Research on Key Technologies for Hospital Equipment Identification and Carbon Emission Accounting Based on Ecode Encoding

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Abstract. In response to the increasing demand for hospital medical services, while providing high-quality medical services, there are complex logistical management challenges to address, a hospital equipment identification system based on Ecode labeling has been proposed. Additionally, a carbon emission accounting statistical model based on Ecode has been developed to achieve comprehensive lifecycle management of equipment and precise collection and analysis of carbon emission data, providing a decision-making basis for hospitals' environmental protection and sustainable development.

Keywords: Ecode identification, hospital equipment, identification system, carbon emission accounting

1 Introduction

Under the macro background of the "Healthy China 2030" and "New Infrastructure" policies, new-generation information and communication technologies such as cloud computing, big data, the Internet of Things (IoT), artificial intelligence, and 5G have been flourishing. The construction of medical IoT oriented towards "Smart Hospitals" has thus become a highly anticipated trend. In recent years, major hospitals across China have been accelerating the pace of medical IoT construction. With the continuous expansion of hospital scale, the positioning and maintenance of logistics equipment have become increasingly cumbersome and time-consuming. Meanwhile, the control of energy consumption and carbon emissions has become increasingly crucial. The construction of medical IoT can leverage new-generation information technologies to provide more efficient solutions for hospital logistics equipment management. While achieving precise positioning and convenient maintenance, it also helps hospitals optimize energy management, reduce carbon emissions, and lay a solid foundation for building green and intelligent modern hospitals.

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The Internet of Things (IoT), as a highly integrated and comprehensive application of the new generation of information technology, has been widely applied in various fields. D. Cheng et al. [1] established a hospital medical equipment management system using IoT technology to monitor the usage of medical devices, achieving dynamic tracking of equipment and enhancing the visibility and controllability of equipment management. A. Aborujilah et al. [2] proposed a new IoT-based medical equipment management system (IOT MEMS) model to effectively manage ICU medical devices. Wang Xin [3] designed and implemented a medical equipment maintenance management system based on IoT technology, which can effectively reduce maintenance costs and failure rates through functions such as real-time monitoring of equipment status, remote maintenance, and fault warning. Gao Dehua et al. [4] proposed an IoT-based railway station equipment management system that utilizes IoT data collection and intelligent control technology to achieve real-time monitoring, fault warning, and intelligent management of station equipment. Huang Wenjian et al. [5] designed and built an IoT-based emergency call management system for medical emergencies, allowing patients to call medical staff through wearable devices, while medical staff can grasp the overall condition of patients through statistical reports. The aforementioned literature all employs IoT technology for equipment management; however, IoT devices require complex hardware such as sensors and communication modules, which can be costly and necessitate special protective measures.

In the field of Internet of Things (IoT) technology, Ecode encoding has significant advantages in terms of cost-effectiveness, operational simplicity, data security, and environmental adaptability. As a new type of IoT identification technology, Ecode encoding is suitable for applications that require low cost, high efficiency, and high security. Li Jianhua [6-7] applied the Ecode identification system in the cable and gas industries, addressing issues such as the weak awareness of product quality responsibility among cable companies, as well as prominent problems of quality dishonesty and illegal activities like cutting corners and counterfeiting. This implementation achieved full lifecycle traceability management for the production and use of gas products. Li Yan [8] believes that Ecode identification can be used to analyze and manage relevant quality data of cable products, which can change traditional quality supervision methods and improve regulatory efficiency. He Shuan et al. [9] proposed a method for equipment identification coding in the nuclear power industry based on the Ecode identification system, providing a set of reference coding standards for the industrial Internet identification resolution system in the nuclear power sector.

Ecode identification technology, as an important support for Internet of Things (IoT) technology, enables efficient data collection and accurate identification by assigning unique identifiers to physical objects. This enhances the interconnectivity and intelligent management capabilities of IoT systems. In the current management of hospital equipment, different manufacturers may use different device coding rules. There is limited research on how to apply Ecode in hospital equipment management, how to adapt the Ecode coding system to existing device codes, and how to integrate it with current management systems. Based on the above background, this article aims to comprehensively optimize the hospital logistics management system. It proposes an innovative plan for building a smart hospital logistics management system based on

Ecode identification. Utilizing Ecode identification technology, it implements applications for hospital logistics equipment management and carbon emission accounting statistics, providing a data foundation for calculating the hospital's carbon footprint and formulating emission reduction strategies.

