



### Abstract

This project focused on improving medical equipment maintenance and procurement at Hospital HIMA San Pablo by implementing a structured, data-driven system using the Plan-Do-Study-Act (PDSA) methodology. Key challenges such as aging equipment, regulatory compliance, part shortages, and financial constraints were addressed through preventive maintenance, predictive analytics, and an automated inventory system with just-in-time procurement. A 20-week maintenance schedule prioritized critical hospital areas, supported by stakeholder engagement and real-time performance monitoring. Results demonstrated increased equipment reliability, reduced downtime, optimized inventory levels, and cost savings, while ensuring compliance and patient safety. The project establishes a sustainable, scalable engineering management model applicable to similar healthcare institutions seeking operational efficiency and improved quality of care.

### Introduction

Efficient engineering management plays a vital role in maintaining the functionality, safety, and reliability of medical equipment in healthcare settings. In environments where patient care depends heavily on technological infrastructure, challenges such as part shortages, aging devices, inconsistent maintenance schedules, and strict regulatory demands can significantly impact operational effectiveness and patient safety. At Hospital HIMA San Pablo, these issues were identified as barriers to timely equipment servicing and procurement efficiency, increasing the risk of unplanned downtime in critical care areas.

This project aimed to develop and implement a structured maintenance and procurement system that enhances equipment reliability, minimizes downtime, and ensures compliance with healthcare regulations. To address these challenges, this project implemented a structured Plan-Do-Study-Act (PDSA) approach, aimed at improving the hospital's medical equipment maintenance and procurement strategy.

The foundation of this project was built on maintenance planning, predictive analytics, inventory control, and equipment lifecycle management. Key insights emphasize the importance of preventive and corrective maintenance, data-driven decision-making, and adaptive procurement models tailored to the specific needs of healthcare institutions. These findings directly informed the project's phases, offering evidence-based support for the development and implementation of scalable solutions.

### Literature Review

Developing robust engineering management strategies for medical equipment requires foundational approaches tailored to the operational needs of healthcare institutions. This includes implementing inspection protocols, preventive routines, and preventive maintenance, all grounded in an understanding of equipment age, usage frequency, and facility demands. In a healthcare organization preventive maintenance is crucial to medical equipment, unlike corrective maintenance which is reactive and occurs only when the device has failed [1]. Preventive maintenance is proactive, aiming to prevent equipment failures before they happen [1].

Predictive maintenance has emerged as a fundamental engineering strategy to minimize equipment downtime and improve long-term performance in healthcare settings. Predictive maintenance combines industry-specific tools with technical data to extend the lifespan of medical devices and reduce operational costs [2]. This allows for maintenance to be performed only when needed, avoiding unnecessary servicing and minimizing the risk of failure [2].

The integration of artificial intelligence into hospital inventory systems has further strengthened predictive maintenance strategies. AI-powered platforms offer real-time monitoring of equipment conditions, automate inventory replenishment, and send alerts when stock levels are low, reducing emergency procurement and enabling proactive planning. These systems can also predict future demand with high accuracy, reducing stockouts and overstocking [3].

Predictive analytics also plays a vital role in supporting inventory management and maintenance decision-making. Calculating ideal inventory levels based on projected demand, lead times, and other pertinent criteria is one of the many benefits that predictive analytics offer [4]. These insights allow biomedical engineers to anticipate needs in advance, thus improving system responsiveness and part availability.

The cost-related benefits of predictive maintenance are also a crucial consideration for healthcare organizations. By addressing potential issues before they escalate, healthcare organizations can significantly lower their maintenance-related expenditures [2].

Furthermore, lifecycle management is essential for engineering managers. It includes defining maintenance schedules based on equipment criticality, assessing vendor reliability, and ensuring compliance with healthcare regulations. These steps help standardize maintenance efforts across organizations and support consistent performance evaluations.

To ensure success, performance indicators such as repair frequency, lead time, and cost efficiency must be tracked continuously. Feedback from clinical and technical staff is also crucial in identifying inefficiencies and refining maintenance strategies. Feedback from frontline staff is a critical component in identifying inefficiencies and continuously improving maintenance strategies [5].

