2

From Reactive to Predictive:

A New Blueprint for Cold Chain Spare Parts Management

Problem

A core challenge of cold chain maintenance is the unpredictability of equipment failure combined with a lack of ready-to-use replacement parts; if the right spare part isn't available at the moment of breakdown, the entire temperature-controlled supply chain fails. This situation is exacerbated in many countries by specific challenges:

- Varied fleet of equipment featuring multiple manufacturers and configurations complicates efforts toward standardization and part interchangeability
- A lack of data-driven forecasting or specialized tools can create inventory imbalances, resulting in stockouts of critical parts, while simultaneously overstocking non-essential ones
- Procurement of spare parts entails long lead times with insufficient local market availability for specialized parts.

Background

The operational reliability of a walk-in cold room (WICR) and walk-in freezer room (WIFR) is fundamental to the integrity of national immunization and health logistics systems. Critical spare parts, such as compressors, are indispensable - without them, a WICR or WIFR becomes completely non-functional.

The network of cold chain equipment (CCE) in Ethiopia is quite diverse in terms of both manufacturer and type, distributed across 19 major hubs and locations, including the Ethiopian Pharmaceuticals Supply Service (EPSS) Center at national level. The inventory primarily consists of WICR and WIFR, with units categorized by their configuration (Split or Monoblock) and manufacturer. EPSS lacked a formal real-time system to manage inventory of parts needed to keep CCE up and running.

The Solution

By implementing a standardized, data-driven approach, health systems can reduce equipment downtime, promote evidence-based inventory planning, and minimize emergency procurement costs. JSI worked with EPSS to develop a standardized, data-driven approach for managing spare parts for WICR and WIFR. Our first step was to build an interim maintenance tracking system to begin collecting this information. We developed an inventory management guideline and a forecasting tool for spare parts, both of which leverage practical experience to ensure operational reliability and optimize resource use across health logistics systems.

Structured Implementation Approach

We implemented our approach to spare parts inventory management through a series of structured steps and analysis:

1. **Cold Chain Inventory:** Standardizes equipment by technical configuration, manufacturer, and model. We worked with EPSS to update WHO's CCE Inventory and Gap Analysis Tool, which includes critical data such as unique identifiers, technical specifications, and operational history while utilizing regular condition assessments to track "health status."
2. **Spare Part Master List:** Standardizes spare parts by name, model, and part number. We incorporated general part categories and precise technical specifications in this list, establishing a mandatory link with all WICR and WIFR models in the cold chain inventory database, mitigating the risk of stocking incompatible parts.
3. **Segmentation and Classification:** We worked with maintenance technicians to categorize spare parts by five criteria: criticality, interchangeability, cost, local availability, and procurement lead time. These categories help to prioritize resources and define a strategic stock-holding policy. Maintenance technicians contributed to the categorization process based on their extensive CCE work experience.
4. **Inventory Holding Strategy:** Using the country context, we defined stock locations based on risk and efficiency considering the segmentation and classification criteria of the WICR and WIFR in the different regions and hubs.
5. **Min-Max Control System:** We developed and implemented a policy where "minimum stock" triggers reorders and "Maximum Stock" prevents overstocking or triggers repositioning.

By synthesizing these core components, we developed a guidance framework and data-driven forecasting tool that translates technical analysis into actionable inventory logic.

"The expectation is that improved spare parts management will contribute to greater efficiency and resilience of national cold chain systems supporting immunization programs." Sami Tewfik

Spare Part Inventory Management Guideline

Together with EPSS, JSI developed the Guideline: Inventory Management and Forecasting for Spare Parts for WICR and WIFR. The guideline is built on principles of reliability, efficiency, and data-driven management. It aims to bolster operational reliability and supply chain efficiency by maintaining a 95% or higher uptime for critical WICR and WIFR units through digital, data-driven management for optimized inventory levels. The guidance uses a specialized segmentation matrix to track inventory across all locations and utilizes a forecasting tool to proactively manage reorder points, thereby minimizing stock-outs and emergency costs. Central to these objectives is the digital integration of maintenance, logistics, and procurement teams, ensuring all departments operate from a single source of truth data to streamline the cold chain lifecycle.

Spare Parts Forecasting Tool

For a practical application of the guidance, JSI developed the Forecasting Tool: Inventory Management and Forecasting for Spare Parts for WICR and WIFR. This tool integrates the Spare Parts Master List and CCE Inventory data to align demand for spare parts with specific age and location of installed WICR and WIFR units. It helps analyze historical consumption and maintenance history, while identifying demand trends and adjusting for variations in maintenance needs as assets age. By linking technical specifications and equipment segmentation (such as criticality and standardization) with current asset profiles, the forecasting tool mitigates the risk of stocking incompatible parts, while ensuring inventory reflects both existing units and planned expansions.

The tool uses a phased forecasting model, taking a naive approach for the first year of data which will transition to an advanced time series models as demand patterns emerge. The resulting forecast quantity is then aggregated by stock keeping unit (SKU) and disaggregated by equipment type and geographic hubs to provide a granular view of quantity and cost requirements. The total supply requirement is calculated by adjusting these forecasts against specific inventory holding policies, ensuring that stock levels are optimized based on the predetermined spare part segments.

Lessons Learned

Our approaches and the implementation of the inventory guideline and forecasting tool has significantly enhanced operational resilience by aligning inventory procurement with actual consumption patterns. Key lessons include:

- **Segmentation and Classification:** Classified spare parts inventory, based on criticality, fleet-wide interchangeability, unit cost, local market availability, and procurement lead times enabled prioritized resource allocation.
- **Tiered Stocking Strategy:** Applying a hybrid stock model balances centralized and decentralized storage based on the specific risk profiles and carrying costs of individual components.
- **Dynamic Inventory Control:** Using a Min-Max system to properly manage inventory and maintain optimized stock buffers accounts for both lead-time fluctuations and consumption variability.
- **Forecasting Integration:** Harmonizing fleet data with historical consumption patterns generates high-accuracy demand forecasts and robust supply plans for spare parts.

With the insight provided by the tools in the first year of use, EPSS successfully procured $10,000 USD worth of critical refrigeration and electrical components and is well-placed for transitioning from reactive troubleshooting to a proactive, data-driven forecasting model that ensures the right parts are consistently available at the point of need.

Key Takeaways

Spare part planning is often forgotten. This unique approach to spare parts management offers critical, practical lessons for immunization supply chain teams around the world:

- **Supply chain best practices are the foundation.** Applying supply chain forecasting logic to the traditionally neglected and unmonitored world of spare parts, we pioneered a first-of-its-kind approach that transforms invisible inventory into a predictable, data-driven asset.
- **Progress over perfection.** Maintenance and spare parts data were not available at the beginning of this project. Using the information that was available, we demonstrated the value of forecasting and created the necessary momentum to improve future data collection and reporting. Essentially, by building the framework with existing data, we have catalyzed a shift toward a more robust, data-centric culture within the health system.
- **Reimagining spare parts as a science.** By applying rigorous forecasting logic, this project shifted the perception of spare parts from an afterthought to a strategic pillar of cold chain management. We have moved beyond simple run-to-failure approach for cold chain equipment, proving that even the most fragmented maintenance system can be mastered through innovative, data-driven management.