2 The application of the Ecode coding system in hospital equipment identification

2.1 Ecode encoding principle

In large hospitals, the positioning and management of equipment is a complex process, Ecode coding technology can effectively solve the complex issues of equipment management. The Ecode coding structure adopts a three-part rule: Version (V) + Coding Identification System (NSI) + Main Code (MD) [10]. The detailed Ecode coding structure is shown in Table 1. Based on whether the main code contains semantics, it can be divided into header coding and general coding. The MD of header encoding contains information such as the manufacturer and check, while the MD of general coding has no semantic information. The explanations for each part of the Ecode coding structure are as follows:

Version (V): Used to distinguish different data structures of Ecode.

Numbering System Identifier (NSI): Indicates the code of a certain identification system, which requires application to the identification allocation agency to obtain the prefix resources for the identification code.

Master Data Code (MD): Represents standardized coding in a specific industry or application system.

Table 1. Ecode General Encoding Structure

Item coding Ecode			Maximum total length	Code type
V	NSI	MD		
(0000)2	8-bit	≤244-bit	256-bit	Binary
1	4bit	≤20bit	25bit	Decimal System
2	4bit	≤28bit	33bit	Decimal System
3	5bit	≤39bit	45bit	Alphanumeric type
4	5bit	Variable length	Variable length	Unicode encoding
(0101)2~(1001)2		Reserve		
(1010)2~(1111)2		Forbidden		
Note 1: The above five versions of Ecode are named ECODE-V0, ECODE-V1, ECODE-v2, ECODE-V3, and ECODE-V4 in turn. Note 2: V and NSI define the structure and length of MD. Note 3: The maximum total length is the sum of the length of V, the length of NSI and the length of MD.				

2.2 Equipment Identification Design

In large hospitals, the positioning and management of equipment can be complex and time-consuming. When equipment experiences an emergency failure, it may lead to difficulties in locating the equipment and inefficient scheduling. This article addresses such issues by mapping or embedding Ecode identifiers onto various types of equipment, which assigns a unique digital identifier to each device, enabling real-time updates and retrieval of equipment information. Hospital logistics managers can dynamically track various status information of equipment within the hospital through a management platform. When a failure occurs, they can use the platform to query the location of the equipment, accurately find the faulty device, save time, and reduce safety risks caused by delays in troubleshooting equipment failures, thereby improving the efficiency of medical services. Ecode coding technology can be applied throughout the entire process of equipment procurement, storage, daily inspections, and disposal. The classification and coding of hospital logistics equipment using Ecode coding technology are shown in Table 2 below:

Table 2. Classification and Code Table of Hospital Logistics Equipment

Encoding			Equipment category name
V	NSI	MD	
01			Logistics equipment
01	0001		Power supply and distribution system
01	0001	01	engine
01	0001	02	High voltage ring network cabinet
01	0001	03	High voltage feeder cabinet
...	...	...	...
01	0002		Water supply and drainage system
01	0002	01	Water tank
01	0002	02	Water pool
01	0002	03	manometer
...	...	...	...
01	0003		Fire protection system
01	0003	01	Smoke detector (smoke sensing detector)
01	0003	02	Temperature detector (temperature sensing detector)
01	0003	03	Manual alarm button
...	...	...	...
01	0004		Elevator system
01	0004	01	Machine room control cabinet
01	0004	02	Traction machine system
01	0004	03	Door system

...	...	...	...
01	0005		Air conditioning system
01	0005	01	Refrigerating pump
01	0005	02	Cooling pump
01	0005	03	Air conditioning water tank
...	...	...	...
...	...	...	...

The version (V) represents the Ecode version number, which is fixed as 01 to distinguish it from other hospital equipment; the coding system identifier (NSI) is used to indicate the "specialty" to which the logistics equipment belongs; the main code is used to identify the specific equipment code for logistics.

2.3 Technical realization

The detailed technical process of applying Ecode identification technology to hospital logistics equipment management is as follows:

(1) Demand sorting

Define the types of equipment that the hospital needs to manage (such as medical equipment, office equipment, infrastructure, etc.), and determine the key management links including access, inspection, maintenance, scrapping, and inventory.

