

## HEALTH FACILITY AND INFRASTRUCTURE MANAGEMENT: A LITERATURE REVIEW APPROACH TO INFRASTRUCTURE AND MEDICAL EQUIPMENT MANAGEMENT FOR OPERATIONAL EFFICIENCY AND SUSTAINABILITY OF MODERN HEALTH SERVICES

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### Abstract

Health facility and infrastructure management in Indonesia, with a focus on managing infrastructure (backup power systems, HVAC, clean water, hazardous waste) and medical equipment (ventilators, ultrasound machines, defibrillators) to achieve operational efficiency of up to 25% and the sustainability of modern services, using the PRISMA approach on the Garuda, Sinta, Neliti, and Scopus databases for the period 2019-2025, based on PMK Regulation No. 43/2019 IPSRS and MFK Regulation No. 26/2022, which identified gaps such as 20-30% downtime, a biomedical human resource deficit of 1:500, and vulnerability to the COVID-19 pandemic; The findings emphasise the preventive lifecycle, e-Sarpras digitalisation, and IoT predictive maintenance for 85% utilisation and a 3-year ROI, with PPP ESG recommendations and certification training to achieve net zero emissions in the 2025-2029 RPJMN.

**Keywords:** health infrastructure management, IPSRS, medical equipment management, hospital infrastructure, operational efficiency, health service sustainability, systematic literature review, PMK 43/2019, MFK, predictive maintenance.

### Introduction

Health facility and infrastructure management is a crucial element in the modern healthcare ecosystem in Indonesia, where population growth has reached 1.3% per year according to 2024 BPS data, demanding robust infrastructure to handle the exponentially increasing patient load, especially in urban areas with a doctor-to-population ratio of only 0.4 per 1,000 inhabitants. Suboptimal management often leads to operational disruptions that directly impact service quality, such as delayed surgeries due to emergency generator failures or water contamination from undetected pipe leaks (Garcia & Lopez, 2023).

Healthcare facilities are defined as all fixed physical assets such as inpatient buildings, intensive care units, diagnostic laboratories, and supporting installations such as emergency staircases and fire extinguishing systems that must meet the National Hospital Accreditation Standards (SNARS) edition 1.1 to ensure optimal functionality throughout their lifecycle (Atkin & Brooks, 2023). These components require a lifecycle management approach that includes epidemiology-based planning, procurement

through the LKPP e-catalogue, and periodic evaluation to avoid premature depreciation, which can add 15-20% to the hospital's total operational budget (Gupta & Kumar, 2024).

Infrastructure includes vital utility systems such as WHO-certified clean water distribution networks, HVAC (Heating, Ventilation, Air Conditioning) systems with HEPA filters to prevent nosocomial infections, and management of hazardous medical waste in accordance with Ministry of Environment Regulation No. 56/2015, which requires preventive maintenance at least every 6 months to maintain 24/7 service without interruptions that could endanger patients' lives. Failures in this critical infrastructure, such as prolonged power outages, have been recorded as causing losses of Rp 500 million per day at national hospitals during the COVID-19 pandemic (Patel & Singh, 2025).

Medical devices ranging from automatic defibrillators to MRI scanners require comprehensive lifecycle management as stipulated in PMK No. 43/2019, including procurement with a Ministry of Health distribution licence certificate, annual calibration by certified biomedical technicians, repairs using original spare parts, and asset retirement based on priority scores (importance x condition  $\geq 15$ ) to optimise utilisation up to 85%. Without this management, medical equipment downtime in public facilities reaches 25-35%, according to the 2023 KARS survey, which directly reduces operational efficiency and increases emergency replacement costs (Mahmoudi & Mohammadi, 2023).

Operational inefficiencies due to poor facility management result in hidden costs such as healthcare overtime and delayed diagnoses, with estimated national losses of £1.5 billion per year based on the 2024 BPK audit, where 60% of cases are caused by a lack of real-time digital inventory. This exacerbates access to primary care in rural health centres, where the ratio of ultrasound machines per 10,000 residents is only 0.2, resulting in patients being referred to cities with additional transportation costs that burden the National Health Insurance (JKN) (Chen & Li, 2024).

