USAID GLOBAL HEALTH SUPPLY CHAIN PROGRAM

PROCUREMENT AND SUPPLY MANAGEMENT

MEDICAL OXYGEN EQUIPMENT MANAGEMENT STRATEGY AND ROADMAP

USAID FROM THE AMERICAN PEOPLE

PEPFAR U.S. President's Emergency Plan for AIDS Relief

USAID FROM THE AMERICAN PEOPLE CDC U.S. President's Malaria Initiative

On site repairs of Oxygen concentrators in the Nacala Velha Health Center. Lack of preventive maintenance and wrong usage led to early breakage. A post-delivery visit was used to re-train technicians and repair the equipment.

Photo: Jan de Jong

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ACRONYMS

3PL	Third-Party Logistics
BMA	Biomedical Assistant
BMET	Biomedical Equipment Technician
CM	Corrective Maintenance
CMMS	Computerized Maintenance Management System
CAPEX	Capital Expenditure
CHAI	Clinton Health Access Initiative
DIEH	Departamento de Infraestrutura e Equipamento Hospitalar (Department for Infrastructure and Medical Equipment)
DNAM	Departamento Nacional de Assistência Medica (National Department for Medical Assistance)
DPM	Deposito Provincial de Medicamentos (Provincial Pharmaceutical Warehouse)
EDM	Electricidade de Moçambique (Mozambican Electrical Company)
GHSC	Global Health Supply Chain
GHSC-PSM	Global Health Supply Chain-Procurement and Supply Management Project
GOM	Government of Mozambique
HTM	Healthcare Technology Management
ICU	Intensive Care Unit
ISO	Independent Service Organization
JHPIEGO	Johns Hopkins Program for International Education in Gynecology and Obstetrics
KPI	Key Performance Indicator
LCM	Life Cycle Management
LOX	Liquid Oxigen
LMIS	Logistics Management Information System
M&E	Monitoring and Evaluation
MISAU	Ministério da Saúde (Ministry of Health)
MMS	Maintenance Management System
MMTR	Mean Time to Repair
MOH	Ministry of Health
OJT	On-the-job Training
OPEX	Operational Expenditures
PATH	Formerly known as the Program for Appropriate Technology in Health
PM	Preventive Maintenance

PPE	Personal Protective Equipment
PSA	Pressure Swing adsorption
QA/QC	Quality Assurance/Quality Control
SC	Supply Chain
SDP	Service Delivery Point
SLA	Service Level Agreement
SOP	Standard Operating Procedure
TA	Technical Assistance
TCO	Total Cost of Ownership
USAID	United States Agency for International Development
WHO	World Health Organization
WMS	Warehousing Management System

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HEALTH TECHNOLOGY DEFINITONS

Term	Definition
Acceptance testing	The initial inspection performed on a piece of medical equipment prior to it being put into service.
Biomedical Engineering	Biomedical engineering encompasses related disciplines with different names, such as medical engineering, electromedicine, bioengineering, medical and biological engineering, and clinical engineering.
Biomedical Engineering Technician/Technologist (BMET)	BMETs are healthcare professionals responsible for the routine maintenance and repair of medical equipment in hospitals. They have a specific level of expertise. BMETs specializing in complex laboratory and radiological equipment can become certified in their specialization without meeting broader engineering requirements. The distinction between a technician and a technologist is based on their training duration, with technicians typically training for two years and technologists for three years, although this may vary by country.
Calibration	Some medical equipment, particularly those with therapeutic energy output (e.g.: defibrillators, electrosurgical units, physical therapy stimulators, etc.), needs to be calibrated periodically. Devices that take measurements (e.g.: electrocardiographs, laboratory equipment, patient scales, pulmonary function analysers, etc.) also require periodic *calibration* to ensure accuracy compared to known standards.
Clinical engineer	A professional who supports and advances patient care by applying engineering and managerial skills to health-care technology.
Clinical engineering department	Engineer/technician or team of engineers/technicians responsible for the management and maintenance of medical equipment.
Corrective maintenance or repair (CM)	A process used to restore the physical integrity, safety and/or performance of a device after a *failure. Corrective maintenance* and *unscheduled maintenance* are regarded as equivalent to the term *repair.* This document uses these terms interchangeably.
Failure	The condition of not meeting intended performance or safety requirements, and/or a breach of physical integrity. A *failure* is corrected by *repair* and/or *calibration.*
Health Technology	Health technology refers to the application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures, and systems designed to address health issues and enhance quality of life. It can also be referred to as health-care technology.
Inspection	*Inspection* refers to scheduled activities necessary to ensure a piece of medical equipment is functioning correctly. It includes both *performance inspections* and *safety inspections.*
Medical Device	A medical device is an article, instrument, apparatus, or machine used for preventing, diagnosing, or treating illnesses, or for detecting, measuring, restoring, correcting, or modifying the body's structure or function for health-related purposes. This category includes medical equipment, implantables, single-use devices, in vitro diagnostics, and some assistive technologies.

Term	Definition
Medical Equipment	Medical equipment is used for specific purposes in diagnosing and treating diseases or aiding in rehabilitation following diseases or injuries. It can be used alone or in combination with other accessories but excludes implantable, disposable, or single-use medical devices. Medical equipment is a capital asset and requires professional installation, calibration, maintenance, user training, and decommissioning, typically managed by clinical engineers.
Preventive maintenance (PM)	PM involves maintenance performed to extend the life of the device and prevent *failure*. PM is usually scheduled at specific intervals and includes specific maintenance activities such as lubrication, cleaning (e.g. filters) or replacing parts that are expected to wear (e.g. bearings) or which have a finite life (e.g. tubing). The procedures and intervals are usually established by the manufacturer. *Preventive maintenance* is sometimes referred to as 'planned maintenance' or 'scheduled maintenance'. This document uses these terms interchangeably.
Safety inspections	These are performed to ensure the device is electrically and mechanically safe.

Source: adapted from several WHO publications

EXECUTIVE SUMMARY

BACKGROUND

Oxygen is vital for treating medical conditions, especially respiratory illnesses like COVID-19. In Low- and Middle-Income Countries (LMICs) like Mozambique, the demand for medical oxygen surged due to the pandemic, but the capacity to meet it often fell short. The Mozambican Ministry of Health (MOH or MISAU) received substantial financial support from various partners in recent years, leading to investments in hospitals and healthcare units, including the addition of oxygen-related equipment. However, many of these acquisitions were ad hoc and lacked a proper equipment management plan or lifecycle management. With the decrease in COVID-19 cases, there's an opportunity to repurpose these resources for other healthcare needs. The challenge is the absence of a robust equipment management system and maintenance planning. Without these elements, there's a risk that these life-saving devices may deteriorate, potentially undoing the progress made. To harness the full potential of these resources and ensure the sustainability of improved healthcare services, Mozambique must establish a comprehensive equipment management system with maintenance, training, and an effective utilization plan. This proactive approach will preserve gains made and build a more resilient healthcare system and improved access to oxygen treatment.

The outlined strategy and roadmap have been tailored to specifically tackle the management and maintenance of five distinct types of medical oxygen equipment: Pressure Swing Adsorption systems (PSAs), Oxygen Concentrators, Oxygen Ramps and Piped Oxygen Systems, Oxygen Cylinders, and Liquid Oxygen Systems (LOX). It is essential to emphasize that although this document focuses primarily on these specific equipment types, the principles and methodologies discussed can be customized for managing various other medical equipment. Additionally, the plan to enhance the Ministry of Health's (MOH) capacity to manage oxygen equipment will inherently contribute to an overall improvement in managing other medical equipment as well.

ASSET LIFECYCLE MANAGEMENT

This document delves into medical equipment management using the asset lifecycle management approach. Through this methodology, we take a structured approach to oversee the management of medical oxygen equipment from acquisition to disposal. This encompasses things like planning, procurement, utilization, maintenance, and training, ensuring optimal equipment function and compliance with regulations. As equipment ages, decisions regarding upgrades or replacements are also guided by the asset lifecycle management approach. This method aids in cost control and ensures the provision of quality patient care by sustaining equipment efficiency throughout its lifecycle.

ROADMAP

The outlined roadmap below highlights essential steps and strategies to support the country in improving the management and maintenance of medical (oxygen) equipment. Acting as a fundamental guide, this roadmap provides a structured framework for addressing key aspects throughout the equipment's life cycle. It includes careful planning, streamlined procurement, efficient utilization, and regular maintenance to ensure optimal functionality and compliance with standards. This comprehensive approach aims to establish a reliable and sustainable system for managing critical medical assets, promoting operational efficiency. By adopting these measures, the country can enhance the overall quality and accessibility of healthcare services, laying the groundwork for meaningful progress in medical equipment management.

Create multidisciplinary project team to develop and implement a medical (oxygen) equipment management plan (MEMP):

- Create multidisciplinary project team responsible for developing and implementing the MEMP.
- Identify key stakeholders from various departments and healthcare facilities who should be included in the project team.
- Define the roles and responsibilities of team members and establish clear lines of communication and reporting.
- Establish the project team's Technical Assistance (TA) budget.
- Facilitate coordination and negotiations with stakeholders and donors regarding the technical and financial backing of the implementation plan.

Perform a medical oxygen capacity analysis:

1. **Oxygen supply assessment**
    - Identify existing oxygen generation and supply infrastructure, including the number and capacity of oxygen plants (PSAs), oxygen concentrators, cylinders, oxygen ramps, piped oxygen systems and other related equipment.
    - Evaluate the condition and operational status of the existing equipment to determine what can be reused, refurbished, or upgraded.
    - Quantify the current oxygen production and distribution capacity, including the flow rates and availability of oxygen in healthcare facilities.

2. **Oxygen demand assessment**
    Calculate the current demand for medical oxygen by considering factors such as:

    - The number and type of patients requiring oxygen therapy.
    - Prevalence of diseases or conditions that necessitate oxygen therapy.
    - The volume of oxygen required per patient.
    - The total annual oxygen consumption by healthcare facilities.

3. **Future demand estimation:**
    Project future demand for medical oxygen by considering:

    - Population growth and changing demographics.
    - Trends in the incidence of diseases requiring oxygen therapy.
    - Expansion of healthcare facilities and services.
    - Advances in medical technology and treatments.

4. **Gap identification:**
    - Compare the projected oxygen demand with the current supply and infrastructure to identify gaps or disparities.

5. **Recommendations and action plan:**
    - Develop a set of recommendations and an action plan to bridge the identified gaps in medical oxygen demand.
    - Develop strategies for equipment replacement based on lifecycle analysis, technological advancements, and changing healthcare needs.
    - Prioritize interventions based on their impact and feasibility
    - Develop long term equipment investment plan.

Development of an inventory system:

- Develop guidelines and standard operating procedures (SOPs) for medical equipment inventory management.
- Prioritize key medical equipment to be included in inventory.
- Establish a comprehensive medical equipment inventory system to track and monitor/update equipment across healthcare facilities.

Implementation of a CMMS:

- Perform needs assessment and requirements gathering.
- Selection and procurement of software solution.
- Procure and distribute hardware.
- Implement system (configuration and customization).
- Execute CMMS training and capacity building.
- Implement a pilot and perform system testing.
- Execute a nationwide rollout.

Policy and regulatory framework:

- Review existing policies, regulations, and guidelines related to medical equipment management.
- Identify gaps and propose necessary updates and additions to align with international best practices.
- Define equipment policy by level of care.
- Develop policies and procedures that cover the entire lifecycle of medical equipment, including procurement, installation, maintenance, and disposal.

Human Resources and capacity building:

- Perform a skills and gap analysis.
- Create a short term, medium term, and long-term training plan.
- Develop a training program to enhance the technical skills of maintenance personnel and establish career development pathways.
- Develop (online) training materials for the management/maintenance of medical oxygen equipment.