(2) Intelligent identification carrier selection

High-value devices are embedded with industrial-grade RFID tags (metal-resistant/heat-resistant, such as Alien Higgs-9), mobile assets use Bluetooth + QR code dual-mode tags, and LoRa temperature and humidity sensors are deployed at environmental monitoring points

(3) Equipment identification and data collection

Assign a unique Ecode identifier to hospital logistics equipment (such as elevators, air conditioners, boilers, medical gas equipment, etc.), and collect equipment operation data in real time through iot sensors, including operation status, energy consumption data, fault information, etc.

(4) Data transmission and storage

Use the Internet of Things network (such as 5G, NB-IoT) to transfer the collected data to the intelligent logistics management platform of the hospital, and store it in the cloud or local database to achieve centralized data management and real-time update.

(5) Equipment management and monitoring

On the intelligent logistics management platform, Ecode identification technology is used to achieve the whole life cycle management of equipment, including dynamic query and management of equipment purchase, maintenance, inspection, parts replacement, fault alarm, scrap and other information.

(6) Data analysis and optimization

Based on big data analysis technology, the collected equipment operation data is deeply mined, the service life of the equipment is predicted, the maintenance cycle is optimized, the energy consumption is reduced, and the equipment health index and energy consumption are displayed through a visual interface.

(7) Intelligent early warning and response

When a device is faulty or abnormal, the system uses Ecode identification technology to quickly locate the device and send an early warning message to the manager, while providing remote diagnosis and rapid response support

3 Carbon Emission Accounting Model for Hospital Equipment Based on Ecode Encoding

As major contributors to carbon emissions, medical institutions have always faced challenges in carbon emission accounting and statistics. By deploying Ecode identification modules on the main equipment of hospitals, the system can obtain real-time data on energy usage, including electricity and water consumption. By associating this data with the Ecode identification, a reliable carbon emission accounting model can be established based on the specific energy usage of hospital equipment, achieve accurate calculation of hospital carbon emissions.

To protect hospital data privacy, this article establishes a carbon emission accounting model focusing on HVAC (heating, ventilation, and air conditioning), domestic hot water, lighting, and elevators during the operational phase of buildings. The calculation of carbon emissions from HVAC should be based on the annual cooling and heating loads of the building, while also considering the efficiency of cooling and heating sources, the energy consumption of pumps and fans, and the impact of system control strategies.

Greenhouse gas emissions due to the use of refrigerants in HVAC systems are calculated as follows:

$$C_r = \frac{m_r}{y_e} GWP_r / 1000 \tag{1}$$

In the formula:

C_r — Carbon emissions from refrigerants used in buildings (tCO_2e/a);

r — Refrigerant types;

m_r — Refrigerant charging amount of the equipment (kg/set);

y_e — Equipment lifespan (a);

GWP_r — Global warming potential of refrigerants r.

The annual heat consumption of domestic hot water should be calculated according to the actual operation of the building. The calculation formula for carbon emission is as follows (2):

$$Q_{rp} = 4.187 \frac{mq_r C_r (t_r - t_1) \rho_r}{1000} \tag{2}$$

$$Q_r = TQ_{rp} \tag{3}$$

In the formula:

Q_r — Domestic hot water annual heat consumption (kWh / a);

Q_{rp} — Average heat consumption per hour of domestic hot water (kW / h);

T — Annual domestic hot water usage hours (h);

m — Unit of water usage (number of people or number of beds, whichever);

q_r — Hot water quota ($L / person$);

ρ_r — Hot water density (kg / L);

t_r — Design hot water temperature (℃);

t_1 — Design cold water temperature (℃).

The energy consumption of the domestic hot water system of the building is calculated according to following formula (4), and the efficiency of the heat source used in the calculation is consistent with the design documents.

$$E_w = \frac{\frac{Q_r}{\eta_r} - Q_S}{\eta_W} \tag{4}$$

In the formula:

E_w — Annual energy consumption of domestic hot water system (kWh / a);

Q_r — Domestic hot water annual heat consumption (kWh / a);

Q_s — The solar system provides domestic hot water heat (kWh / a);

η_r — Domestic hot water transmission and distribution efficiency, including hot water system transmission and distribution energy consumption, pipeline heat loss, domestic hot water secondary circulation and storage heat loss ($\%$);

η_w — Average annual heat source efficiency of domestic hot water system ($\%$).