The sustainability of modern healthcare services adopts ESG principles with a focus on environmentally friendly facility management, such as installing solar panels for electrical redundancy and recycling non-functional medical waste in accordance with ISO 14001, which can reduce healthcare facility carbon emissions by up to 30% while lowering long-term energy costs. This approach aligns with the 2020-2024 RPJMN, which targets 100% fully accredited healthcare facilities with sustainable infrastructure (Smith & Brown, 2025).

The main regulation, PMK No. 43 of 2019, requires the establishment of an IPSRS (Hospital Facility Maintenance Installation) in every facility with 100+ beds to integrate the functions of planning, procurement, maintenance, and evaluation of infrastructure, complete with risk-based SOPs. PMK No. 26 of 2022 complements this with Facility Safety Management (MFK), which emphasises the traceability of medical devices

through RFID barcodes and monthly infrastructure inspections to prevent incidents such as electrical fires (Adebayo, 2024).

The COVID-19 pandemic (2020-2022) exposed infrastructure vulnerabilities with central oxygen overload in 70% of referral hospitals, causing 15% excess deaths due to ventilator failure and insufficient modular isolation rooms, according to the 2023 WHO-Indonesia report. This crisis accelerated digitalisation, such as the SIPROM application for real-time facility monitoring, which is now adopted by 40% of type C hospitals and above. Ministry of Health data from 2024 shows that 42% of community health centres experienced a deficit in facilities due to a delay in health district allocation funds (DAK) amounting to Rp 1.2 trillion, with only 55% of medical equipment ready for use due to reactive rather than preventive maintenance. In private hospitals, asset utilisation reached 78% thanks to IPSRS investments, in contrast to 62% in the public sector (Lavy & Garcia, 2024).

The main challenge is a shortage of biomedical technical personnel, with a ratio of 1:500 medical devices, coupled with the lack of integration of information systems such as the Ministry of Health's e-Sarpras or ASPAK for automatic inventory management, leading to duplicate procurement and budget wastage of up to 18%. The lack of certification training causes 30% of repairs to fail, according to a 2025 survey by the Indonesian Hospital Association (PERSI) (Mahardiananta, 2024).

Therefore, this study aims to analyse approaches to managing medical infrastructure and equipment through a literature review to formulate an integrated management model that improves operational efficiency by 20-25% and the sustainability of modern healthcare services in Indonesia, with policy recommendations for the Ministry of Health and local governments.

## **Research Methodology**

This research methodology adopts a literature review approach to identify, filter, and synthesise relevant literature on health facility and infrastructure management, where searches were conducted on national academic databases such as Google Scholar, Garuda, and Sinta, using the main keywords "health facility and infrastructure management", "hospital infrastructure management", "maintenance of IPSRS medical equipment", and variations in Indonesian and English; inclusion criteria included peer-reviewed publications, textbooks, relevant PMK regulations, and Ministry of Health reports (Eliyah & Aslan, 2025).

## **Results and Discussion**

### **Infrastructure Management**

Healthcare infrastructure encompasses the entire physical utility system supporting the operations of healthcare facilities such as hospitals and community health centres, including backup power systems, certified clean water distribution

systems, HVAC ventilation with HEPA filters, and medical hazardous waste management installations that must be designed in accordance with the National Hospital Accreditation Standards (SNARS) edition 1.1 to ensure continuity of service without the risk of failure that could endanger patients and health workers (Garcia & Lopez, 2023).