Maintenance practices and standards:

- Develop of a set of best maintenance practices and maintenance standards for medical devices, aligned with international guidelines.
- Develop protocols for preventive maintenance, calibration, and quality assurance.
- Establish mechanisms for regular monitoring, data collection, and reporting on equipment status, maintenance activities, and equipment performance.

Health and safety plan and manual:

- Develop a comprehensive Health and Safety plan for medical (oxygen) equipment.
- Ensure that all maintenance technicians and clinicians receive comprehensive training on the safe use and maintenance of medical oxygen equipment. This should cover handling, troubleshooting, and emergency procedures.

Supply chain of spare parts:

- Examine the current supply chain for spare parts, pinpointing areas for enhancement. This analysis should encompass decisions on the extent to which activities should be managed in-house versus outsourced.
- Develop a strategy/plan to ensure the availability of high-quality spare parts and consumables for medical devices.
- Implement a spare part supply chain improvement plan.

Procurement of equipment/services and donations:

- Develop a procurement strategy for new medical devices, ensuring technical specifications meet the requirements of the MEMP (including harmonization of equipment purchases).
- Develop template tender documentation and procurement contracts,
- Develop protocols for the acceptance and management of donated medical devices.
- Develop protocols for contracting 3PL maintenance services.
- Design monitoring and evaluation mechanisms to ensure adherence to SLAs.

Equipment Disposal:

- Develop guidelines for the safe disposal and replacement of medical equipment, adhering to environmental and regulatory requirements.

Monitoring and evaluation framework and indicators:

- Design of a framework to monitor and evaluate the implementation of the maintenance strategy.
- Develop key performance indicators (KPIs) to measure the performance of medical equipment management.
- Establish mechanisms for regular monitoring, data collection, and reporting on equipment status, maintenance activities, and equipment performance.

Emergency response plan development:

- Develop a detailed emergency response plan that outlines the procedures for prioritizing oxygen supply, coordinating with healthcare facilities, and responding to oxygen shortages. In anticipation of equipment failures or oxygen supply disruptions, the plan should include provisions for backup oxygen sources or alternative equipment to ensure patient safety during emergencies.

Financing and sustainability:

- Develop a long-term financial plan for the medical (oxygen) equipment management plan, long term investment plan and maintenance plan, including budgeting and resource mobilization strategies.

Development of yearly implementation and action plans:

- Develop yearly implementation plans, setting clear objectives, activities, timelines, and responsibilities.

Refer to Annex K for the proposed implementation calendar.

CONCLUSION

The effort to improve medical oxygen equipment management and maintenance in Mozambique, is a challenging, long-term initiative that requires the collaboration of a variety of experts and stakeholders. This comprehensive project will demand substantial financial investments and serious commitment from both the Mozambican government and donors. A key factor in its success is shifting from the traditional equipment acquisition approach to adopting a proactive equipment management mindset. It's clear that to make a lasting and meaningful impact in the management of medical oxygen equipment, we need to move beyond concentrating solely on one aspect, like maintenance in isolation. Embracing a more comprehensive lifecycle approach that takes into account all aspects of equipment management is essential. This approach ensures a more effective and sustainable management of medical equipment, from acquisition to maintenance and eventual disposal.

Historically, maintenance of medical equipment has not been a priority within the Ministry of Health (MOH), donors, and implementing partners This lack of attention is one of the key reasons why departments like the DIEH receive insufficient support both from within the MOH and externally and consequently suffer from chronic underfunding. The scope of this challenge is extensive, and there are no quick or easy solutions. One of the crucial tasks facing the Government of Mozambique (GoM) is to persuade donors and implementing partners to actively participate in this area. To transform the prevailing mindset and establish a new culture around medical equipment management, it is imperative for the GoM to lead by example and make a sincere and dedicated commitment to prioritize this activity. By doing so, the government can inspire others to invest their resources and efforts in improving medical equipment management in the country. To make these necessary changes will take considerable time, effort and funding.

A possible first step could be for the MOH to set up and lead a diverse project team to create and put into action the development Medical (Oxygen) Equipment Management Plan (MEMP). This could mark the beginning of meaningful work and improvements in this neglected area.

1: INTRODUCTION

BACKGROUND

Oxygen is an indispensable component in the treatment of various medical conditions, and its availability is paramount for saving lives, particularly in the context of respiratory illnesses such as COVID-19. Many Low- and Middle-Income Countries (LMICs) like Mozambique have witnessed a surge in the demand for medical oxygen in recent years due to the pandemic, yet the capacity to meet this demand remained often inadequate.

In the past few years though the Mozambican Ministry of Health (MOH or MISAU), with substantial financial support from multiple partners, has made substantial investments in the construction and equipping of hospitals and healthcare units with diagnostic and therapeutic equipment, including oxygen-related equipment. Many of these donations and procurements where ad hoc and not based on the execution of a medical equipment management plan or management by lifecycle. With the decline in COVID-19 cases, there is an opportunity to make the most of these oxygen equipment investments by repurposing them for other patient needs, such as Maternal Child Health and surgical blocks.

However, the challenge lies in the absence of a robust medical equipment management system, which includes maintenance provisions and a comprehensive plan. Without these crucial elements, there is a risk that these life-saving devices may deteriorate and fail in the near future, potentially undoing the progress made. This would represent a missed opportunity to improve the standard of oxygen therapy treatment in Mozambique, transforming it from a previously neglected area into a much higher level of service delivery.

To harness the full potential of these resources and ensure the sustainability of improved healthcare services, it is essential that Mozambique establishes a comprehensive medical equipment management system that includes maintenance, training, and a clear plan for the effective utilization of these valuable assets. This proactive approach will not only preserve the gains made but also lay the foundation for a stronger and more resilient healthcare system in the country.

The outlined strategy and roadmap have been tailored to specifically tackle the management and maintenance of five distinct types of medical oxygen equipment: Pressure Swing Adsorption systems (PSAs), Oxygen Concentrators, Oxygen Ramps and Piped Oxygen Systems, Oxygen Cylinders, and Liquid Oxygen Systems (LOX). It is essential to emphasize that although this document focuses primarily on these specific equipment types, the principles and methodologies discussed can be customized for managing various other medical equipment. Additionally, the plan to enhance the MOH's capacity to manage oxygen equipment will inherently contribute to an overall improvement in managing other medical equipment as well.

National Oxygen Assessment:

In 2022, the MOH, with financial and technical support from GHSC-PSM and CHAI, concluded an Oxygen Assessment to determine the country's current capacity in providing, managing, and maintaining oxygen treatment within the public health system. The assessment provided an overview of the status of oxygen equipment and auxiliary equipment (e.g., generators) and outlined the current level of competency and knowledge among hospital staff regarding oxygen equipment management and maintenance. In general, a majority of the oxygen equipment suffered from a lack of maintenance, rendering them either nonfunctional, obsolete, or operating sub optimally. Recent donations of oxygen equipment have exacerbated the already precarious situation.

In summary, the current challenges in oxygen equipment management and maintenance encompass, but are not limited to:

- Procurement without proper solicitation of Department for Infrastructure and Hospital Equipment (DIEH) and Clinicians leading to the acquisition of in-appropriate (as in technology) and un-supported and un-serviceable equipment.
- Lack of national oxygen quantification of current and future demand.
- No strategic medical equipment management plan (MEMP) available.
- Lack of accurate and up to date inventory information.
- Existing infrastructure and oxygen equipment lacking maintenance.
- Large dependence on a few external suppliers of oxygen with long and supply chains.
- Lack of maintenance culture and habits.
- Several International Standard being followed leading to incompatibility between systems and equipment.
- Lack of a (computerized) maintenance management system (CMMS).
- Lack of trained technicians and no training program or training plan for existing employees or in service training available,
- Lack of a regular preventive maintenance program/planning,
- Centralized maintenance system with long communication and administrative lines causing long response times for corrective repairs due to administrative bottle necks,
- Limited human resource capacity to manage and maintain the equipment.
- Lack of trained operators due to low staff retention, leading to misuse of the equipment.
- Inefficient internal (MOH) supply chain for replacement parts.
- Lack of workshops, tools and measuring/calibration devices.
- No Health and Safety plan or standards in place.
- Limited funding for maintenance thus e.g., impeding regular site visits and contracting 3PL maintenance providers where and when needed.
- Unsolicited and un-coordinated donation of medical devices.
- Shortage of competent maintenance service providers in the local market.
- No measuring or benchmarking program (lacking KPIs and M&E plan).
- Lack of a long-term investment plan and budgeting for replacement and maintenance of medical oxygen equipment.

For instance, concentrators are common way of providing oxygen treatment and typically low-maintenance devices found in health facilities. Approximately 88% of these facilities are equipped with at least one concentrator. However, our findings indicate that 22% of these concentrators are currently non-operational. In rural hospitals, this percentage increases to 40%, and in rural health facilities, it climbs to 50%.

These findings are in line with other studies done in other countries in Sub-Saharan Africa. To address these challenges, it is a necessary to build a system and capacity for management of oxygen equipment which includes maintenance and repair within the current government system. It is important to understand that although maintenance is a crucial factor in the management of medical (oxygen) equipment is only one of the elements for comprehensive medical equipment management.

Management (including maintenance) of oxygen equipment lie within the responsibility of the Department for Infrastructure and Hospital Equipment (DIEH), and the provincial maintenance systems and teams. Expanding the scope of the existing structures within the DIEH and facility maintenance teams, as well as training these relevant stakeholders, will help to increase functionality of existing oxygen equipment and prolong the lifespan of substantial amount of new equipment which have come in during the COVID-19 pandemic response. The main tasks of the DIEH related to medical oxygen equipment:

- Provide technical input in the selection and procurement of medical oxygen equipment.
- Provide technical input in the development of the oxygen demand planning.
- Implement and maintain an inventory and maintenance management system.
- Ensure all oxygen medical equipment used within the facility is maintained to specific standards to allow safe operation and immediate readiness.
- Encourage safe and effective use of medical equipment by staff and practitioners within the health facility.
- Ensure the existence of a trained medical equipment maintenance cadre.
- Develop, update the MEMP.
- Develop and monitor KPIs and M&E plan.

The DIEH currently boasts a workforce of around 300 individuals, with 200 dedicated maintenance technicians strategically stationed nationwide (Source: DIEH). Their responsibilities extend to managing the infrastructure of health facilities, including buildings, as well as overseeing both medical and non-medical equipment such as generators. This collective effort spans across four (4) Central Hospitals, ten (10) Provincial Hospitals, three (3) General Hospitals, two (2) specialized hospitals, 47 District Hospitals, and over 1700 Health Centers. Despite the absence of recent inventory data, the last national inventory conducted in 2000 reported approximately 15,000 pieces of equipment in use across all hospital services. It is estimated that this number has since quintupled, underscoring the increasing demands on the DIEH's capabilities (Source: DIEH).

DIEH has been allocated an annual budget of approximately one (1) million US dollars, equivalent to about 64 million meticais at the current exchange rate. Given the estimated overall CAPEX, a significantly increased budget allocation will be imperative to ensure the continued functionality of current and future equipment. Securing sustainable funding for the outlined goals and the implementation of the oxygen supply strategy will require proactive efforts from the Ministry of Health. This includes working towards obtaining the necessary budget and mobilizing additional resources from donors and collaborative partners. These resources are essential for various needs, such as technical assistance, technology procurement, equipment maintenance, acquisition of spare parts, and human resource training. It's noteworthy that while in developed nations, this budget typically corresponds to 5-10% of annual CAPEX, in low-income countries like Mozambique, this percentage is expected to be considerably higher (Source: WHO).

Given the constraints of limited resources, a prioritization activity for equipment should be undertaken, considering factors like the life-saving status of the equipment, availability of technical experts, equipment complexity, cost-effectiveness, and geographical area.

