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Research on the Analysis of Hospital Medical Equipment Maintenance Costs and Cost Reduction Strategies under the Multi-Hospital Model

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Abstract: This study analyzes the growth of hospital medical equipment maintenance costs and cost control strategies under the multi-campus model. Through the analysis of equipment maintenance data from 2019-2024, the key to the growth of maintenance costs is identified, and targeted programs such as technical training, maintenance optimization, and collaborative management of multi-campus districts are adopted. The results of the study show that after the implementation of targeted measures, the proportion of maintenance costs to the total value of equipment assets in 2022-2024 decreased by 47% compared with the previous three years, and the cost of circuit board maintenance decreased by 27%, proving that targeted strategies after an in-depth analysis of maintenance costs are able to effectively reduce the cost of medical equipment maintenance.

Keywords: Medical Equipment; Maintenance Cost Analysis; Cost Reduction; Multihospital Areas; Technical Training.

1. Introduction

As people's demand for medical care continues to rise, the national "Fourteenth Five-Year Plan" has set the target for the number of beds per 1,000 population at 6.5. Many regions have increased their investment in quality medical resources, resulting in the development of public hospitals with multiple districts. Opening new hospital districts has become an important means of expanding quality medical resources. Since 2020, a total of 102 Tertiary public hospitals across the country have carried out branch hospital construction [1-3]. In China, according to the 2023 China Health and Wellness Statistical Yearbook, the total value of hospitals' million-dollar equipment nationwide has increased by 157 billion yuan, the average value of equipment in hospitals has increased by 3.8 million yuan, and the average amount of equipment in hospitals has increased by 18 units. Hospitals spent between 1% and 3% of the total equipment value on equipment repair, maintenance, upkeep and warranty. Nationwide, medical equipment repairs, maintenance, upkeep and warranties cost tens of billions of dollars [4]. How to achieve maintenance cost optimization in the context of the annual growth of the total value of equipment assets has become an important challenge for medical workers [5].

From 2014 to 2021, the total value of our hospital's medical equipment assets will grow rapidly at an average annual rate of 23%, with an average growth rate of 32% from 2019 to 2021. Accompanied by an average annual growth of 16% in the number of reported repairs of equipment and a cumulative increase of 37% in maintenance costs over three years, the problem of dispersed staff, decentralized distribution of equipment and complex demand for maintenance technology will intensify after the new hospital districts are put into operation from 2020 to 2021, and there is an urgent need to build a targeted cost-control system.

2. Analysis of Maintenance Cost Components and Key Issues

2.1. Distribution of Repair Costs by Department

Table 1. Section Maintenance Costs as a Percentage (%), 2019-2021

particular year	1st position	percentage	2nd place	percentage	3rd position	percentage
2019	operating rooms	18.77%	ward	13.04%	outpatient service	12.91%
2020	outpatient service	21.52%	operating rooms	12.82%	ward	10.28%
2021	ultrasound department	17.56%	operating rooms	16.76%	Sterilization and Supply Center	12.37%

A detailed analysis of maintenance cost composition reveals that, according to data from 2019 to 2021, the operating room, wards, and outpatient departments consistently accounted for the top three maintenance costs (Table 1). Among these, the proportion of maintenance costs for the operating room fluctuated from 18.77% in 2019 to 16.76% in 2021, outpatient department maintenance costs increased from 12.91% to 21.52% before declining to 10.40%,

and ultrasound department maintenance costs rose significantly from 11.10% to 17.56%. This reflects a substantial increase in the frequency of equipment use in specialized departments across multiple campuses, as well as instability in medical equipment maintenance and management under the multi-campus model.

2.2. Equipment Type Dimension Cost Characteristics

Analysis of equipment types shows that equipment such as diagnostic ultrasound machines, monitors, and anesthesia machines account for the major portion of repair costs (Table 2). Among them, the proportion of maintenance costs for diagnostic ultrasound instruments jumps from 12.18% in 2019 to 22.24% in 2021, and the proportion of circuit board maintenance climbs year by year (14.51% → 16.10% → 20.46%), mainly involving diagnostic ultrasound instruments, endoscopic camera systems, respiratory machines and other equipment (Figure 1).