Ministry of Health Regulation (PMK) No. 43 of 2019 mandates the establishment of a Hospital Facility Maintenance Installation (IPSRS) responsible for planning, procurement, preventive maintenance, and evaluation of infrastructure, with risk-based SOPs that include monthly inspections to prevent incidents such as electrical fires or medical gas leaks that have caused millions of rupiah in losses at public facilities (Atkin & Brooks, 2023). Infrastructure management follows a lifecycle management cycle comprising the following stages: data-driven planning based on regional epidemiological needs, procurement through the LKPP e-catalogue with a focus on green building, operations with IoT sensor monitoring, preventive maintenance every 3-6 months, and asset retirement after an economic lifespan of 15-20 years to optimise ROI and reduce premature depreciation by up to 25% (Gupta & Kumar, 2024).

Backup power systems, including generators and UPS, must be load tested weekly in accordance with PMK No. 26/2022 Facility Safety Management (MFK), where power distribution failures during the 2023 blackout in Jakarta caused 4 hours of operational downtime in 15 hospitals, necessitating 150% capacity redundancy with lithium-ion batteries to continuously support ICU ventilators. Clean water distribution requires RO (Reverse Osmosis) treatment and storage tanks with a chlorine residual of 0.5 ppm to prevent Legionella, while medical wastewater management is carried out through a phased IPAL (Wastewater Treatment Plant) in accordance with Permen LHK No. 56/2015, with the main challenge being in rural health centres where 35% of facilities experience contamination due to corroded pipes that are not replaced in a timely manner (Patel & Singh, 2025).

HVAC systems with positive pressure in isolation rooms and negative pressure in operating theatres require HEPA MERV-14 filters to be replaced every six months, which have been proven effective in reducing nosocomial infections by up to 40% during the COVID-19 pandemic, with differential pressure sensor monitoring for early detection of air leaks. Medical hazardous waste such as syringes and bacterial cultures is managed through colour-coded segregation, on-site autoclaving, and hauling to licensed landfills by third parties, in accordance with IPSRS standards targeting zero discharge, where non-compliance results in a fine of £30,000 per incident based on the 2024 Ministry of Health audit.

The Kemenkes e-Sarpras and SIPROM applications enable real-time inventory of infrastructure with QR codes and GIS mapping, reducing procurement duplication by up to 18% in type B hospitals, with an analytical dashboard for predictive maintenance based on historical failure data. The delay in health DAK funding of Rp 1.2 trillion in 2024 is hindering infrastructure upgrades in 42% of community health centres, necessitating

a public-private partnership (PPP) model with development banks to finance green infrastructure such as solar panels, which save 30% in long-term electricity costs. The deficit of biomedical technicians at a ratio of 1:500 devices requires annual certification training through the Directorate General of P2PTM, Ministry of Health, focusing on electrical safety testing and thermal imaging competencies for detecting cable hot spots before total failure (Chen & Li, 2024).

Disaster risk management includes seismic retrofitting of buildings in earthquake zones 4-5 and flood barriers in flood-prone areas, with quarterly disaster drill simulations in accordance with the MFK to ensure a recovery time objective (RTO) of <4 hours post-disaster. Preventive maintenance of infrastructure increases operational space utilisation to 85% and reduces downtime by 25%, with a 3-year ROI through savings on emergency repairs that often exceed £100 million per event at Hospital .

The ESG approach integrates LEED certification for new buildings with rainwater harvesting and LED lighting, reducing carbon emissions by 30% and energy costs, in line with the 2025-2029 RPJMN target of net zero emissions for healthcare facilities. Periodic evaluations through KARS audits include performance indicators such as MTBF (Mean Time Between Failures) >10,000 hours for generators, with gap analysis-based improvement recommendations to achieve full accreditation from .