OBJECTIVES

This document serves as a guide to outline the vital elements of a successful medical oxygen equipment management program. Its primary objective is to support National Department for Medical Assistance (DNAM) and the Department of Infrastructure, Equipment, and Healthcare (DIEH) in developing, overseeing, and executing a comprehensive and pragmatic oxygen equipment management plan.

This activity has one main objective:

Design a 5-year road map to support DNAM and DIEH in the Management of Medical (Oxygen) Equipment.

METHODOLOGY

The document was developed in conjunction with DNAM, DIEH, GHSC-PSM and with collaboration of JHPIEGO. The roadmap is developed based on an earlier National Oxygen Equipment assessment (2022), available literature (desk research), past site-visits, oxygen equipment trainings and training material development, procurement and commissioning of medical oxygen equipment, MOH policy documents, maintenance workshops and regular discussions with the DIEH staff and other stakeholders. This report is structured around the physical asset lifecycle and the role management plays in influencing the economical lifespan of medical oxygen equipment.

Limitations of the strategy/roadmap:

There is limited historical information on the use of oxygen for therapy. Mozambique has not conducted a national oxygen needs assessment or projected future oxygen consumption in the public health system. It also does not have an approved equipment policy by level of care. Without baseline information and a calculation of future needs, it is difficult to determine the oxygen equipment gap, create an oxygen equipment network design, and determine the quantities of each equipment at each level of care. E.g.: Once this information is available you would be able to create an equipment investment plan and determine the management, maintenance and operating budget needed to maintain the inventory. It's evident that we are at the initial stages of a comprehensive journey to enhance the management quality of medical oxygen equipment, as well as medical equipment in a broader context.

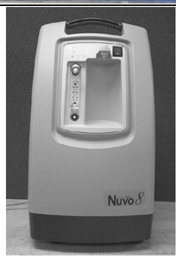
Item	Maintenance Roadmap Included Equipment	Picture
1	PSA Plants	
2	Oxygen concentrators (low and high flow)	
3	Oxygen Cylinders (all sizes)	
4	Liquid Oxygen Tanks (with all included equipment)	
5	Oxygen distribution systems (including oxygen ramps)	

Table1: Prioritized Medical Oxygen Equipment

This specific strategy and roadmap are designed to address the management and maintenance of five distinct types of medical oxygen equipment, as outlined in Table 1. It's important to note that while this document primarily targets these five equipment types, the principles and methodologies discussed herein can be adapted for the management of other medical equipment.

2: ASSET LIFECYCLE MANAGEMENT

In this chapter, we will utilize Figure 1 below to systematically explore medical equipment management within the context of the asset lifecycle management. We will explain the components of asset lifecycle management (ALM) and illustrate how each element correlates with the overall management of medical oxygen equipment.

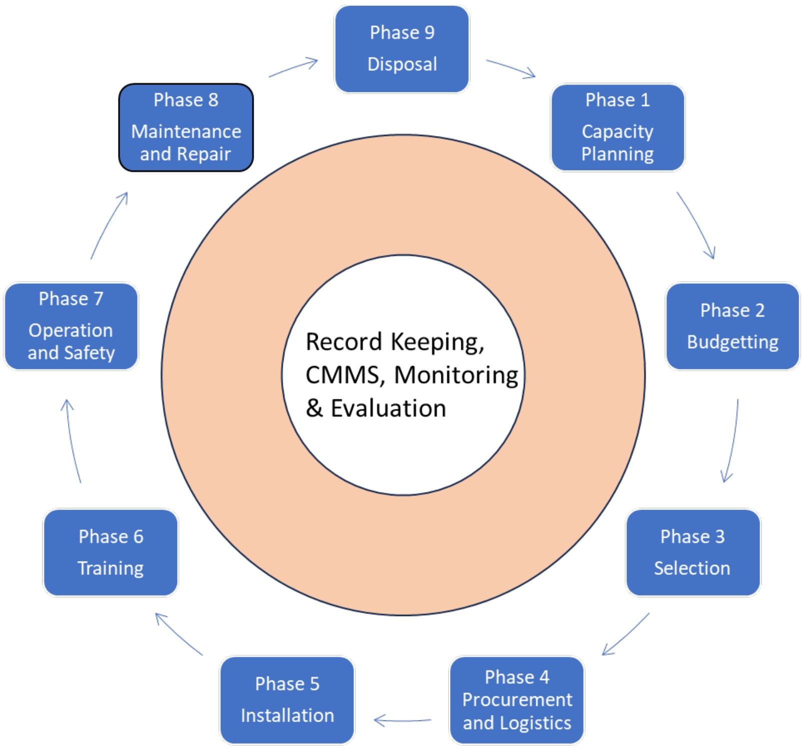


Figure 1. Physical Asset Lifecycle

PHASE 1: CAPACITY PLANNING

Capacity planning for medical oxygen equipment is important, but in Mozambique, there hasn't been a thorough assessment of medical oxygen demand at both facility and country levels. Additionally, essential inventory information for priority oxygen equipment is either incomplete or unavailable, making it difficult to plan for required investments and the necessary maintenance to ensure the safe, effective, and efficient operation of both existing and future equipment. Capacity planning for medical oxygen equipment in Mozambique serves as a fundamental initial step, laying the groundwork for broader improvements in medical equipment management throughout its life cycle. This capacity planning process is about ensuring that Mozambique has the right amount of medical oxygen equipment, strategically located to meet healthcare demands effectively. By doing so, it helps prevent equipment shortages and failures.

Capacity planning

1) The initial phase of capacity planning for medical oxygen equipment, especially when confronted with incomplete inventory data, involves conducting a comprehensive evaluation of the current equipment. Even though an inventory was conducted as part of the National Oxygen Equipment Assessment, this information has already become obsolete, given the influx of additional equipment donations in the past year. This assessment should encompass the following elements:

   - Identifying existing oxygen generation and supply infrastructure, including the number and capacity of oxygen plants, LOX tanks, Internal piping systems and Oxygen ramps. oxygen concentrators, cylinders, and other related equipment.
   - Evaluating the condition and operational status of the existing equipment to determine what can be reused, refurbished, or upgraded.
   - Quantifying the current oxygen production and distribution capacity, including the flow rates and availability of oxygen in healthcare facilities.

2) Conducting a comprehensive needs assessment is crucial as well if one wants to determine what oxygen equipment investments are needed in the future. This assessment should include:

   - Analyzing healthcare data (in case available) to identify common respiratory diseases, the prevalence of COVID-19 or other diseases requiring oxygen therapy, and expected patient numbers.
   - Consultations with healthcare professionals to estimate oxygen demand in different healthcare settings (hospitals, clinics, field hospitals, etc.).
   - Estimating future oxygen demand by considering population growth, disease trends, and healthcare infrastructure expansion.

Various organizations, including WHO, UNICEF, and PATH, offer a range of tools for conducting needs assessments at the bedside, facility, and national levels. You can find links to these instruments in Annex A: Oxygen Quantification Tools.

3) Based on the information gathered through inventory assessment and needs assessment, develop a comprehensive capacity planning plan. This plan should include:

   - Short-term and long-term goals for oxygen supply capacity.
   - Investment priorities, including upgrading existing equipment, procuring new equipment, and expanding infrastructure.
   - Budget estimates and funding sources, including seeking international assistance and grants. These budget estimates should include operational and maintenance costs.
   - Timeline for implementation and monitoring.

4) Execute the capacity planning plan systematically. This includes:

   - Procuring new equipment, repairing or upgrading existing equipment, and expanding oxygen generation capacity.
   - Training healthcare personnel on the proper use and maintenance of oxygen equipment.
   - Monitoring the progress of the plan and adjusting it as needed based on evolving needs and circumstances.
   - Establishing a robust data monitoring and reporting system to track oxygen usage and distribution.

Effective capacity planning paves the way for more substantial enhancements in medical oxygen equipment management. It enables informed decisions regarding equipment quantity and types, efficient resource allocation, and the establishment of a sustainable infrastructure for equipment management. In essence, it's the starting point for creating a resilient and efficient system that ultimately benefits healthcare services in Mozambique.

PHASE 2: BUDGETTING AND FINANCING

The real cost of a PSA or other oxygen equipment is far more than just the initial purchase price. A comprehensive approach to estimate total lifetime costs is to do a lifecycle costing exercise. To estimate Life Cycle Costs or Total Cost of Ownership (TCO) for oxygen equipment is to include the following costs:

- Cost for buying the equipment (as per the capacity planning plan plan), including its price, shipping, taxes, admin costs and setup costs.
- Consultants (technical assistance)
- Cost for maintenance and repairs. Including maintenance contracts.
- Cost for training activities.
- Cost of site improvements like electrical upgrades or facility renovations to support the equipment.
- Cost of spare parts: Include the costs of buying spare parts and essential items like oxygen cylinders and masks.
- Cost of emergency supplies of oxygen and equipment for unexpected situations.
- Operational costs (like electricity, water, rent etc.)
- Cost for the decommissioning of oxygen Equipment

The total life time cost of equipment, such as a PSA, can rapidly escalate, often more than doubling the ex-factory cost price. (Source: GHSC-PSM sustainability plan for the Monapo District Hospital PSA).

To secure the necessary funding for the plan and ensure sustainable, high-quality, and safe oxygen treatment for patients, the MOH should take the following steps:

- Based on the results of the capacity planning exercise the MOH should consider various financing options for the program. These may include government funds, donations, grants, or partnerships.
- Include equipment management funding in the government budget cycle.
- Implement a strong system to monitor spending and ensure funds are used responsibly, possibly including regular financial audits.
- Create a long-term financial plan to keep the oxygen program running in a sustainable manner.
- Advocate for ongoing support from international organizations and others interested in improving healthcare in Mozambique.
- Maintain open communication to keep stakeholders and the public informed about fund allocation and usage for medical oxygen equipment. This ensures reliable and sustainable healthcare services for the Mozambique's population.

PHASE 3: SPECIFICATION AND SELECTION OF THE RIGHT TYPE OF EQUIPMENT

Based on the initial information coming out if the planning stage, budget and financing options, technical specifications and cost comparison a final choice can be made. The selection process of medical oxygen equipment in Mozambique should be carefully aligned with the maintenance system and strategy. Prioritizing equipment that is suitable, simple, well-documented, and aligned with local capacity can significantly enhance the effectiveness and sustainability of the maintenance efforts. Factors which are important to select the right equipment:

Equipment reliability

Reliability of the equipment, supplier reputation and the quality of the after-sale service available play the single most important role in selecting the equipment. There are examples where "cheap" oxygen equipment was bought but due to lack of aftersales services and low-quality manufacturing standards this equipment ends up being discarded soon after commissioning or has constant problems and low operability. Regrettably the operational cost per liter of oxygen produced ends up to be much higher than equipment with higher purchase price with an established aftersales support network.

Standardization possibilities

Concentrating on a narrower selection of oxygen equipment within the Mozambican health system presents an effective strategy to improve efficiency, cut costs, and elevate the quality of healthcare. By concentrating on a smaller range of equipment your technical, procedural, and training skills will increase and your costs and logistical requirements will decrease. You will also have to deal with less maintenance or after sales service providers and it can become more efficient and feasible to have maintenance service level agreements (SLAs). The following practical steps outline how the Mozambican healthcare system can achieve this goal: 1) Use capacity planning information to identify oxygen equipment requirements across various healthcare settings, such as general wards, neonatal care, emergencies, and surgical units. 2) Evaluate the existing inventory of oxygen equipment, taking into account brand, model, and overall condition to gauge the scope for consolidation. 3) Then engage healthcare professionals, biomedical engineers, biomedical technicians and other stakeholders in the decision-making process to make informed equipment selections. 4) Define and agree on a set of technical specifications for all prioritized oxygen equipment[1] 5) Propose a restricted range of oxygen equipment brands and models, emphasizing reliability, spare part availability, and affordability, based on the needs assessment and stakeholder feedback. 6) You do need to regularly review and adapt equipment selections to ensure alignment with evolving healthcare needs and technological advancements.

