# Medical Equipment Maintenance Programmes

A Condensed Practical Guide to Planning, Managing, and Implementing Hospital Biomedical Equipment Maintenance — From Inventory to Repair

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***Important note on scope and use:*** *This document is an original, independently written condensed guide reflecting widely-known, publicly discussed principles of medical equipment maintenance programme management in health-care facilities (planning, resourcing, scheduling, prioritization, performance monitoring, and safe implementation of inspection/preventive/corrective maintenance). Portions of this field's terminology and risk-scoring concepts are informed by long-established, publicly cited clinical engineering practice (including a well-known equipment risk-classification approach first published by Fennigkoh & Smith, and further popularized through WHO's freely-available 2011 technical guidance, "Medical equipment maintenance programme overview"). This guide is written in the author's own words and reorganized for quick field use; it is* ***not a reproduction of the WHO document or any other copyrighted source****, and is not a substitute for it. WHO's original publication is freely downloadable from who.int and remains the authoritative reference; consult it directly for full detail, sample policy language, and citations.*

# 1. What a Maintenance Programme Covers

Medical equipment maintenance in a health-care facility divides into two broad categories that together keep equipment safe, accurate, and available for patient care:

- **Inspection and Preventive Maintenance (IPM)** — all scheduled activity that confirms equipment is working correctly (performance and safety inspections) and extends equipment life (preventive tasks such as calibration, part replacement, lubrication, and cleaning).
- **Corrective Maintenance (CM) / Repair** — unscheduled work that restores a failed device's physical integrity, safety, or performance after a fault is reported or discovered.

Inspections confirm a device's condition *at the moment of testing* — they reduce but cannot eliminate the chance of failure between scheduled visits, since electrical and mechanical components can fail at any time. A mature programme therefore combines both IPM and CM, supported by good planning, management, and performance monitoring.

# 2. Planning a Maintenance Programme

Programme planning generally rests on three critical, interdependent factors:

## 2.1 Inventory — deciding what to track and maintain

- Not every item in a facility needs to sit in the formal maintenance programme — studies and practical experience consistently show most facilities lack the staff to inspect everything, so equipment should be selected using a documented, risk-based method (see Section 6).
- The clinical engineering/biomedical team owns the inventory: adding new equipment at receipt, periodically verifying that listed equipment can still be physically located, and retiring records for decommissioned items.

## 2.2 Methodology — deciding who performs the work

- Options range along a spectrum: fully in-house technical staff, full-service manufacturer/vendor contracts, independent service organizations (ISOs), or (most commonly) a blended model.
- Even when work is outsourced, the facility needs internal capability to manage and monitor vendor performance, cost, and contract terms.

## 2.3 Resources — financial, physical, and human

| Resource type | What it includes |
|---|---|
| Financial | Space, tools, test equipment, vehicles (initial); operation/utilities, calibration, service contracts, parts, travel (ongoing). A useful benchmark is the "cost-of-service ratio": total annual maintenance spend divided by the replacement value of the equipment inventory. |
| Physical | Workspace (clean, well-lit, with utility access and storage), tools and test equipment matched to the complexity of the inventory, consumable supplies, spare/replacement parts, and access to manufacturer operation and service manuals. |
| Human | A mix of biomedical/clinical engineers (management, complex/specialized work, supervision of vendors) and biomedical equipment technicians (BMETs, hands-on IPM/CM), supplemented by external service providers for equipment beyond in-house capability. |

# 3. Managing an Ongoing Programme

## 3.1 Financial management

- Track actual time and expense per device (via work orders / CMMS) to build a maintenance cost history.
- Compare actual spend to budget regularly; investigate significant variances — unplanned corrective maintenance is the most common source of budget swings, so keep IPM and CM costs in separate accounts for clearer analysis.

## 3.2 Personnel management

- Match work assignments to technician skill level; balance IPM and CM workload.
- Where external vendors are used, monitor their performance against the service agreement (full-service, time-and-materials, or shared-responsibility models each carry different cost/response trade-offs).
- Invest continually in training — both self-study/manufacturer materials and, for complex/software-based systems, paid vendor training — since this is often the deciding factor in whether work can be brought in-house over time.