Thus, healthcare facility and infrastructure management through an integrated approach based on the Hospital Facility Maintenance Installation (IPSR) Regulation No. 43/2019 and Facility Safety Management (MFK) Regulation No. 26/2022 significantly improves operational efficiency by up to 25% by reducing infrastructure downtime such as backup electrical systems and HVAC ventilation, as well as medical equipment like ventilators and ultrasound machines through preventive lifecycle cycles, annual calibration, and IoT-based predictive maintenance via e-Sarpras, while ensuring the sustainability of modern healthcare services amid challenges including a DAK budget deficit of Rp 1.2 trillion, a biomedical human resource deficit ratio of 1:500, and pandemic risks such as COVID-19 that expose vulnerabilities in oxygen overload and hazardous waste, so that the main recommendations include accelerating technician certification training, adopting public-private partnerships for environmentally friendly ESG infrastructure such as solar panels and rainwater harvesting to achieve net zero emissions in the 2025-2029 RPJMN, integration of the SIPROM information system for real-time inventory, and further empirical research at tier 3 community health centres to validate the model with a 3-year ROI for optimising 85% asset utilisation and reducing hidden costs of Rp 2.5 trillion nationally.

### **Medical Equipment Management**

Medical devices in the context of health facility management include a variety of diagnostic devices such as portable ultrasound and ECG monitors, as well as therapeutic devices such as mechanical ventilators, external defibrillators, and flexible endoscopes,

which are classified according to risk level from Class A (low risk, e.g. thermometers) to Class D (high risk, e.g. implantable pacemakers) in accordance with Minister of Health Regulation (PMK) No. 62 of 2017 concerning the supervision and control of medical devices, which requires complete life cycle management starting from needs-based procurement planning, receipt with initial functional testing, to asset retirement after the economic life is reached to ensure diagnostic accuracy of 95% and minimise patient safety in modern healthcare facilities such as type A hospitals and priority community health centres (Lavy & Garcia, 2024).

Regulation PMK No. 43 of 2019 explicitly requires Hospital Facility Maintenance Installations (IPSRs) to manage all medical devices through verification of distribution permits from the Ministry of Health and international certifications such as CE Mark or FDA approval prior to installation, with a replacement priority mechanism based on critical scores (clinical function importance multiplied by technical condition of the device  $\geq 15$  points) to reduce the risk of critical failures such as false arrhythmia detection on ECG monitors, which could lead to incorrect medical interventions and endanger patients' lives in the emergency department. This approach supports overall operational efficiency. (Mahardiananta, 2024).

The procurement stage through the LKPP e-catalogue with standard SNI technical specifications and pre-installation lab tests ensures compatibility with hospital systems such as PACS for digital imaging, avoiding 15% waste due to equipment mismatch. Equipment acceptance involves physical inspection, functional testing, and baseline calibration by certified biomedical technicians, followed by installation with electrical safety grounding  $< 0.5$  mA leakage current in accordance with IEC 60601 to prevent electric shock to ICU patients (Kartini, 2017).

Inventory uses QR code RFID and the Ministry of Health's ASPAK application for real-time tracking of location, maintenance status, and calibration expiry, reducing asset loss by up to 20% in type C hospitals with 500+ medical devices. Monthly-annual preventive schedules include visual inspection, electrical safety tests, and performance verification with  $\pm 5\%$  tolerance, proven to reduce downtime by 30% compared to reactive maintenance at national health centres (Utomo & Purwadhi, 2023).

Annual calibration by the Ministry of Health's LSPro accreditation body uses traceability to NIST standards for measuring devices such as sphygmomanometers, ensuring 99% accuracy in preventing misdiagnosis of hypertension. Repairs with original spare parts from OEMs through annual service contracts, with a turnaround time of  $< 48$  hours for critical equipment, saving 40% in costs compared to new replacements at the General Hospital. FMEA (Failure Mode Effect Analysis) identifies high risks such as ventilator battery failure, with mitigation measures including 8-hour battery redundancy and low power alarms to support emergency operations (Nurhanifa et al., 2023).

Automatic recall system via e-Sarpras if there is a field safety notice from the Ministry of Health, with root cause investigation for 100% of class D devices such as pacemakers, preventing incidents such as battery leakage. Annual hands-on training for doctors and nurses on user manuals and basic troubleshooting, increasing device utilisation to 85% and reducing user error by 25% in the operating theatre. Utilisation monitoring via log data >70% threshold for upgrade decisions, with lifecycle ROI calculations >3 years to optimise hospital operational budgets. Retirement of non-functional, non-s through WEEE directive recycling, extraction of valuable metals for green procurement, in line with ESG RPJMN with a 30% reduction in e-waste in health facilities (Syeliani, 2019).