Table 2. Equipment Type Maintenance Costs as a Percentage (%), 2019-2021

particular year	1st position	percentage	2nd place	percentage	3rd position	percentage
2019	ultrasound diagnostic equipment	12.18%	monitor (device)	9.09%	DR	7.58%
2020	monitor (device)	13.35%	mammogram	10.16%	DSA	9.58%
2021	ultrasound diagnostic equipment	22.24%	mammogram	7.86%	anesthesia machine	5.75%

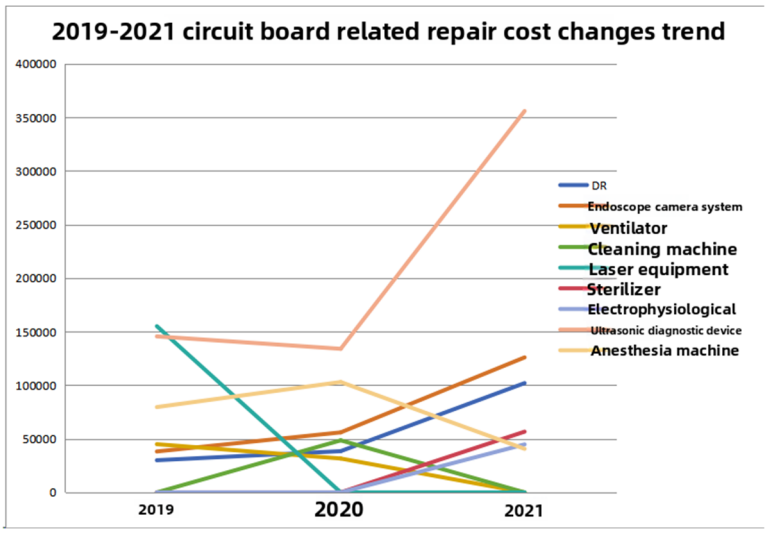

Figure 1. Board Maintenance Cost Trends, 2019-2021 (in dollars)

2.3. Core Issue Identification

Increased maintenance volume and circuit board repair costs, analyzed through the maintenance cost registry records, found the following problems: (1) multi-campus technical force dispersion: difficult circuit board repair can not be effectively discussed, experience sharing is not in place; (2) engineers are overloaded: per capita annual maintenance volume increased by 16%, unable to study the technical difficulties in-depth, in the case of the department's urgent need for equipment can only be used in the original manufacturer to pay for the maintenance; (3) preventive maintenance strategy needs to be adjusted: key equipment (such as diagnostic ultrasound) maintenance frequency is insufficient, low-risk equipment over-maintenance; (4) Insufficient clinical training: On-site training for the use of equipment in the new hospital area was rushed, and unskilled operators were prone to misoperations that led to malfunctions; (5) the maintenance of resources need to be expanded: the operating room, endoscopy maintenance costs remain high, mainly for the maintenance of surgical instruments, such as surgical instruments accounted for a high proportion of maintenance costs, such as surgical instruments. The maintenance cost of operating room and endoscopy room remains high, mainly for the maintenance of surgical instruments, such as the original maintenance cost of surgical instruments is 33 times of that of the third party, whether to introduce third-party maintenance resources.

3. Implementation of Multiple Improvement Strategies

3.1. Construction of Maintenance Technology Training System

The original approach was to have manufacturers conduct maintenance training after acceptance of new equipment, which was a wide net model. Now it will take a more proactive approach to maintenance training, cooperating with high-tech manufacturers to conduct maintenance training for certain aspects. In order to adapt to the model of multiple hospital districts, in 2022, it will carry out 12 special trainings combining online and offline, covering core areas such as ultrasound diagnostic equipment, anesthesia machines, and

circuit board maintenance. In circuit board repair training, taking the UC3842 switching power supply chip repair as an example, the training content extends from circuit principle analysis to actual case review, requiring engineers to master the entire process of chip manual retrieval, schematic analysis and fault location. Through the "theory - practice - case sharing" trinity training, the engineers' independent maintenance capability has been significantly improved.