## 3.3 Operational management

- **IPM procedures:** start from the manufacturer's maintenance manual as the conservative baseline; only deviate once real operating experience justifies a change, and document the justification.
- **Setting IPM frequency:** default to manufacturer-recommended intervals until the facility has enough history to justify adjusting them — any deviation should be reviewed periodically (e.g., annually).
- **Scheduling:** group inspections by clinical department or by device type to reduce travel and setup time; schedule by calendar interval or by hours of use, depending on the device.
- **Prioritization:** when staff capacity cannot cover 100% of scheduled work, use a tiered approach — highest-risk/life-support equipment first — rather than spreading effort thin across everything equally.
- **Records:** every work order should capture device ID, description, time spent, findings, and cost; undocumented work is, for regulatory and quality purposes, equivalent to work not done.
- **CMMS:** a computerized maintenance management system supports inventory tracking, IPM scheduling, result recording, and the reporting needed for performance monitoring — a paper-based system can be an interim step for smaller facilities.
- **Tags and labels:** unique ID tags identify each device unambiguously; inspection labels/stickers (often color-coded by year) show at a glance when a device was last serviced and when it is next due.
- **Communication with clinical staff:** a strong working relationship with clinicians improves problem reporting, equipment location accuracy, and mutual understanding of maintenance needs.
- **Managing use/user error:** distinguish genuine "use error" (a systemic mismatch between user, device, and environment) from simple user mistakes; both call for targeted training rather than blame.

## 4. Measuring and Improving Performance

Common performance indicators used to monitor and improve a maintenance programme:

| Indicator | What it tells you |
|---|---|
| IPM completion rate | Percentage of scheduled IPM actually completed in the period; a common target is above 90%, higher for the highest-risk equipment tier. |
| Equipment location rate | Percentage of scheduled equipment that could actually be found and inspected — reflects inventory accuracy. |
| IPM yield | Percentage of inspections that uncover a functional or safety problem — indicates overall equipment reliability and how well the programme (or clinical users) catch issues early. |
| IPM productivity | Actual time to complete an inspection versus the expected/estimated time — used to identify training needs or process inefficiencies. |
| CM measures | Mean time between failures, repeat-failure rate, response time, repair time, equipment downtime, and rate of overdue ("delinquent") work orders. |

Performance improvement is a repeating cycle: identify an opportunity from the data above → identify a best practice relevant to it → make a targeted change → re-measure over several periods to confirm the change actually helped, adjusting again if it did not.

# 5. Day-to-Day Implementation

## 5.1 Corrective maintenance / repair levels

- **Component-level** repair — replacing a single failed part (resistor, capacitor, fuse, etc.); often the most cost-effective option where feasible, though modern digital boards are frequently not component-repairable.
- **Board-level** repair — replacing an entire circuit board rather than tracing a single component fault.
- **Device/system-level** replacement — used when board-level work is too slow or costly to justify.
- Choice of level depends on urgency, available skill, and cost — high-priority failures often favor faster, higher-level replacement even if less "efficient" in isolation.

## 5.2 Common contributing factors in equipment failure

- **Electrical power quality** — voltage stability, surges/spikes, and outages; mitigated with voltage regulators, surge protection, UPS units, and tested backup generators.
- **Interaction with other utilities** — medical gas/vacuum, water, HVAC, and IT/network infrastructure can all affect device performance and should be checked rather than assumed adequate.
- **Physical environment** — heat, humidity, dust, and vibration outside the device's designed operating range accelerate wear and failure.
- **Facility age/condition** — older utility infrastructure may be degraded, overloaded, or built to superseded standards even in newer buildings.

## 5.3 Return to service after repair

- Always perform a post-repair performance and safety check (and re-calibration where relevant) before returning equipment to clinical use.
- Advise clinical staff to verify settings and run a basic operational check before first patient use after any maintenance, since inspection/repair activity often resets configurable settings.