Across all the research, a common theme emerges: the successful management of medical equipment requires a systems-based approach that blends preventive maintenance, strategic procurement, and real-time inventory monitoring—anchored by iterative evaluation and continuous improvement. These strategies improve operational efficiency and enhance patient safety by minimizing equipment downtime and ensuring timely availability of certified, compatible replacement parts.

### Methodology

#### PLAN Phase

Several key challenges were identified during the initial phase of the project, including delays in obtaining equipment parts, strict regulatory compliance requirements, the aging condition of many devices, and financial limitations that affect procurement and inventory planning.

To address these issues, an inventory audit was conducted, and detailed equipment assessments were carried out across all hospital departments. Stakeholder engagement played a crucial role in shaping the planning process, with input gathered from clinical engineering teams, procurement staff, and department heads to ensure alignment with operational needs. Predictive analysis was useful to improve forecasting and decision making.

A comprehensive 20-week maintenance timeline was then developed using project management software, resulting in a detailed Gantt chart that serves as both a visual and organizational guide for the project. The use of big data analytics and cloud computing directly supports the development and execution of the Gantt chart made. The project prioritized critical care areas such as the Emergency Room, Intensive Care Unit (ICU), and Operating Rooms, to minimize the risk of disruptions and ensure patient safety throughout the maintenance cycle.

#### DO Phase

An automated inventory system has been implemented, which provides live alerts to notify staff when stock levels fall below the predefined threshold. Certified suppliers were contacted with the goal of meeting the scheduled delivery timelines, ensuring a smooth supply chain alignment with the maintenance schedule. Maintenance activities have been carried out efficiently, using a Gantt chart with detailed maintenance of all the departments and their total medical devices, with the team servicing an average of 20 devices per week, maintaining high productivity. Compliance checks for every part have been completed prior to installation, guaranteeing proper certification and compatibility with the equipment. The just-in-time delivery model has been successfully tested, designed to reduce storage costs and support a more efficient workflow. Maintenance teams ensure that inventory is kept at optimal levels without delays or excess storage. The entire system has been integrated, with ongoing feedback from staff leading to continuous improvements.

#### STUDY Phase

Key performance indicators (KPIs) were measured and analyzed to assess the effectiveness of the maintenance and procurement strategies. This data supports the importance of preventive maintenance by providing measurable indicators such as maintenance completion rates and repeat repair frequency, which help assess equipment reliability and identify gaps in servicing. Additionally, cost-benefit comparisons between stockpiling and just-in-time procurement align with the goal of optimizing maintenance budgets and reducing downtime. The color-coded Gantt chart effectively tracked weekly progress and department task distribution.

Biweekly failure trend analyses identified patterns in equipment performance. Notably, ICU equipment showed accelerated wear, validating the earlier recommendation to increase inspection frequency in that department. By investing in regular preventive maintenance, healthcare institutions can extend the useful life of their equipment, optimize their maintenance budgets, and avoid the high costs associated with unplanned repairs and replacements. The data also indicated that just-in-time procurement reduced storage costs without negatively impacting maintenance timelines, making it a viable long-term strategy. Lessons learned from the analysis have been documented to inform the next cycle of planning and continuous improvement. It is recommended that the organization work together to develop an action plan that will test improvements in your identified process to help reach the given goal.

#### ACT Phase

Post-maintenance evaluations are being finalized across all departments, with quality assurance reviews confirming that updated maintenance protocols have effectively reduced downtime and repeat repairs. Custom maintenance schedules were successfully implemented based on department-specific needs, particularly in high-priority areas like the ICU, where earlier failure trends had been observed.

Procurement frameworks were revised to incorporate performance insights, including adjustments to lead times, emergency part handling, and supplier coordination. A hospital-wide performance dashboard was launched to provide real-time visibility of KPIs, facilitate early detection of issues, and promote data-driven decision-making across departments.

The improvements and lessons learned throughout the project are trying to be formally integrated into the hospital's long-term maintenance policies. This cyclical, data-driven approach reflects current healthcare recommendations for sustainable systems improvement.