The right technology

The right level of technology and complexity needs to be considered. You have to ask yourself if will you be able to find and/or train the right operators. Can the equipment be maintained properly with the current level of mechanics in the country? What is the general technology standard for oxygen equipment in the country or region. What are the expected operational costs? It makes it easier to maintain your equipment if the models in use are common enough to have spare parts available and mechanics have experience working on the equipment.

To make sure that equipment will ultimately function as intended site assessments have to be performed. Site assessments at a healthcare facility level are essential before procuring and installing medical oxygen equipment. By thoroughly investigating and assessing a location during the pre-site assessment, healthcare facilities can better prepare for the installation and long-term management (including maintenance) of medical oxygen equipment, ensuring consistent and safe oxygen supply for patients.

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[1] The publication titled "Priority Medical Devices List for COVID-19 Response and Associated Technical Specifications" by the World Health Organization provides comprehensive specifications for oxygen equipment.

- Assess current and future facility oxygen needs by determining the current patient load and oxygen consumption patterns at the healthcare facility. This data informs the capacity planning process by determining the required oxygen output and storage capacity. Capacity planning also considers future growth or changes in patient demographics. It ensures that the medical oxygen equipment chosen can be expanded or upgraded as needed to meet increasing oxygen demand without major disruptions to operations.
- Assess the distance between the installation site and maintenance facilities or workshops where routine maintenance and repairs will be conducted. A closer proximity reduces the time it takes for maintenance technicians to reach the site in case of equipment breakdowns, minimizing downtime and interruptions in oxygen supply.
- Investigate the ease of access for maintenance technicians to reach the installation site. Consider factors such as road conditions, transportation availability, and any logistical challenges that may hinder or delay maintenance visits. Overcoming these barriers ensures timely equipment servicing.
- Determine whether there are skilled technicians or Biomedical Equipment Technicians (BMETs) available locally who possess the necessary expertise to perform maintenance and repairs on the medical oxygen equipment. If local technicians lack the required training, plans for training or capacity building will be needed to ensure ongoing maintenance.
- Check the availability of spare parts and consumables for the equipment within the local area. Having a readily accessible supply of critical spare parts is essential for promptly addressing equipment issues and minimizing downtime.
- Evaluate the existing infrastructure, particularly the electrical supply and its stability. Reliable power is crucial for the operation of medical oxygen concentrators, PSAs, LOX tanks and related equipment. Any deficiencies in infrastructure should be addressed to prevent interruptions in oxygen supply.
- Assess the capacity for storing spare parts, consumables, and oxygen cylinders on-site. Effective inventory management ensures that there are adequate reserves to prevent shortages and that equipment maintenance is carried out efficiently.
- Assess environmental factors that may affect equipment maintenance, such as extreme temperatures, humidity, or exposure to dust and contaminants. Adequate protection measures, such as climate control or dust filtration, may be necessary to maintain equipment reliability. E.g.: Altitude influences the kind of oxygen equipment which can be installed and made operational.
- Assess the security measures at the installation site to prevent theft or tampering with equipment and oxygen cylinders. Additionally, evaluate safety measures to protect both staff and patients from potential hazards associated with oxygen equipment.
- Check if the installation site meets safety and maintenance regulations for medical oxygen equipment, bearing in mind that Mozambique lacks specific regulations, so international standards can serve as a starting point for assessment.
- Verify that proper documentation and record-keeping practices are in place. This includes maintaining detailed maintenance logs, service records, and reports of equipment inspections.
- Assess the availability of reliable communication infrastructure, such as phone or internet connectivity, to facilitate communication between on-site staff and maintenance teams. Effective communication is essential for reporting issues and coordinating responses promptly.

In summary, site assessments at healthcare facilities are necessary before installing medical oxygen equipment because they ensure that the infrastructure is suitable, staff members are trained and sufficient, maintenance plans are in place, and capacity planning aligns with both current and future needs.

PHASE 4: PROCUREMENT AND DONATIONS

Based on our earlier remarks about relative low importance of the initial purchase price versus the importance of Total Cost of Ownership (TCO) it is important not to adjudicate and order oxygen equipment based on lowest price only. Apart from the technical parameters for the equipment the tender documents and the bid comparison process should give importance to the following evaluation criteria:

- Cost of maintenance (contracts).
- Operational costs
- Rationalization/harmonization of the quantity of different brands/models (will lower management costs, maintenance costs, training costs).
- Supplier reputation.

The World Health Organization (WHO) has developed a Model for Quality Assurance (MQAS) for procurement based on "best value" according to the following criteria, which includes, but is not limited to:

- Product availability (lead time)
- Quality of products
- Price of commodities
- Customer service by the supplier and its representatives (ease of doing business)
- Maintenance and service agreements
- Product training
- Supplier performance and supplier (financial and operational)
- Long-term viability
- Compliance with World Health Organization or alternative stringent regulatory authority standards.
- Compliance with national codes of conduct for Suppliers in case available.

It would be beneficial for Mozambique to demand that not only certain pre-established brands and models can enter the country but also that these items need to accompanied with quality training, spare parts and with SLAs when appropriate. The latter to give the MOH the time to include these costs in their budget.

Donations

The WHO states that the majority of medical equipment in LMICs is imported, mostly funded by international donors or foreign governments. Donating medical equipment can be costly and may not significantly improve health outcomes. Only a small portion, estimated at 10-30%, of donated equipment becomes functional.

This highlights the complexity of receiving medical oxygen equipment donations, which require careful consideration. While these donations aim to enhance healthcare infrastructure, they can also pose challenges and potential downsides. Guidance on the procurement of new medical devices is crucial to ensure that technical specifications align with the medical equipment management plan and more specifically the maintenance strategy, thus promoting harmonization in equipment purchases. This involves providing expertise to make informed decisions during the acquisition process, verifying that the selected devices are compatible with the maintenance and support infrastructure, and streamlining procurement practices to meet the needs of healthcare facilities effectively. Additionally, assistance in developing comprehensive protocols for the acceptance and management of donated medical devices is equally vital. These protocols should encompass detailed guidelines on the evaluation, acceptance criteria, maintenance procedures, and integration of donated equipment into the existing healthcare system. By establishing these protocols, Mozambique can effectively harness donated resources while maintaining consistency with the broader medical equipment management strategy.

Here are some reasons to approach medical oxygen equipment donations thoughtfully:

1) Infrastructure and maintenance challenges:

- Limited infrastructure: Mozambique, similar to many low-resource nations, might not have the needed infrastructure for complex medical oxygen systems. This means they may lack reliable electricity, oxygen pipelines, and trained personnel for equipment maintenance. A thorough site assessment should typically reveal these shortcomings.
- Maintenance Challenges: Donated equipment like procured equipment demands continuous maintenance, calibration, and occasional part replacements. Without enough resources and expertise for upkeep, the equipment may stop working, resulting in wasted resources.
- Non-compliance of donated equipment with local standards.

2) Resource allocation:

- Mismatch with priorities: Donations can sometimes lead to a misalignment with a country's healthcare priorities. While medical oxygen equipment is important, other pressing healthcare needs, such as vaccines, essential medications, and primary care infrastructure, may take precedence.
- Operating costs: Donated equipment often incurs operational costs, such as electricity and consumables. These costs can strain already limited healthcare budget, diverting resources from other critical healthcare services.

3) Sustainability:

- Dependency on donors: Relying heavily on donations for essential medical equipment can create long-term dependency on external aid, making the healthcare system vulnerable to disruptions if donations decline or cease.
- Sustainability Planning: A sustainable approach involves capacity-building efforts, including training local healthcare professionals, establishing maintenance protocols, and developing sustainable funding mechanisms to support ongoing operations and maintenance.
- Non-compliance with national medical equipment investment and equipment harmonization plan: This can cause a range of issues, including inefficiencies, increased costs, maintenance challenges, reduced interoperability, and inconsistent quality of care, ultimately impacting the effectiveness and quality of healthcare services. Often this type equipment is quickly abandoned due to lack of aftersales service, spare parts or qualified staff to operate the equipment.

4) Regulatory and Quality Assurance:

- Quality and Standards: Donated equipment should meet international quality and safety standards to ensure that it functions reliably and safely. Low-quality or substandard equipment can pose risks to patient care.
- Regulatory Compliance: Compliance with local regulatory requirements and importation procedures must be considered to avoid delays or complications in getting the equipment into the country.

In conclusion, while medical oxygen equipment donations can be a valuable contribution to improving healthcare in Mozambique but they need to be carefully considered and part of a broader strategy for strengthening the healthcare system. This involves addressing infrastructure challenges, ensuring sustainability, align with the Mozambican priorities and needs, and maintaining a focus on quality and local regulatory compliance. Collaborative efforts with donors and other stakeholders are crucial to ensure that donations have a positive and lasting impact on healthcare delivery in Mozambique and do not become a burden instead.

When procuring or receiving donated medical equipment there are many things to consider to ensure the equipment is utilized to its full potential. Both donors and recipients need to ask questions to ensure the proper items are sent.

Key Considerations for Donors	**Key Questions**
Selection/Procurement	Does the equipment comply with local or regional standards. Is there local capacity to maintain the equipment (private or otherwise)? Does the equipment capacity match current and future needs of the facility? Does the equipment fit within the national standardization policy?
Installation	Is the facility ready for this equipment? Do they have the infrastructure to support this equipment? Electricity? Internet? Who will install the equipment?
Training	Who will train the clinical staff? Who will train staff on maintenance and repair? How will the facility find spare parts and get equipment repaired?
Ongoing operational costs for the facility	What will it cost the facility to keep this equipment operational? What disposables does this equipment need? How will we find these disposables? What will the ongoing costs be to the facility? When software is involved- What licenses are needed to operate the equipment? Who “owns” these licenses? At what cost and for how long?

Table 2: Key considerations for donated oxygen equipment (Source: WHO)

PHASE 5: INSTALLATION

The installation of medical oxygen equipment at a site presents a multifaceted challenge that involves various departments, entities, and organizations. Notable actors include the Ministry of Health (MOH), DIEH, donors, implementing partners (both at headquarters and field offices), the procurement department, building contractors, external testing companies, equipment suppliers, receiving health facilities, hospital staff, and transporters. Effective coordination mechanisms among these diverse actors and stakeholders are vital to ensure alignment and complementarity of activities. Moreover, certain factors influencing the project timeline are beyond the control of project management, including unpredictable events like severe weather disruptions, civil unrest, strikes, and variability in ocean shipping times, which can introduce delays and complicate the installation process.

Recommended actions for installation of medical oxygen equipment.

- Create a project team and clearly assign roles and responsibilities and maintain frequent communication to all parties involved.
- Ensure the necessary infrastructure is in place, including reliable power sources, oxygen delivery pipelines, and storage facilities. As an example of an infrastructure checklist see Annex C.
- Compile and create a set of official commissioning documents that outline the proper installation and operation of the equipment. This includes equipment manuals, steps for installation, commissioning and acceptance forms. This official step is essential for a successful handover and future use of the equipment.
- Add the newly installed equipment to the facility's inventory system to track its use, maintenance, and replacement needs.
- Provide comprehensive training to the healthcare staff who will be using the specific equipment. This ensures safe and effective operation.
- It's a good practice to conduct a check-up or evaluation six months post-installation to confirm that clinical and non-clinical staff are correctly using and maintaining the equipment. This visit should also incorporate refresher training.