## 5.4 Safety during maintenance work

- **Lockout/tagout:** disconnect equipment from its power source before internal work; physically lock the disconnect where possible, or post clear tag-out signage where a physical lock isn't feasible.
- **Hazard awareness:** be alert to chemical (chemotherapy agents), radiation (imaging/therapy sources), magnetic (MRI), and compressed-gas hazards specific to certain device types, and use appropriate PPE.
- **Infection control:** visibly contaminated equipment should be cleaned by clinical staff before technical work begins; technicians should follow facility isolation/PPE protocols and be aware that immunocompromised patients can be affected by dust or spores disturbed during maintenance.

# 6. Risk-Based Equipment Classification (Fennigkoh & Smith Model)

A long-established and widely used method for deciding which equipment belongs in a formal maintenance programme — and how often it should be inspected — was first published by Fennigkoh & Smith (1989) and remains one of the most widely cited risk-scoring approaches in clinical/biomedical engineering practice (it is also the basis for the risk-scoring example presented in WHO's 2011 technical guidance, cited above). It scores each device *type* across four factors and sums them into a single "equipment management" (EM) number.

## 6.1 The formula

**EM # = Function # + Application # + Maintenance # + History #**

Each of the four components is scored on its own point scale (below), then all four are added together for a given device type to produce its EM number.

## 6.2 Function — role of the equipment

| Function category | Points |
|---|---|
| Life support | 10 |
| Surgical and intensive/critical care | 9 |
| Physical therapy and treatment | 8 |
| Surgical/intensive care monitoring | 7 |
| General physiological monitoring and diagnostic | 6 |
| Analytical laboratory | 5 |
| Laboratory accessories | 4 |
| Computers and related equipment | 3 |
| Patient-related and other miscellaneous equipment | 2 |

## 6.3 Application — physical risk if the device fails

| Risk of failure | Points |
|---|---|
| Potential for patient death | 5 |
| Potential for patient or operator injury | 4 |
| Potential for inappropriate therapy or misdiagnosis | 3 |
| Potential for equipment damage only | 2 |
| No significant risk identified | 1 |

## 6.4 Maintenance requirement — how much upkeep the device needs

| Maintenance level | Points |
|---|---|
| Extensive: routine calibration and part replacement required | 5 |
| Above-average maintenance need | 4 |
| Average: routine performance verification and safety testing | 3 |
| Below-average maintenance need | 2 |
| Minimal: visual inspection only | 1 |

## 6.5 History — adjustment based on actual failure experience

| Failure frequency | Adjustment |
|---|---|
| Significant: more than one failure every 6 months | +2 |
| Moderate: about one failure every 6–9 months | +1 |
| Average: about one failure every 9–18 months | 0 |
| Minimal: about one failure every 18–30 months | -1 |
| Insignificant: fewer than one failure in 30 months | -2 |

**Interpreting the total EM number:** facilities typically set an inclusion threshold (a commonly used reference point is around 12) below which a device type is tracked for repair only, without scheduled IPM. Above the threshold, higher totals justify shorter inspection intervals — for example, roughly: totals in the high teens or above → inspect every 4–6 months; moderate totals → annual inspection; totals well above the highest band → consider quarterly or more frequent checks for the highest-acuity life-support devices. Exact cut-offs are a local policy decision, not a fixed universal rule, and should be approved by the facility's equipment/safety committee.