3.2. Multi-campus Collaborative Management Mechanism

Regularly conduct online case sharing meetings. Engineers are required to leave traces of repairs in their daily work, focusing on photo documentation, and conduct monthly online case workshops to promote replicable repair solutions through an online video conferencing platform.2022-2024 Cumulative collection of cases 96 . For example, Medtronic's alternative solution for repairing the repeated battery failures of temporary pacemakers allowed the repair cost to be reduced from 2,000 RMB to 60 RMB. At the same time, engineers in this department submit an average of more than 12 articles to annual conferences each year, participate in medical engineering academic conferences, and share and learn advanced maintenance experiences from their peers [6].

3.3. Preventive Maintenance Program Optimization

Reconfigure maintenance programs based on equipment risk level and equipment maintenance frequency [7-8]:

High-risk and high-frequency maintenance equipment (diagnostic ultrasound, respiratory machines): frequency of maintenance has increased from 2 to 3-4 times per year, with the addition of fine maintenance such as dusting of circuit boards;

Low-risk and low-frequency maintenance equipment (electrically operated beds, centrifuges, thermal blankets): the frequency of maintenance has been reduced from two to one per year, relying on condition monitoring as a substitute for regular maintenance and introducing a long-term observation mechanism that dynamically adjusts the frequency of maintenance in the event of an increase in the number of malfunctions;

3.4. Establishment of Regular Hospital-Wide Utilization of Training Mechanisms

Strengthen the use of training, joint nursing department, medical department regularly carry out hospital-wide online use of equipment training (training video can be viewed online), improve the use of the department's operating standards, reduce human failure.

3.5. Introduction of Third-Party Maintenance Resources

For some of the low-risk surgical instruments and equipment, seek third-party repair and observe the quality of use. In conjunction with the user departments, we will continue to monitor the use of surgical instruments repaired by the third party, do quality assessment, and continue to cooperate if the quality assessment is good.

4. Assessment of the Effectiveness of implementation

4.1. Cost Control Effectiveness

In 2022-2024, the total value of equipment assets grows by 180% compared with 2019, but the total maintenance cost grows by only 2.5%, and the average value of maintenance cost to asset ratio decreases by 47% (Table 3). In particular, board maintenance costs decreased by 27%, technical service costs decreased by 18%, and surgical instrument maintenance costs decreased by 30%, reflecting the dual benefits of technological autonomy and management optimization.

Table 3. Comparison of key indicators of maintenance costs

norm	2019-2021	2022-2024	rate of change
Compound growth rate of total assets	32%	23%	-
Compound growth rate of maintenance costs	12.3%	0.8%	-93.5%
Maintenance costs as a percentage (average)	0.7%	0.37%	-47%
Circuit board repair costs	reference value	Decrease of 27%	-27%

4.2. Maintenance Efficiency Gains

Under the continuous growth of maintenance volume, the engineer independent maintenance rate will increase from 70% in 2019 to 86% in 2024, and the average processing time of complex faults will be shortened from 72 hours to 48 hours. Under the mechanism of multi-campus collaboration, online technical exchanges across campuses are smooth, and engineers are able to show their respective strengths, so that the support response time is controlled within 2 hours.

5. Summary

By constructing a multi-campus maintenance cost control system of "maintenance cost analysis - improvement measures - multifaceted technical training - online collaborative management in multi-campus areas - maintenance optimization", this study confirms that targeted interventions can effectively curb cost growth brought about by the expansion of hospital and equipment scale. In the future, we can introduce equipment IoT data, play the role of artificial intelligence in fault prediction, and optimize the maintenance program based on artificial intelligence [9-10], so as to promote the transformation of medical equipment operation and maintenance management to intelligence and refinement.

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