### Results and Discussion

The project resulted in significant improvements in the management of medical equipment maintenance and procurement throughout the hospital. Initial assessments revealed key challenges such as aging equipment, regulatory compliance requirements, supply chain delays, and financial constraints. Figure 1 shows that these findings informed the creation of a focused 20-week maintenance schedule for the departments, where every 6 months each medical device would be maintained. Each department is supported by advanced data analytics and active stakeholder involvement.

The introduction of an automated inventory system with real-time alerts, combined with a just-in-time procurement model, optimized supply chain efficiency. Maintenance teams consistently serviced an average of 20-25 devices per week while ensuring full compliance with certification standards for replacement parts. This approach effectively balanced inventory levels, minimized storage costs, and aligned maintenance activities with Operational demands.

Ongoing analysis demonstrated the success of preventive maintenance efforts, with improved completion rates and fewer repeat repairs. Equipment failure trends identified the ICU as requiring more frequent inspections, confirming earlier planning decisions. Financial assessments further validated just-in-time procurement as a cost-effective strategy that did not compromise maintenance schedules.

Post-maintenance evaluations confirmed reduced equipment downtime and enhanced reliability. Customized maintenance plans were established based on departmental needs, especially in high-priority units. Procurement processes were refined using performance data. Table 1 demonstrates a hospital-wide dashboard was implemented to monitor key performance indicators. Collectively, these outcomes reflect the establishment of a data-driven, sustainable equipment management system aligned with current healthcare best practices.