## 6.6 Worked examples

The table below illustrates how the four scores combine into an EM number and a resulting maintenance tier for several common device types. These are illustrative example scorings, not fixed values — each facility should score its own equipment based on its own experience and context.

| Device type | Func. | Appl. | Maint. | Hist. | EM # | Suggested tier |
|---|---|---|---|---|---|---|
| Defibrillator/monitor | 9 | 5 | 4 | 0 | 18 | Semiannual |
| Infusion pump | 8 | 4 | 3 | 0 | 15 | Semiannual |
| Mechanical ventilator | 10 | 5 | 5 | 0 | 20 | Quarterly / highest tier |
| Multiparameter patient monitor | 7 | 4 | 3 | 0 | 14 | Semiannual |
| 3-channel ECG machine | 6 | 3 | 3 | +2 | 14 | Semiannual |
| Electrosurgical unit | 9 | 4 | 3 | 0 | 16 | Semiannual |
| Ultrasound diagnostic scanner | 6 | 3 | 3 | 0 | 12 | Annual |
| Table-top laboratory centrifuge | 5 | 2 | 2 | 0 | 9 | Annual (or extended) |
| Manual sphygmomanometer | 2 | 2 | 1 | 0 | 5 | Repair-only / not in formal IPM |

*Example walkthrough — mechanical ventilator: function = 10 (life support) + application = 5 (potential patient death on failure) + maintenance = 5 (extensive calibration/parts) + history = 0 (average failure rate) → EM # = 20. This places it in the highest maintenance tier regardless of local failure history, consistent with treating life-support equipment as top priority.*

## 6.7 Other prioritization lenses used alongside EM scoring

- **Mission-based:** prioritize equipment tied to the facility's core clinical focus areas first, then apply risk scoring to what remains.
- **Maintenance-based:** prioritize devices most likely to malfunction specifically *because* IPM was skipped, and exclude devices with no evidence that scheduled IPM changes their failure rate.
- **Resource-based:** blend any of the above with realistic staffing/budget constraints to set an achievable, tiered work plan when full coverage of every device isn't feasible.

# 7. Practical Checklists

*The following checklists translate the sections above into field-usable tools. Adapt thresholds, intervals, and required fields to your facility's own equipment management plan and regulatory context.*

## A. Programme Planning / Setup Checklist

| Check Item / Action | Status |
|---|---|
| ■ Complete inventory of medical equipment created and entered into a spreadsheet or CMMS. | Y / N / NA |
| ■ Risk-based classification applied to each device type (see Section 6) to decide programme inclusion. | Y / N / NA |
| ■ Maintenance methodology decided per device type: in-house, vendor contract, or blended. | Y / N / NA |
| ■ Initial and ongoing budget estimated (space, tools, test equipment, training, contracts, parts, travel). | Y / N / NA |
| ■ Workspace identified with adequate lighting, utility access, storage, and documentation space. | Y / N / NA |
| ■ Core tools and test equipment list matched to the device types in the inventory. | Y / N / NA |
| ■ Manufacturer operation and service manuals obtained (or a plan in place to obtain them) for all included equipment. | Y / N / NA |
| ■ Staffing plan defined: number/level of engineers and technicians versus inventory size and complexity. | Y / N / NA |
| ■ Training plan established for new and existing technical staff. | Y / N / NA |

## B. New/Incoming Equipment Acceptance Checklist

| Check Item / Action | Status |
|---|---|
| ■ Delivered equipment matches purchase order (model, accessories, quantity). | Y / N / NA |
| ■ All required accessories present and undamaged. | Y / N / NA |
| ■ Operation manual and technical/service manual received (in an appropriate language). | Y / N / NA |
| ■ Functional/performance check completed against manufacturer specification. | Y / N / NA |
| ■ Clinical alarm functions (if any) tested and audible/visible as expected. | Y / N / NA |
| ■ Electrical safety inspection passed, where applicable. | Y / N / NA |
| ■ Risk classification / EM number assigned or confirmed; device included in or excluded from the formal programme accordingly. | Y / N / NA |
| ■ Acceptance sticker/tag applied; device entered into inventory/CMMS with assigned IPM interval. | Y / N / NA |
| ■ User in-service/training arranged where needed. | Y / N / NA |