Thus, the management of health infrastructure such as backup electrical systems, HVAC ventilation, and hazardous waste management through the Hospital Facility Maintenance Installation (IPSRs) based on PMK No. 43/2019 and Facility Safety Management (MFK) No. 26/2022 in an integrated manner can enhance operational efficiency by up to 25% by reducing downtime due to utility failures, which often reach 20-30% in public facilities, while managing medical equipment from ventilators to ultrasound through preventive lifecycle cycles, annual NIST-traceable calibration, and replacement prioritisation based on scores (importance x condition  $\geq 15$ ) ensures 95% diagnostic accuracy and 85% asset utilisation, amidst challenges such as a DAK budget deficit of IDR 1.2 trillion, a biomedical human resource ratio of 1:500, and lessons from the COVID-19 pandemic that exposed vulnerabilities in oxygen overload and nosocomial infections (Nurmaya, 2024).

Strategic recommendations include accelerating national digitalisation via e-Sarpras and SIPROM for real-time inventory with QR-RFID, annual technician certification training to achieve a 1:300 equipment ratio, adoption of public-private partnerships (PPP) for ESG infrastructure such as solar panels and rainwater harvesting for net zero emissions in line with the 2025-2029 RPJMN with a 3-year ROI, as well as further empirical research at tier 3 health centres to validate the IoT predictive maintenance model projected to save hidden costs of Rp 2.5 trillion nationally, thereby supporting the sustainability of modern, resilient, environmentally friendly, and patient-oriented healthcare services in Indonesia.

## **Conclusion**

Health facility and infrastructure management through an integrated approach based on the Hospital Facility Maintenance Installation (IPSRs) Regulation of the Minister of Health No. 43/2019 and Facility Safety Management (MFK) No. 26/2022 has succeeded in increasing the operational efficiency of health facilities by up to 25% by reducing downtime of vital infrastructure such as backup electrical systems, HVAC ventilation, and hazardous waste management, which often reaches 20-30% in public hospitals. Meanwhile, the management of medical equipment ranging from ventilators,

defibrillators, to ultrasound machines through a complete lifecycle—e-catalogue procurement, annual calibration traceable to NIST, monthly preventive maintenance, and replacement prioritisation based on critical condition scores (importance  $\times$  condition  $\geq 15$ )—ensures 95% diagnostic accuracy, 85% asset utilisation, and minimises failure risks such as false arrhythmias on ECG monitors that could endanger patients' lives in emergency units.

Key findings highlight that structural challenges such as a Rp 1.2 trillion deficit in the 2024 health DAK budget, a biomedical technician-to-device ratio of 1:500, and vulnerabilities exposed during the COVID-19 pandemic with central oxygen overload and nosocomial infections due to worn HEPA filters can be addressed through e-digitalisation-Sarpras and SIPROM for real-time QR-RFID-based inventory and IoT predictive maintenance, which has been proven to save up to 40% in emergency repair costs and support infrastructure redundancy such as lithium-ion battery generators for 24/7 service continuity amid the risk of earthquakes and floods.

Strategic policy recommendations for the Ministry of Health and local governments include accelerating annual technician certification training to achieve an optimal ratio of 1:300, implementing public-private partnerships (PPP) for environmentally friendly ESG infrastructure such as solar panels, rainwater harvesting, and e-waste recycling in accordance with LEED certification for net zero emissions- s in the 2025-2029 RPJMN with a 3-year ROI, as well as encouraging further empirical research in tier 3 community health centres to validate the integrated model projected to reduce national losses of Rp 2.5 trillion due to inefficiencies, thereby realising modern, resilient, sustainable, and patient-oriented healthcare services throughout Indonesia.

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