Figure 2. Handover and installation of oxygen concentrators in Nampula province. (Pictures: Jan de Jong)

PHASE 5: HUMAN RESOURCES, TRAINING AND SKILL DEVELOPMENT

In Mozambique, problems like inconsistent energy and water supply, limited distribution and infrastructure, the unavailability of spare parts and necessary supplies, financial constraints, and high costs significantly affect the usability and operation of medical (oxygen) equipment. Additionally, a major cause for equipment downtime is the shortage of skilled and trained (BMET) professionals responsible for managing and repairing medical equipment.

Human Resources:

In 2016, Specialized Biomedical engineering professionals were active in 129 of the 194 WHO Member States. Based on the same data, it's evident that Mozambique was one of the countries without a single biomedical/clinical engineer. The DIEH employees at the central and provincial level do possess engineering degrees, but they come from various engineering backgrounds, such as structural or electrical engineering and are not specialized in Biomedical Engineering. Although there is a good reason for the DIEH to have non-Biomedical Engineers as the unit is for example also responsible for management and maintenance of the general hospital infrastructure and buildings it is also desirable and important to have Biomedical Engineers as they play a crucial role in healthcare institutions. E.g.: They assist in identifying technology needs and planning options, selecting suitable technologies, managing equipment installation, maintaining assets over time, integrating devices with IT systems and medical records, and managing the replacement of devices, when necessary, whether due to obsolescence or the availability of better and cost-effective alternatives.

Human Resources at the health facilities

At tertiary/quaternary level health facilities in Mozambique, there is typically a maintenance department with a team of up to 10 to 20 general technicians, including electricians, plumbers, and carpenters. There's a separate department dedicated to repairing biomedical equipment, which usually consists of 3 to 4 biomedical technicians, although their troubleshooting and repair skills are limited. In secondary-level facilities, there is usually one technician available for general repairs on-site. At primary-level facilities, a full-time technician is not usually present on-site. Because of funding limitations travel of technicians is not regularly done and some sites did not receive a visit of technician for years. Even with a site visit the impact on the state of the equipment is limited due to lack of proper tools and lack of availability of spare parts (source: National Medical Oxygen Assessment).

The same National Oxygen Assessment reveals that health facilities in Mozambique lack personnel trained in oxygen management and generally lack staff with formal medical gas training, including safe use, management, and handling of oxygen equipment. At the time of the Assessment only three technicians in the country received a training during the installation of a specific PSA unit installed at the Quelimane General Hospital, but there was no written evidence or certificates to verify their training. Knowledge and skills are primarily passed from more experienced colleagues to their less experienced peers, with experienced individuals sharing practical knowledge with others. Although training and skill development of the DIEH is just one piece of the medical equipment puzzle it is critical that attention, time and funds need to be directed to the area.

Training and skill development:

In a broad sense, learning can be divided into two categories: education and training. Education is primarily focused on gaining knowledge, while training emphasizes acquiring practical skills. When we apply these types of learning to the field of biomedical professions and educational institutions, education typically pertains to universities that produce biomedical engineers, while vocational training institutes are responsible for training biomedical engineering technicians and technologists.

Training involves two primary stages: pre-service training, which individuals typically complete before entering the workforce on a full-time basis, and in-service training, which can be attained through short-term courses or part-time programs. Pre-service training is often offered by vocational training institutes, while in-service training can be provided by commercial companies, professional associations, NGOs, or other relevant organizations.

With the recent increase in investments related to COVID-19, the main contributors have been partners working with the Ministry of Health (MOH) and DNAM/DIEH. Particularly in the domain of oxygen treatment training, these partners have played an important role in providing specialized training on specific oxygen equipment. They've developed and conducted various training modules for the use and maintenance of concentrators, addressing both clinical and non-clinical audiences. Additionally, PSA training sessions for users and senior technical staff have been organized at central and provincial levels. While valuable, it's worth noting that this training is currently reaching a limited number of technicians and users in occasional settings and is not systematically part of any national curriculum. In an environment with frequent staff turnover, this may not be sufficient to establish and maintain the desired level of capacity and skills.

Skills Gap Analysis and Training Plan

Developing a skills gap analysis and training plan for the maintenance unit (DIEH) within the Ministry of Health (MOH) in Mozambique is important for several reasons. It helps make sure that medical (oxygen) equipment works well by identifying where the maintenance unit might need more skills and knowledge. Plus, it helps the MOH meet the growing need for healthcare, especially during times like the COVID-19 pandemic. Creating a focused training plan based on this analysis ensures that resources are used wisely to fill these skill gaps, making the workforce more capable. This also allows you to track and measure improvements in employee skills and competencies over time.

1. Establish a mutual understanding of the core business processes and tasks within the DIEH organization. This **could** lead to a potential redesign of these processes and the proposal of a new organizational structure.
2. Establish selection criteria for each position in the new organogram:
    - Create job profiles and job descriptions for all DIEH positions.
    - Utilize occupational standard criteria for biomedical staff
3. Develop a skill and competency profile:
    - Gather general information by reviewing resumes of current staff.
    - Request employees to complete a self-evaluation questionnaire, emphasizing their experience in various tasks within the realm of the DIEH department.
    - Conduct face-to-face interviews with each candidate. The resume and self-evaluation questionnaire results will provide guidance in evaluating competence areas.
    - Ask candidates to complete brief assessments, including tests related to logical thinking, technical knowledge, etc.
4. Conduct a job match analysis to align the profiles of staff members with the job profiles for positions in the organogram.
5. Identify gaps by comparing the current skills with the skills needed for each job role. This will help pinpoint areas where employees lack essential skills.
6. Prioritize the identified skill gaps based on their impact on the organization's goals. Some gaps may be more critical than others. Evaluate trainability of each staff within a specified timeframe.
7. Create a training plan:
    - Define specific training objectives that address the prioritized skill gaps.
    - Create training programs tailored to address the identified gaps. These programs can include workshops, courses, online learning, and on-the-job training.
    - Determine the resources required for the training plan, including budgets, trainers, materials, and facilities.
8. Carry out the training programs as planned.
    - Monitor progress and collect feedback from participants.
    - Evaluate the effectiveness of the training programs. Collect feedback from employees and assess whether the skill gaps have been reduced. If necessary, make adjustments to the training plan.

A thorough Skills Gap Analysis is important because it reveals where employees may be lacking in skills and where training can make the most difference. Creating a focused training plan based on this analysis ensures that resources are used wisely to fill these skill gaps, making the workforce more capable. This also allows us to track and measure improvements in employee skills and competencies over time.

Before creating a training plan, it's vital to figure out what training would be most useful for Mozambique. Since the country has limited resources, making the best use of them is essential. Mozambique also needs to act quickly to handle the influx of a large amount of oxygen equipment. To avoid breakage of this equipment in the coming few years, an innovative and cost-effective approach is needed.

The traditional approach would be to train Biomedical Equipment Technicians (BMETs) and Biomedical Engineers, which is necessary and valuable but not the quickest solution to the current medical equipment management and maintenance problems in Mozambique. Although Biomedical engineers are essential for using medical technology effectively to reach universal health coverage and sustainable development goals, the downside of concentrating solely on high level technicians is the lengthy training period. Normally it would take 2-7 years to finish the curriculum and even more time gain valuable work experience. In the case of Mozambique this training would need to be done outside the country as no Bio Medical Engineering degree is offered in the country. This would also increase the risk of graduated students not returning and continuing their career outside the country. Considering this it would make sense to find alternative solutions for the lack of adequately trained oxygen equipment technicians for the short and medium term.

An opportunity exists for the medium-term horizon: several studies (source: Malkin) have revealed that equipment maintenance and repair problems can be simplified as one-third of these issues result from operator errors, another third are minor technical problems like a blown bulb, fuse, or lose power cord that trained operators can easily handle. Advanced troubleshooting skills and specialized equipment knowledge are only needed for the remaining one-third of problems. Consequently, training equipment users properly can resolve at least two-thirds of the issues. In places like Mozambique, teaching staff to perform daily equipment checks and minor repairs can save costs by avoiding expensive service provider interventions, such as traveling to remote areas, and can also speed up response times. This evidence highlights that a typical BMET curriculum designed for well-funded settings is unnecessary for most repairs in resource-constrained environments.

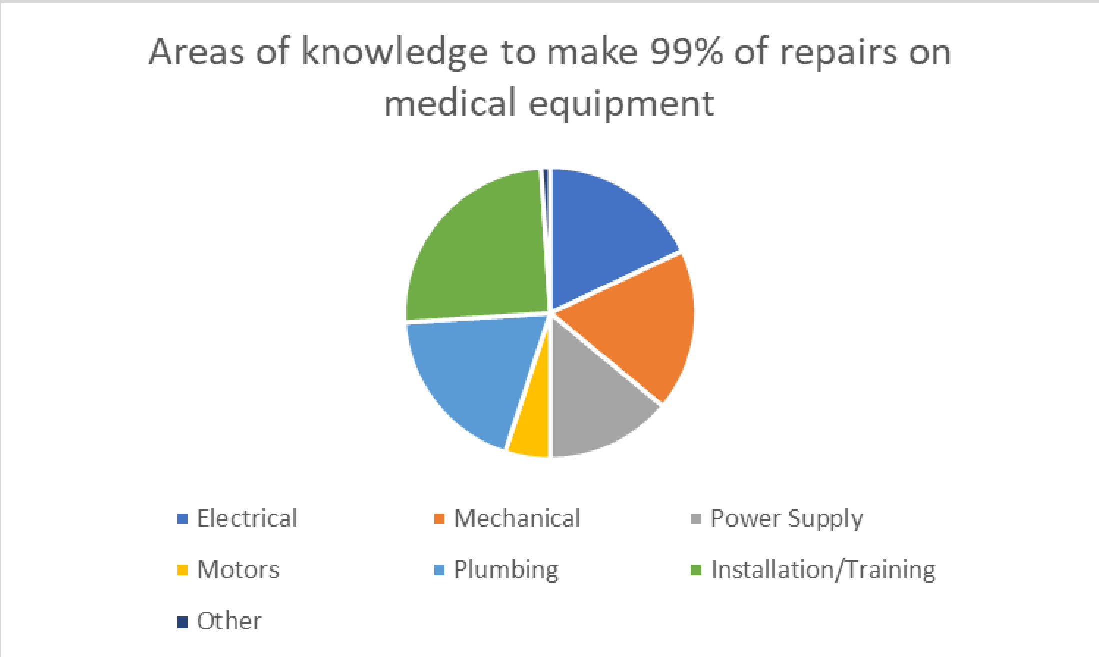

Figure 3. Areas of knowledge to make 99% of repairs on medical oxygen equipment. (Source: Robert Malkin and Allisson Keane)

In Mozambique individuals with a basic secondary school education can make a significant contribution if they acquire a few essential skills, tools, some financial support, and access to experts online. To tackle the challenges of lengthy post-secondary education and the tendency for graduates to leave the public health sector in such areas, an alternative could be to train people to become something equivalent to "Biomedical Technician Assistants" (BTAs). BTAs would receive something similar as six months of part-time on-the-job training and several weeks of basic classroom instruction. Afterward, they should be able gain 1-2 years of practical experience with expert support and international certification.

Compared to traditional programs like Biomedical Engineering (BME) or Biomedical Equipment Technician (BMET), BTAs would undergo less classroom training, reducing costs and entry requirements. The students would only need a secondary education, and most of their training would happen while they work, minimizing income loss during their studies. BTAs are also more likely to remain in their healthcare jobs because their knowledge is more specific to certain equipment and the local environment.