## C. IPM Scheduling & Execution Checklist

| Check Item / Action | Status |
|---|---|
| ■ Devices due for IPM in the coming period identified from the CMMS/inventory. | Y / N / NA |
| ■ Required parts (filters, batteries, seals, etc.) ordered/available in advance. | Y / N / NA |
| ■ Work assigned to technicians matched to skill level and current workload. | Y / N / NA |
| ■ Correct written IPM procedure and test equipment gathered before starting. | Y / N / NA |
| ■ Visual/physical inspection completed. | Y / N / NA |
| ■ Electrical safety test completed and within limits. | Y / N / NA |
| ■ Functional/performance test completed against specification. | Y / N / NA |
| ■ Alarm and safety-interlock functions verified. | Y / N / NA |
| ■ Results (pass/fail and measured values) documented on the work order / CMMS. | Y / N / NA |
| ■ IPM label/tag applied with date and next-due date. | Y / N / NA |
| ■ Any problem found during IPM triaged: completed on the spot, or a corrective work order opened with the device tagged out of service if unsafe to use. | Y / N / NA |

## D. Corrective Maintenance / Repair Workflow Checklist

| Check Item / Action | Status |
|---|---|
| ■ Service request logged with device ID, location, reporter, and problem description. | Y / N / NA |
| ■ Priority assigned (emergency/urgent/routine/deferred) based on patient-safety impact. | Y / N / NA |
| ■ Troubleshooting performed to isolate the fault (component, board, or device/system level). | Y / N / NA |
| ■ Repair performed using manufacturer, generic-equivalent, or reclaimed parts as appropriate — risk-assessed and approved if not using manufacturer parts. | Y / N / NA |
| ■ Root cause considered, not just the immediate symptom (check use error, environment, utility quality). | Y / N / NA |
| ■ Post-repair performance and safety inspection completed before return to service. | Y / N / NA |
| ■ Recalibration performed where relevant. | Y / N / NA |
| ■ Work order completed with time, cost, parts used, and outcome documented. | Y / N / NA |
| ■ Clinical user notified equipment is back in service and advised to verify settings before patient use. | Y / N / NA |

## E. Maintenance Safety Checklist (Technician Self-Check)

| Check Item / Action | Status |
|---|---|
| ■ Equipment disconnected from power source before internal work; lockout applied or tag-out posted. | Y / N / NA |
| ■ Device-specific hazards identified (chemical, radiation, magnetic, compressed gas) before starting. | Y / N / NA |
| ■ Appropriate PPE available and worn for the task. | Y / N / NA |
| ■ Visibly contaminated equipment cleaned by clinical staff before technical work begins. | Y / N / NA |
| ■ Facility isolation/infection-control protocol checked before entering a restricted clinical area. | Y / N / NA |
| ■ Electrical safety re-verified (ground resistance, leakage current) after any work affecting safety-related parts. | Y / N / NA |
| ■ Device settings reviewed/reset and clinical user notified before returning equipment to patient use. | Y / N / NA |

## F. Monthly/Quarterly Performance Monitoring Checklist

| Check Item / Action | Status |
|---|---|
| ■ IPM completion rate calculated for the period (target commonly >90%, higher for top-risk tier). | Y / N / NA |
| ■ Equipment location rate calculated (inventory accuracy check). | Y / N / NA |
| ■ IPM yield calculated (percentage of inspections finding a real problem). | Y / N / NA |
| ■ IPM productivity reviewed (actual vs. expected time per procedure). | Y / N / NA |
| ■ CM measures reviewed: mean time between failures, repeat failures, response time, repair time, downtime, delinquent work orders. | Y / N / NA |
| ■ Cost-of-service ratio reviewed against budget and prior periods. | Y / N / NA |
| ■ Findings and trends reported to the relevant safety committee / department management. | Y / N / NA |
| ■ At least one performance-improvement action identified, implemented, and scheduled for re-measurement. | Y / N / NA |

***Reminder:*** *this guide condenses widely-used general practice for orientation and field use. For authoritative detail, sample policy templates, job descriptions, and complete reference lists, consult WHO's freely available "Medical equipment maintenance programme overview" (2011) directly, alongside your own facility's equipment management plan and applicable national regulation.*