to improve the management efficiency, resource utilization and safety of the road maintenance base, thus realizing higher economic and social benefits.

4 Challenges Faced and Future Development Direction

The application of IoT technologies in smart road maintenance bases is still facing a number of challenges, such as security and privacy protection, technical standards and interoperability, cost and sustainability. To address these issues, future directions include enhancing data protection and privacy protection, establishing unified IoT standards and protocols, reducing the cost of IoT devices, and optimizing the energy consumption of IoT technologies. Meanwhile, the combination of IoT technology with artificial intelligence, big data and other technologies can be further explored to realize smarter and more efficient production of intelligent road maintenance bases.

4.1 Challenges Faced

(1) There is still a disconnect between the requirements and perception layers.When the IoT and 3D visualization technology is applied to the construction of smart road

maintenance bases, we need to carry out perceptual layer technology innovation work based on specific functional requirements. Due to the current perception layer technology not being fully applicable to the field of smart road maintenance.Therefore, there are high requirements for optimizing the distribution of sensing devices, miniaturizing technology, making it multifunctional, and reducing power consumption. So we need to innovate application of IoT and 3D visualization technology to meet the specific needs of the smart road maintenance field.

(2) The complexity and scale of data are increasing.In the context of the closer connection between the Internet of Things and 3D scenes, a large amount of data will be generated, including geometric models, sensors, devices, personnel, and other aspects of data.Processing and analyzing these massive amounts of data is a challenge that requires efficient data storage, computation, rendering, and processing capabilities.Data quality is crucial for accurate 3D visualization. However, data in the Internet of Things environment may be affected by sensor failures, noise interference, data loss, and other issues, which may lead to inaccurate visualization results.

(3) The research on underlying models and algorithms is weak.The road maintenance base can collect a large amount of road maintenance related data through Internet of Things technology. At the application layer, theoretical algorithms such as data cleaning and analysis, deep learning, etc. based on a large amount of historical data can provide more accurate safety production and consulting services at the current stage. However, there is still a lag in the application layer in this regard, and it is necessary to strengthen the research on the underlying models and algorithms. Consider improving the application layer level from multiple factors.

(4) The quality of grassroots talents is not high.Due to the limited exposure of grassroots practitioners to IoT knowledge, the reconstruction of IoT infrastructure is severely hindered [11].Therefore, it is necessary to strengthen the training of relevant personnel, optimize talent introduction plans, and create a high-quality and high-level team of grassroots practitioners in the IoT. Moreover, the government should strengthen the construction of relevant laws and regulations to create a good atmosphere for the IoT and 3D visualization technology in the field of smart road maintenance bases.

The IoT and 3D visualization technology faces many challenges in the intelligent management and control of road maintenance bases. Therefore, it is necessary to guide innovation in the perception layer through demand guidance, research on bottom strengthening layer models and algorithms, and vigorously cultivate grassroots talents. Completing these tasks can promote the construction of smart road maintenance bases and the application of IoT and 3D visualization technology. This will further improve the quality and efficiency of maintenance work, and bring significant improvements to road maintenance management.

4.2 Future Development Direction

One of the future directions of IoT technology in smart road maintenance bases is data intelligence. With the wide application of IoT devices, the maintenance base will be able to collect and analyze a variety of data in real time, including road condition information, equipment operation status, traffic flow and so on. By integrating big data technology and artificial intelligence algorithms, these data can be intelligently processed and analyzed to extract valuable information and make predictions. For example, by analyzing road cameras and mining traffic flow data, changes in road conditions can be predicted in advance, providing maintenance personnel with timely maintenance plans.

Another development of IoT technology in the smart road maintenance base is automated monitoring and control. Real-time monitoring of maintenance equipment, road conditions and environmental parameters can be realized by installing sensors and collection devices on the equipment. These monitoring data can be transmitted to the center console through wireless communication technology to provide administrators with timely alarms on work status and abnormalities. In addition, IoT technology can also realize remote control of equipment, allowing managers to operate equipment remotely through intelligent terminal devices, thus improving operation and maintenance efficiency and response speed.

Another important development direction of IoT technology in the smart road maintenance base is predictive maintenance and optimization. With the monitoring and data analysis capabilities of IoT technology, real-time monitoring and prediction of the health status of maintenance equipment can be realized. By obtaining the vibration, temperature, current and other parameters of the equipment, combined with advanced algorithmic analysis and modeling, it is possible to predict the possible failure of the equipment in advance and carry out reasonable maintenance planning and optimization scheduling according to the prediction results. This can avoid stoppages and delays caused by equipment failures and improve the reliability and operational efficiency of the equipment, thus reducing maintenance costs and improving work efficiency.

The future development direction of IoT technology in smart road maintenance base mainly includes data intelligence, automated monitoring and control, predictive maintenance and optimization. These development directions will provide smarter and more efficient management and services for the work of smart road maintenance bases, and improve the quality and efficiency of roads in the maintenance process.

5 Conclusion

By analyzing the application case of IoT technology in base central control room, this paper shows that IoT technology plays an important role in improving the management and operation efficiency of base central control room.

(1) The road maintenance base applying IoT technology improves the efficiency of the whole production as well as improves the production system by removing the time of material conversion and reducing the redundant operation links.
(2) Comparison of the energy consumption of the road maintenance base using IOT technology and the traditional road maintenance base shows that although the energy consumption is higher in the new model, it can be balanced by optimization strategies.
(3) Comparison of the production capacity of road maintenance bases applying IOT technology and traditional road maintenance bases shows that the production capacity of the new model has a greater increase and the conversion between the production of different types of products is also faster.

At present, the application of Internet of Things technology in intelligent road maintenance base is not particularly mature, but the impact is very far-reaching, with the rapid development of Internet of Things technology, through further research and innovation, the application of Internet of Things technology in the field of intelligent road maintenance base will be more extensive and in-depth, for road maintenance to bring greater benefits and improvements.

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