Figure 4. Equipment specific training of clinical and maintenance staff in the preventive maintenance of concentrators (Photo: Jan de Jong)

An alternative, concurrent approach with a short-term planning horizon involves training both clinical and technical staff in generic and equipment-specific terms, focusing on the existing oxygen equipment within the country. This approach has been implemented, particularly for oxygen concentrators and PSA installations at hospital or health center sites. However, this process is often time-consuming and expensive, given that many health centers are located in remote areas, resulting in complex logistics for both personnel and equipment transportation. Typically, only one or two health centers can be visited in a single day (source: GHSC-PSM). Furthermore, a group of central and provincial-level DIEH technicians received training in the general operation and maintenance of concentrators and PSAs, with the intention that these technicians would provide On-the-Job Training (OJT) for provincial maintenance staff upon their return to the province. Although this training is beneficial, it addresses only a fraction of the broader need. The majority of oxygen equipment which entered the country was distributed to end-user locations without substantial additional support or training, with the expectation that the staff already possessed limited knowledge of equipment operation and maintenance.

A noteworthy recent more economical development is the introduction of training opportunities on the Mozambican Telesaude portal, managed by the Ministry of Health (MOH), which provides various training modules. This technology offers a cost-effective way to deliver quality competency-based training to technicians and clinicians across the country. Currently, three training modules related to the use and maintenance management of oxygen equipment are accessible through this platform. Although it presents a promising alternative to traditional in-class training, the portal is not widely known yet within the MOH labor force and could benefit from someone championing its training options within the country. As more training modules become available in the future, it's likely to gain popularity and can become a well-established educational resource.

Though advancements have been made in various areas, it is evident that to address the current situation and close the knowledge and skills gap, a comprehensive training plan or strategy is necessary. This document should outline short to long-term strategies for improving capacity and skills in medical oxygen equipment management.

Figure 5. Interactive oxygen concentrator course on the Telesaude platform

PHASE 7: HEALTH & SAFETY

Maintaining medical oxygen equipment is closely tied to health and safety. Adequate maintenance is vital for a dependable and secure oxygen supply. Take electrical safety, for instance: Unsafe electrical currents can pose risks to patients, medical staff, and maintenance workers. To prevent such hazards, it is essential to routinely check electrical safety during equipment inspections, regular maintenance, and after any repairs.

Figure 6. Examples of unsafe electrical connections (photos: Marcello Passarana)

Currently, there is no existing Health and Safety plan or protocol in place. Therefore, it is essential for the DNAM/DIEH to establish a health and safety plan as part of the upcoming medical equipment and maintenance management plan. This plan should prioritize the well-being of maintenance technicians, clinicians responsible for using and maintaining medical oxygen equipment, and the patients they serve. Key areas of focus within this plan include:

- Ensure that all technicians and clinicians receive comprehensive training on the safe use and maintenance of medical oxygen equipment. This should cover handling, troubleshooting, and emergency procedures.
- Provide essential PPE such as gloves, masks, and safety glasses to protect technicians and clinicians from potential hazards when working with oxygen equipment.
- Regularly inspect and test all oxygen equipment to identify and address any safety issues or malfunctions promptly. Prioritize routine safety checks and preventive maintenance.
- Develop clear and practiced emergency response protocols for oxygen-related incidents, including leaks, fires, or equipment failures. Ensure that all staff know how to respond safely and effectively.
- Ensure that areas where oxygen equipment is used and stored are well-ventilated to prevent the buildup of oxygen-enriched atmospheres, which can pose a fire risk.
- Clearly label oxygen equipment and storage areas with standardized signs and symbols to reduce the risk of mishandling or confusion.
- Safely store oxygen cylinders and equipment in a designated, secure area to prevent unauthorized access and minimize the risk of theft or tampering.
- Implement proper lifting techniques and provide equipment (e.g., carts or lifts) to assist in moving heavy oxygen cylinders to reduce the risk of injuries.
- Ensure that electrical connections and equipment associated with oxygen concentrators or delivery systems are safely installed and regularly inspected to prevent electrical hazards.
- Implement infection control measures, including regular cleaning and disinfection of equipment to prevent the spread of infections.
- Maintain accurate records of equipment maintenance, safety inspections, and staff training. This documentation helps track equipment history and compliance with safety protocols.
- Establish a system for ongoing supervision and reporting, where technicians and clinicians can report safety concerns or incidents promptly.
- Allocate resources for safety measures, including staff training, PPE, equipment maintenance, and infrastructure improvements as needed.

A safety plan for medical oxygen equipment safeguards the well-being of maintenance technicians, clinicians, and patients, ensuring the secure and efficient use of this vital equipment.

PHASE 8: MAINTENANCE AND REPAIR

Medical devices play a pivotal role in directly impacting people's lives. They represent significant investments and are frequently associated with substantial maintenance costs. Consequently, implementing a medical (oxygen) equipment maintenance program is critical for any healthcare facility or health system, regardless of size. The complexity of the program may vary based on factors such as facility size, type, location, and resources required. However, the principles of a good maintenance program remain the same, whether in an urban area of a high-income country or in a rural area of a low- to middle-income country.

To be effective, a maintenance program must have the full support of the MOH and the DIEH management. High level management must be convinced that an orderly system of inspection, tune-up and equipment overhaul is necessary. A maintenance culture needs to be created and responsibilities clearly defined.

Maintenance responsibilities undertaken by the DIEH include:

- Plan all maintenance and repair work.
- Monitor and control the work of external maintenance contractors.
- Budget and allocation of sufficient funds for all maintenance/repair costs.
- Organize timely payment of maintenance providers. Without the service will flounder.
- Project future equipment needs.
- Ensure technical participation at management level.
- Hire suitably skilled maintenance staff.
- Facilitate in-service training to improve the skills required for equipment.
- Ensure that staff performance, with regards to good and bad practice when maintaining and using equipment is monitored.
- Identify training resources and train staff according to a training plan.

User maintenance responsibilities include:

- Perform their jobs to the best of their ability, according to their job descriptions.
- Take good care of equipment.
- Operate equipment properly and safely.
- Undertake user-initiated PM (care and cleaning of equipment, daily checklist)
- Report faults promptly to their supervisors.
- Educate and supervise new users.

In a country like Mozambique with limited resources it's crucial to create and plan for a maintenance program and create sustainable methods to make the most of medical equipment. This means focusing on equipment maintenance and repair of priority equipment, training local technicians to identify and fix problems, and ensuring a dependable supply chain for replacement parts.

Planning a maintenance program is part of a broader effort to establish a comprehensive program for healthcare technology management (HTM). This planning process includes a review of critical factors, as shown in Figure 7. The challenge for planners is to balance these factors to design a maintenance program that will be appropriate and cost effective for the Mozambican situation.

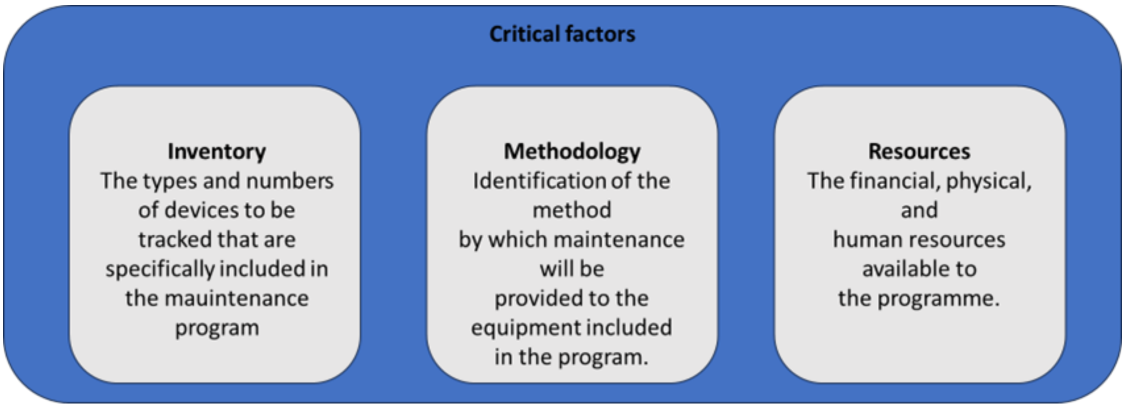

Figure 7. Critical factors in planning a maintenance program (Source: WHO)

Inventory

Early in the process of planning a maintenance program, it is essential to determine the types of devices that need to be included in the inventory and in the maintenance program. studies have shown that not all equipment needs to be tracked in an inventory, inspected or maintained, and very few hospitals or health-care organizations have the manpower to accomplish this level of effort. The DIEH (with the assistance of the health facilities) is responsible for developing and maintaining the inventory. They are responsible for routinely checking that all the included equipment is being tracked within a healthcare facility is in the inventory and that all the equipment listed in the inventory can be located.

Resources

Resources needed for maintenance activities are difficult to project. To project the resources needed for a maintenance program you will need information on the inventory, maintenance history, calculations of the staff requirements for each type of maintenance activity and knowledge of the appropriate staff skills, education and experience. Outside vendors are necessary for the maintenance of complex equipment. With limited historical data available (as is the case for Mozambique) this task becomes even more difficult.

Financial Resources:

The initial step in cost calculation involves determining the necessary physical and personnel resources. This determination is influenced by factors such as the quantity and categories of medical equipment in inventory, along with the chosen level and methodology of maintenance. The future quantity of equipment will be contingent on the results of supply gap analyses and the corresponding long-term equipment investment plan. While estimating the costs of corrective maintenance may pose an initial challenge, these estimates tend to refine themselves over time with accumulated experience. Regarding service contract expenditures, these can be established through negotiations with external service providers, and there is also historical data available, such as SLAs for USAID-donated PSAs installed in Monapo and Mocuba.
The cost-of-service ratio serves as an important metric to evaluate the financial efficiency of a maintenance program. It is calculated by dividing the annual expenses associated with running a medical equipment maintenance plan by the initial value of the medical equipment in stock. In the developed countries, this ratio generally falls between 5% to 10%. It's worth mentioning that this metric may be significantly higher in developing countries, and it can be a helpful guideline for planning (Source: WHO).

	Initial Costs	**Operational Costs**
Physical Resources	Tools, Test Equipment, Infrastructure, Transport capacity	Utilities, calibration, fuel and vehicle maintenance, building maintenance
Human Resources	Recruitment and Initial Training	Salaries, benefits, education
Maintenance	Not Applicable	Service contracts, parts, travel, shipping.

Table 3: Financial resources required for a maintenance program (source: WHO)

Physical Resources:

A maintenance program relies on a number of physical resources. These include the workspace, tools and test equipment, supplies, replacement parts, and operation and service manuals needed to perform maintenance. The location of the workshops should be considered when developing the program. Some equipment can be moved and transported to a workshop

(E.g.: concentrators) while other equipment cannot (PSA plants). The life of tools can exceed 10 years when properly taking care off but test equipment typically needs to be replaced every seven (7) years (Source: WHO). For a list of basic tools and test equipment please see Annex E.

<u>Supplies:</u>

A quick evaluation of the primary DIEH spare parts warehouse situated at Mavalane Hospital revealed deficiencies in the system for providing replacement parts in several key areas:

- Lack of an inventory management system.
- Outdated infrastructure, including the warehouse building and storage systems.
- A significant portion (majority) of spare parts is obsolete and no longer required.
- Ad hoc procurement lacks forecasting, supply planning and budgeting.
- Limited availability of spare parts for current equipment.
- The current system for sending parts to the repair location is ad hoc and inefficient.

Figure 8. Obsolete electronic parts in the main spare part warehouse in the Mavalane General Hospital. (Picture: Jan de Jong)

Before fully committing to enhancing and developing the internal supply chain for spare parts, it's essential to define the functions this supply chain is expected to perform and decide on the extent to which maintenance and repair should be outsourced. Key decisions include identifying the clients the supply chain will serve, determining the products it will encompass, and specifying the service level it will deliver. This consideration is crucial as the creation and implementation of n spare parts supply improvement plan can be both costly and resource-intensive. It might be more advantageous for the Ministry of Health (MOH) to explore outsourcing options for the inventory management and distribution of spare parts and concentrate on its core business.