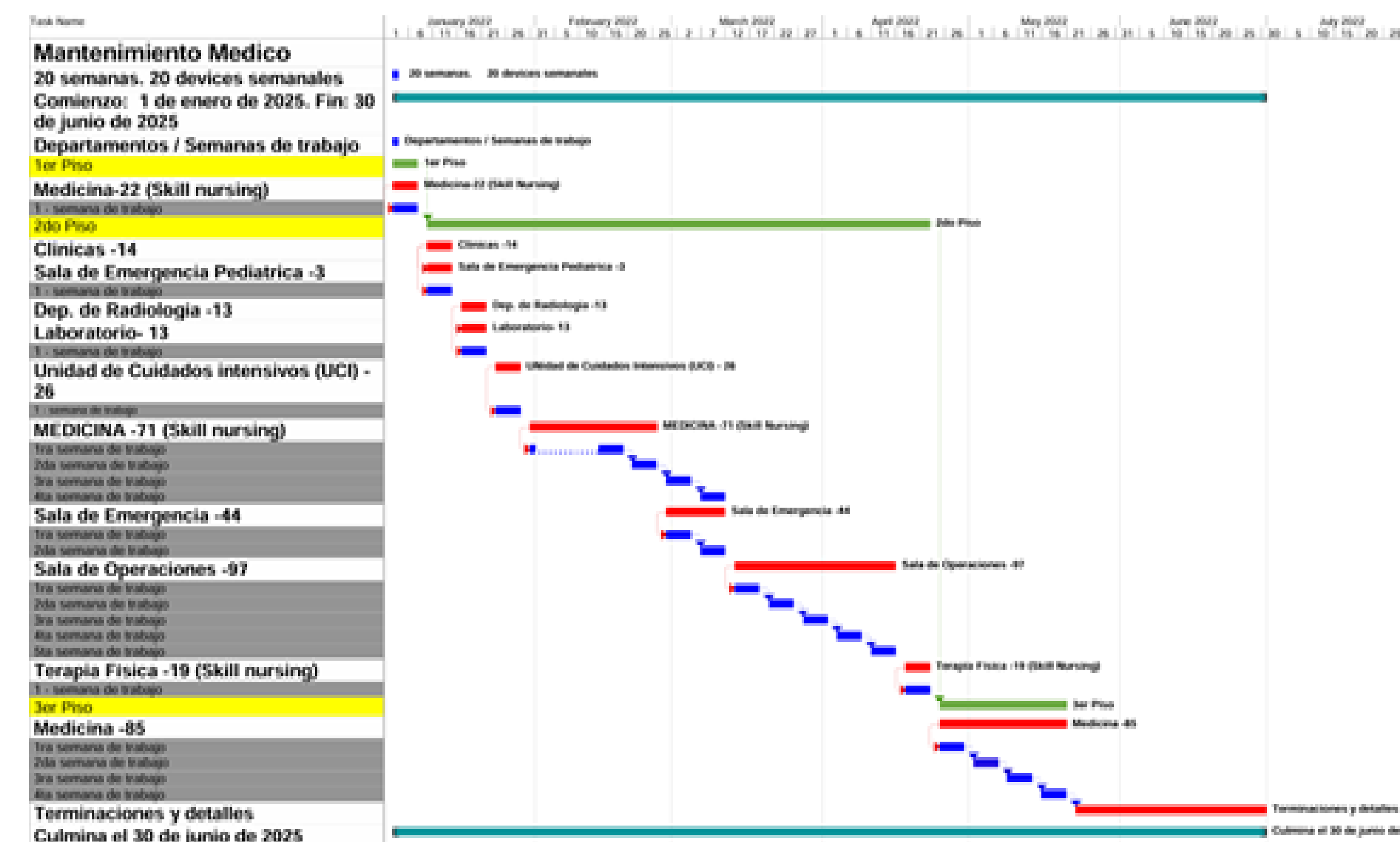


Figure 1  
Medical Maintenance

Table 1  
Key Performance Indicator

KPI	Target	Actual
Average Devices Serviced Weekly	20 devices/week	20 devices/week
Inventory Cost Reduction	≥ 15% savings	18% savings
Equipment Downtime	↓ by 40%	↓ by 42%
Compliance with Certification	100%	100%
Stakeholder Satisfaction	Positive trend	Achieved

### Conclusions

The implementation of a structured, data-driven maintenance and procurement system at Hospital HIMA San Pablo has demonstrated measurable improvements in medical equipment reliability, operational efficiency, and patient safety. By applying the Plan-Do-Study-Act (PDSA) methodology, the project successfully addressed critical challenges such as aging devices, regulatory compliance, and supply chain constraints through preventive maintenance, predictive analytics, and just-in-time inventory management. Key outcomes included reduced equipment downtime, optimized maintenance schedules tailored to departmental needs, and cost-effective procurement processes supported by real-time monitoring and stakeholder collaboration. This systems-based approach not only enhanced hospital performance, but also provides a scalable model for sustainable engineering management in other healthcare settings facing similar challenges.

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### References

- [1] S. J. Patel and H. D. Patel, "Role of Biomedical Engineers in Medical Equipment Management in Hospitals," *Int. J. Eng. Res. Dev.*, vol. 20, no. 9, pp. 62–70, 2020. [Online]. Available: <https://www.ijerd.com/paper/vol20-issue9/2009162170.pdf>
- [2] A. Saxena, "Predictive Maintenance in Healthcare Equipment: An Industrial Perspective," *SSRN*, May 2024. [Online]. Available: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=5005057](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5005057)
- [3] Chooch AI. (2023, Nov. 20). How AI Is Transforming Hospital Inventory Management [Blog post]. Available: <https://www.chooch.com/blog/how-ai-is-transforming-hospital-inventory-management/>
- [4] M. A. Mushtaque, M. G. Rabbani, M. A. H. Mondal, and S. M. S. Islam, "The Role of Predictive Analytics in Inventory Management: A Systematic Literature Review," *ResearchGate*, 2023. [Online]. Available: [https://www.researchgate.net/publication/384125046\\_The\\_Role\\_of\\_Predictive\\_Analytics\\_in\\_Inventory\\_Management](https://www.researchgate.net/publication/384125046_The_Role_of_Predictive_Analytics_in_Inventory_Management)
- [5] American Medical Association. (2020). Plan-Do-Study-Act (PDSA) Cycles Primer [Toolkit]. Available: <https://edhub.ama-assn.org/steps-forward/module/2702507>