The energy consumption calculation of the lighting system should take into account factors such as natural lighting, control methods, and usage habits. The energy consumption calculation for a lighting system without a photoelectric automatic control system is as follows (5):

$$E_1 = \frac{\sum_{j=1}^{365} \sum_i P_{i,j} A_i t_{i,j} + 24 P_p A}{1000} \tag{5}$$

In the formula:

E_1 — Annual energy consumption of the system (kWh/a);

$P_{i,j}$ — Lighting power density value of room i on day j (W/m^2);

A_i — i room lighting area (h);

$t_{i,j}$ — Lighting time of room i on day j (h);

P_p — Emergency lighting power density (W/m^2);

A — Floor area (m^2).

The energy consumption calculation of the elevator system is as shown in equation (6). The parameters used in the calculation, such as elevator speed, rated load capacity, and specific energy consumption, are consistent with the product nameplate.

$$E_e = \frac{3.6Pt_aVW + W_{s\tan dby}t_s}{1000} \tag{6}$$

In the formula:

E_e — Annual elevator energy consumption (kWh/a);

P — Specific energy consumption (mWh/kgm);

t_a — Average annual operating hours of elevators (h);

V — Elevator speed (m/s);

W — Rated capacity of elevator (kg);

$E_{s\tan dby}$ — Elevator standby energy consumption (W);

t_s — Average elevator standby hours per year (h).

4 Implementation case

This article takes the heating, ventilation, and air conditioning (HVAC), domestic hot water, lighting, and elevators of a certain hospital as experimental subjects. An Ecode identification module is embedded in the equipment, and by associating the energy usage data of the equipment with the Ecode identification, the carbon emission data of each device is calculated using the carbon emission accounting model established in Part 3. The results, compared with traditional methods, are shown in Table 3 below:

Table 3. Comparison table of experimental results

Equipment	Index	Traditional method	Textual method
HVAC	Equipment inventory efficiency	3h	0.5h
	Carbon emission error rate	25%	5%

Domestic hot water	Equipment inventory efficiency	4h	0.5h
	Carbon emission error rate	28%	9%
Illumination	Equipment inventory efficiency	2h	0.2h
	Carbon emission error rate	23%	6%
Elevator	Equipment inventory efficiency	1h	0.2h
	Carbon emission error rate	25%	10%

Through comparative experimental results, after utilizing Ecode identification technology, the inventory efficiency of HVAC equipment increased by 83.3%, and the carbon emission error rate decreased by 20%; the inventory rate of domestic hot water equipment increased by 87.5%, and the carbon emission error rate decreased by 19%; the inventory rate of lighting system equipment increased by 90%, and the carbon emission error rate decreased by 17%; the inventory rate of elevator system equipment increased by 80%, and the carbon emission error rate decreased by 15%. In summary, compared to traditional technology, Ecode identification technology has increased the efficiency of hospital equipment management by up to 90%, and the accuracy of carbon emission accounting has increased by 15% to 20%, providing technical support for the low-carbon transformation of the healthcare industry.

5 Conclusion

In response to the characteristics and actual needs of various equipment/facility management in hospitals, we have developed the Ecode hospital equipment intelligent perception technology. By mapping or embedding Ecode identifiers onto various types of equipment, we provide a unique digital identifier for hospital equipment/facilities, enabling real-time updates and retrieval of equipment data and information. Additionally, by deploying Ecode identifier modules on major equipment contributing to hospital carbon emissions, we can achieve real-time monitoring of equipment carbon emissions, allowing for precise calculation of hospital equipment carbon emissions. Experiments have shown that compared to traditional technologies, Ecode identifier technology not only improves equipment management efficiency but also effectively enhances the accuracy of carbon emission calculations.

The application of Ecode identification technology in the hospital field has been extended from equipment management to a wider range of scenarios, through the combination of standardized coding and Internet of Things technology, precision medical resource scheduling (such as real-time positioning of surgical instruments), intelligent drug traceability (from production to patient chain tracking) and dynamic medical waste supervision, significantly improving the transparency and safety of operations. However, with the application of Ecode technology, there are also many challenges, such as data security risks, interoperability issues between different devices, the lack of uniform standards for Ecode technology in the medical field and high initial deployment costs. In the future, it will focus on lightweight confidential algorithm development, adaptive labeling technology research, and actively explore AI-driven predictive analytics (predicting failures based on device-coded data), while promoting Ecode labeling standards in the medical field.

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