If the MOH opts to retain (part of) the internal function of the spare parts supply chain, it is essential to formulate and execute a project plan. The plan would encompass the following phases:

Phase 1: Assessment and Planning

- Assess current inventory: Conduct a comprehensive audit of all existing spare parts to identify obsolete items, prioritize essential parts, and assess their condition and shelf life.
- Inventory management system: Select and implement an inventory management system to track stock levels, expiration dates, and reorder points (see below more on this in the CMMS part of this document).
- Infrastructure upgrade: Evaluate and upgrade the current warehouse building and storage systems or construct a new premises to ensure efficient storage, organization, and easy access to spare parts. This may involve repairs, shelving installation, and safety improvements.

Phase 2: Spare Part Optimization

- Obsolescence mitigation: Develop a strategy for dealing with obsolete parts, including disposal.
- Demand forecasting and supply planning: Introduce demand forecasting and supply planning processes to ensure that spare parts are procured based on actual needs.

Phase 3: Inventory Replenishment and Distribution

- Procurement improvement: Establish formal procurement procedures, including supplier evaluation, pricing negotiation, contracts and quality assurance to ensure the availability of quality spare parts.
- Inventory replenishment: Regularly monitor inventory levels and reorder spare parts to maintain optimal stock levels.
- Distribution efficiency: Develop a structured distribution system, including efficient picking and packing processes, transportation scheduling, and route optimization to minimize delays and ensure timely part delivery.

Phase 4: Capacity Building and Training

- Training programs: Conduct training for warehouse personnel, supply chain staff, and procurement teams on the new inventory management system, demand forecasting, supply planning, and budget management.

Phase 5: Monitoring and Continuous Improvement

- Key Performance Indicators (KPIs): Define and monitor KPIs such as inventory turnover rate, stockout rate, lead time, and order fulfil rate to evaluate the effectiveness of the new system.
- Regular stock takes: Schedule regular stock takes to assess the accuracy of inventory data and identify areas for improvement.

Phase 6: Sustainability and Scalability

- Scalability: Evaluate the potential to scale this system to cover a broader range of medical equipment.
- Sustainability: Develop a sustainability plan that includes continued maintenance of infrastructure, system updates, and staff training to ensure long-term success.

Phase 7: Reporting and Documentation

- Reporting mechanism: Develop a reporting system to document the performance and impact of the new spare part warehouse, inventory system, and distribution channel.

This implementation plan will address the identified issues and work towards establishing an efficient and sustainable spare part supply chain for medical equipment in Mozambique taking into consideration the possibility of outsourcing part of the activity.

Figure 9. New PSA plant installed in the Nampula Central Hospital. (Picture: Marcello Passarana)

Maintenance planning:

Maintenance planning is also part of the life cycle of physical assets and part of a broader effort to establish a comprehensive Healthcare Technology Management (HTM) program. It is important to understand that while maintenance is a major influencing factor in optimizing costs and maximizing the utilization and economic life of equipment such as a PSA plant, there are other influencing factors that contribute and are important to consider. For example: If the operators are not well trained and do not practice responsible (safe) behavior, even the best equipment with a state-of-the-art maintenance program will fail and shut down more often than desirable and necessary.

Medical equipment maintenance can be categorized into two primary types: preventive maintenance (PM) and corrective maintenance (CM). Preventive maintenance (PM) involves scheduled activities aimed at ensuring equipment functions properly and preventing breakdowns. It includes performance and safety checks to confirm the equipment's safe and efficient operation. Preventive maintenance includes tasks like calibration, part replacement, lubrication, and cleaning. These tasks can range from simple functionality checks (performance assurance) to more extensive procedures, sometimes requiring the replacement of components like O-rings, batteries, filters, and various sensors. PM is a crucial function of the DIEH.

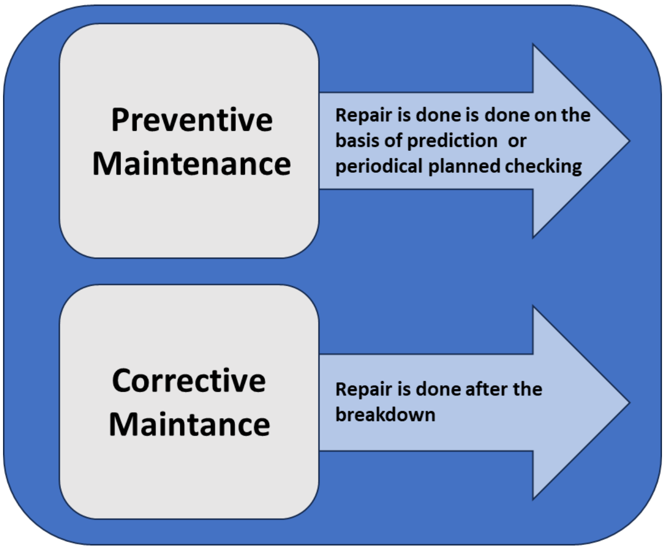

Figure 10. Main types of maintenance

Benefits of Preventive Maintenance

Preventive maintenance provides the following benefits:

- Increased safety.
- Increased uptime.
- Reduced total maintenance/repair costs by reducing repairs
- Maximized useful life of equipment.

Corrective maintenance or repair for medical oxygen equipment refers to the process of addressing and resolving issues or malfunctions in the equipment after they have occurred. It involves diagnosing the problem, performing necessary repairs, and restoring the equipment to its optimal functioning state. While it is challenging to completely avoid the need for corrective maintenance, the frequency and severity of such interventions can be significantly reduced through the implementation of a preventive maintenance program.

There are three possible ways to organize a maintenance program:

- All maintenance work can be done in-house. This typically requires a large capital investment in some workshop, diagnostic equipment, tools, parts, inventory, and personnel.
- Preventive maintenance and minor repairs can be handled in house while major repairs are sent out. This results in smaller but still substantial investments for equipment, tools, parts, and personnel.
- (Part of the) maintenance including preventive maintenance can be outsourced to a third party. Someone within the organization should be managing the program and supervising the service provider to make sure that the maintenance and repairs are done with quality and according to the schedule.

Maintenance service level agreements (SLAs) for medical oxygen equipment can vary based on the specific needs and requirements of healthcare facilities. It depends also on the perceived risks involved for the service provider. In the case of Mozambique this is seen as high. There are various types of maintenance service level agreements (SLAs) for medical oxygen equipment. The choice of SLA depends on facility needs, budget, and equipment criticality, requiring careful consideration and qualified providers for equipment safety and reliability.

The decision between in-house maintenance and outsourcing to Third-Party Logistics (3PL) maintenance providers for medical oxygen equipment should be based on a thorough analysis of various strategic considerations:

- Expertise and skills: Consider the complexity of the medical equipment. In-house maintenance requires building and retaining a skilled workforce, while 3PL providers often have specialists with expertise in a wide range of equipment.
- Capacity for oversight: Do you have the capacity and skills to monitor and supervise the 3PL provider in the execution of the maintenance program?
- Cost analysis: Calculate the total cost of ownership. In-house maintenance might involve higher upfront costs for staffing, training, and equipment, while 3PL providers can provide cost-effective solutions.
- Scalability: Think about your facility's potential for growth. In-house maintenance can be scaled up, but it may involve additional investment, whereas 3PL providers can adjust services to your evolving needs.
- Downtime tolerance: Consider the criticality of the equipment. For equipment that must have minimal downtime (e.g., life support systems like oxygen equipment), 3PL providers often offer quicker response times.

- Regulatory compliance: Ensure that both in-house and 3PL providers adhere to the relevant industry regulations and standards. 3PL providers often have specialized knowledge in this area.
- Risk management: Evaluate the risks involved in each option. 3PL providers can share some operational risks, while in-house maintenance puts the onus on your facility.
- Performance metrics: Determine the key performance indicators you want to track. 3PL providers often have established reporting systems that can provide valuable insights into maintenance effectiveness.
- Equipment lifecycle: Consider the age and condition of your equipment. Older equipment may require more frequent maintenance and in-house expertise.
- Spare parts availability: Check the availability of spare parts for your equipment. 3PL providers may have established supplier relationships and access to spare parts.
- Focus on core operations: If maintenance is not a core competency, outsourcing to 3PL providers can free up your staff to concentrate on patient care.
- Emergency response: Assess the provider's ability to respond to emergencies, which can be crucial for critical medical equipment. 3PL providers often have established protocols.
- Legal and contractual Aspects: Be thorough in creating clear and legally binding contracts for 3PL providers to ensure your interests are protected.
- Service quality: Consider the reputation and track record of 3PL providers in terms of service quality and client satisfaction.

The MOH must weigh these strategic considerations to make an informed decision that aligns with its specific needs, resources, and long-term objectives. In the case of medical oxygen equipment in the Mozambican Public Health system a mix of in-house and 3PL maintenance would be probably be appropriate. Whereas the DIEH would concentrate on preventive maintenance and small repair of some equipment (e.g.: oxygen concentrators) and use 3PLs to perform PM and CM on more complex equipment like PSA's. For a more in-depth overview of the suggested approach to organizing maintenance for each of the five (5) priority oxygen equipment, refer to Annex J.

PHASE 9: CONDEMNATION & DISPOSAL OF OXYGEN EQUIPMENT

When looking at the lifespan of equipment, factors such as technology type, component quality, usage patterns, operating time, environmental conditions, age, and past maintenance practices all play a role. In Mozambique, it's crucial to think about the end-of-life or condemnation of medical oxygen equipment for responsible healthcare management. Including effective disposal management in the long-term investment plan is important. However, there's a common issue in Mozambique with improper equipment disposal, resulting in equipment accumulation at healthcare facilities. The disposal process, particularly for donated equipment, is challenging and inefficient, adding to the complexities.


Figure 11. Example of an equipment graveyard in a Health Facility

The following are a few key condemnation/disposal considerations:

Phase 1: Equipment Assessment and Evaluation:

- Regular inspections: Establish a regular schedule for inspecting and assessing the condition of medical oxygen equipment. This should include both visual checks and functional testing.
- End-of-Life criteria: Define specific criteria for determining when equipment should be considered at the end of its useful life. This could be based on factors like performance degradation, safety concerns, and repair costs.

Phase 2: Environmental Impact:

- Safe disposal: Ensure that condemned equipment is disposed of safely and in an environmentally responsible manner. Hazardous materials, if present, should be handled and disposed of in accordance with local regulations.

Phase 3: Financial Planning:

- Budgeting for replacement: Develop a financial plan that allocates funds for the replacement of condemned/obsolete equipment. This planning should consider the expected lifespan of equipment and ensure that replacement is financially sustainable.
- Cost-benefit analysis: Conduct cost-benefit analyses to determine whether repairing or replacing condemned equipment is more cost-effective in the long term.

Phase 4: Training and Capacity Building:

- Technical skills: Ensure that local healthcare staff have the technical skills and knowledge required to assess the condition of equipment and make informed decisions about condemnation.

Phase 5: Data Tracking and Documentation:

- Asset management: Implement an asset management system that tracks the lifespan of medical oxygen equipment, maintenance history, and condemnation decisions.
- Documentation: Maintain detailed records of equipment inspections, repairs, and condemnations to support accountability and decision-making.

Phase 6: Local Regulations and Standards:

- Compliance: ensure that all condemnation and disposal activities comply with local regulations and standards for healthcare equipment and waste management.
- Donated Equipment: As a significant portion of the medical oxygen equipment is donated, ensure that there is a process in place to manage the end-of-life phase of donated equipment responsibly.

Phase 7: Sustainability Planning:

- Long-Term strategy: Consider how the replacement and condemnation of equipment fit into the long-term sustainability plan for healthcare services in Mozambique. This may involve seeking partnerships and funding sources for equipment replacement.

Phase 8: Inventory Management:

- Effective inventory management: Maintain an accurate inventory of medical oxygen equipment to prevent overstocking or understocking. Effective inventory management can reduce the chances of equipment becoming obsolete.

Phase 9: Emergency Preparedness:

- Contingency plans: Develop contingency plans for unexpected equipment failures or condemnations to ensure uninterrupted medical oxygen supply during emergencies.

A well-defined strategy that takes into account the factors mentioned above can help ensure that condemned equipment is handled in a manner that aligns with local needs and resources

RECORD KEEPING, CMMS AND MONITORING & EVALUATION

The purpose of a record keeping system is to implement effective control and means of analyzing the data. The records must be accurate, up-to-date, and describe the problems and costs encountered fully for each equipment.

Maintenance records should show what work was done, when it was done, who did it, and the cost. There are many ready-made CMMS systems available This can be a software or excel based. Either way, this useful information can be helpful in scheduling future maintenance and determining the effectiveness of the maintenance program.

Computerized Maintenance Management System

A Maintenance Management System (MMS) is a structured approach to managing the upkeep and repair of medical equipment and devices used in healthcare facilities. Its primary goal is to ensure that all medical equipment remains in optimal working condition to support accurate diagnosis, safe patient care, and overall operational efficiency within healthcare institutions.

A paper-based MMS typically involves manually recording and tracking information related to medical equipment maintenance. Technicians and engineers fill out physical maintenance logs, detailing the history of equipment servicing, including maintenance schedules, work orders, and repairs. These records are typically stored in physical files or binders, and often require a considerable amount of paperwork and manual data entry.

A next step would be to transition from a paper-based maintenance management system to a computerized management system (CMMS). A CMMS offers numerous advantages: A CMMS streamlines maintenance operations, allowing for efficient work order management, preventive maintenance scheduling, and real-time equipment tracking. It enhances data accuracy and accessibility, allows for data centralization, reduces administrative workload, and assists to have quicker response times to equipment issues. CMMS also facilitates comprehensive equipment history records, reporting and KPI monitoring, helping in decision-making and budgeting, while minimizing downtime. This transition improves overall efficiency, extends equipment lifespan, and ultimately enhances patient care, making it a valuable shift for the MOH. However, before fully committing and initiating the implementation of a CMMS, it is important to carefully consider the following contraindications.

1. **Cost:** The initial investment and ongoing maintenance expenses associated with a CMMS can place a significant burden on limited financial resources, necessitating a thorough cost-benefit analysis to ensure the investment is financially sound.

2. **Infrastructure:** Mozambique often faces challenges with inadequate infrastructure, such as unreliable power supply and internet connectivity, which can hinder the implementation and effectiveness of a CMMS.

3. **Training Requirements:** Training healthcare personnel to use the CMMS can be time-consuming and may divert resources from critical patient care.

4. **Maintenance Backlog:** Implementing a CMMS can reveal a substantial maintenance backlog, which may not be immediately addressable due to resource constraints.

5. **Sustainability:** Sustaining the CMMS over the long term may be difficult, particularly if there is a high turnover of staff or insufficient funding for system updates and maintenance.

6. **Customization Needs:** Tailoring a CMMS to the unique needs of healthcare facilities in Mozambique may require additional resources and technical expertise.

After thorough research and addressing all contraindications, when the decision to proceed with implementing a CMMS in Mozambique is reached, the following steps should be taken:

1. **Needs assessment:** Begin with a comprehensive assessment of the current state of medical oxygen equipment maintenance in healthcare facilities across Mozambique. Identify the equipment in use, maintenance practices, challenges, and existing infrastructure. This information is already available from the National Oxygen Assessment but would need to be updated with the latest information available.

2. **Stakeholder engagement:** Engage healthcare professionals, biomedical engineers, and relevant stakeholders to gather insights and input on the development and implementation of the system. Their expertise and feedback are crucial for its success.

3. **System selection:** Choose an appropriate computerized maintenance management system (CMMS) that aligns with the specific needs and resources of Mozambique's healthcare system. Consider software options designed for healthcare settings.

4. **Customization and integration:** Customize the selected CMMS if need be to meet the unique requirements of Mozambique's healthcare infrastructure.

5. **Staff training:** Train healthcare staff, biomedical engineers, and technicians on how to use the new system effectively. Provide ongoing support and resources for continued learning.

6. **Standard Operating Procedures (SOPs):** Develop standardized operating procedures for medical oxygen equipment maintenance, incorporating the new computerized system into the workflow. Ensure that all healthcare facilities follow these guidelines.

7. **Data management and reporting:** Configure the CMMS to capture data on equipment maintenance, performance, and inventory management. Set up automated alerts for scheduled maintenance and reporting features.

8. **Pilot program:** Implement the system on a small scale in a few healthcare facilities to test its effectiveness and identify any necessary adjustments.

9. **Scale up:** Gradually expand the implementation to more healthcare facilities across Mozambique. Monitor its performance and gather feedback for continuous improvement.

10. **Quality assurance:** Implement quality assurance measures to ensure the system is achieving its intended goals. Regular audits and evaluations help maintain healthcare standards.

11. **Community and staff awareness:** Educate healthcare staff and local communities about the benefits of the computerized system and the importance of proper medical oxygen equipment maintenance.

12. **Continuous Improvement:** Periodically review and refine the system to align with changing healthcare needs, technological advancements, and lessons learned during implementation.

Implementing a computerized medical oxygen equipment maintenance system in Mozambique can significantly enhance the reliability and efficiency of healthcare delivery, A CMMS can also play a crucial role in measuring Key Performance Indicators (KPIs) related to maintenance. It provides a centralized platform for collecting, storing, and analyzing data, manuals and technical documents making it easier to monitor and evaluate maintenance performance.

Monitoring and Evaluation

Measuring the quality of maintenance performed on medical oxygen equipment is crucial for ensuring the safe and effective operation of these life-saving devices. Here are some key performance indicators (KPIs) to assess the quality of maintenance:

1. **Equipment uptime**: This KPI measures the percentage of time that the medical oxygen equipment is operational. A high uptime indicates effective maintenance and minimal downtime.
2. **Preventive maintenance compliance**: Assess how well the maintenance provider adheres to the schedule for preventive maintenance tasks. High compliance rates suggest a commitment to proactive care.
3. **Corrective maintenance response time**: Measure how quickly maintenance teams respond to reported issues. A shorter response time indicates quicker issue resolution.
4. **Mean time to repair (MTTR)**: MTTR assesses the average time taken to repair and restore equipment to working order after a reported problem. A lower MTTR suggests more efficient maintenance.
5. **First-time fix rate**: Evaluate the percentage of repairs completed successfully on the first visit. A higher first-time fix rate indicates better diagnostic accuracy and parts availability.
6. **Quality of repairs**: Implement a quality assessment process to ensure that repairs meet safety and performance standards.
7. **Compliance with regulatory standards**: Ensure that maintenance providers adhere to all relevant regulatory and safety standards to guarantee the quality of maintenance.

8. **User satisfaction**: Collect feedback from healthcare providers, clinicians, and technicians who interact with the equipment. High satisfaction scores are indicative of the quality of service.
9. **Spare parts availability**: Evaluate the availability of spare parts and consumables. Quick access to replacement components is essential for quality maintenance.
10. **Safety and quality Incidents**: Monitor the occurrence of safety or quality incidents related to maintenance work. Reducing these incidents is crucial for patient safety and equipment quality.

If you want to focus on a single key performance indicator (KPI) to measure the effectiveness of medical equipment management and maintenance, the ratio of functional equipment in use for its intended purposes is an excellent choice. While uptime, or the time equipment is operational, is important, it doesn't provide a complete picture of how well equipment is serving its intended functions. The ratio of functional equipment in use takes into account not only the equipment's technical condition but also its actual utility in patient care. Some functional equipment may not be used for various reasons, such as lack of staff training or workflow inefficiencies. This KPI ensures that equipment is not only operational but also fulfilling its essential role in delivering healthcare services effectively and efficiently, making it a more comprehensive metric for evaluating the success of medical equipment management and maintenance.

3: PROPOSED ACTIONS AND MEMP ROADMAP

The progress of medical oxygen equipment management and maintenance in Mozambique, as discussed earlier, is a complex, long-term effort that requires collaboration from various experts and stakeholders. This project entails significant financial investments and a strong commitment from both the government and donors. A shift in perspective is needed, moving away from the traditional approach of equipment acquisition to adopting a proactive equipment management mindset. The following chapter provides an initial roadmap, outlining the key steps and strategies to guide the country, acting as a foundation for substantial improvements in medical (oxygen) equipment management and maintenance.

Create multidisciplinary project team to develop and implement a medical (oxygen) equipment management plan (MEMP):

- Create multidisciplinary project team responsible for developing and implementing the MEMP.
- Identify key stakeholders from various departments and healthcare facilities who should be included in the project team.
- Define the roles and responsibilities of team members and establish clear lines of communication and reporting.
- Establish the project team's Technical Assistance (TA) budget.
- Facilitate coordination and negotiations with stakeholders and donors regarding the technical and financial backing of the implementation plan.

Perform a medical oxygen capacity analysis:

1. **Oxygen supply assessment**
    - Identify existing oxygen generation and supply infrastructure, including the number and capacity of oxygen plants (PSAs), oxygen concentrators, cylinders, oxygen ramps, piped oxygen systems and other related equipment.
    - Evaluate the condition and operational status of the existing equipment to determine what can be reused, refurbished, or upgraded.
    - Quantify the current oxygen production and distribution capacity, including the flow rates and availability of oxygen in healthcare facilities.

2. **Oxygen demand assessment**

    Calculate the current demand for medical oxygen by considering factors such as:

    - The number and type of patients requiring oxygen therapy.
    - Prevalence of diseases or conditions that necessitate oxygen therapy.
    - The volume of oxygen required per patient.
    - The total annual oxygen consumption by healthcare facilities.

3. **Future demand estimation:**

    Project future demand for medical oxygen by considering:

    - Population growth and changing demographics.
    - Trends in the incidence of diseases requiring oxygen therapy.
    - Expansion of healthcare facilities and services.
    - Advances in medical technology and treatments.

4. **Gap identification:**
   - Compare the projected oxygen demand with the current supply and infrastructure to identify gaps or disparities.

5. **Recommendations and action plan:**
   - Develop a set of recommendations and an action plan to bridge the identified gaps in medical oxygen demand.
   - Develop strategies for equipment replacement based on lifecycle analysis, technological advancements, and changing healthcare needs.
   - Prioritize interventions based on their impact and feasibility
   - Develop long term equipment investment plan.

Development of an inventory system:

- Develop guidelines and standard operating procedures (SOPs) for medical equipment inventory management.
- Prioritize key medical equipment to be included in inventory.
- Establish a comprehensive medical equipment inventory system to track and monitor/update equipment across healthcare facilities.

Implementation of a CMMS:

- Perform needs assessment and requirements gathering.
- Selection and procurement of software solution.
- Procure and distribute hardware.
- Implement system (configuration and customization).
- Execute CMMS training and capacity building.
- Implement a pilot and perform system testing.
- Execute a nationwide rollout.

Policy and regulatory framework:

- Review existing policies, regulations, and guidelines related to medical equipment management.
- Identify gaps and propose necessary updates and additions to align with international best practices.
- Define equipment policy by level of care.
- Develop policies and procedures that cover the entire lifecycle of medical equipment, including procurement, installation, maintenance, and disposal.

Human Resources and capacity building:

- Perform a skills and gap analysis.
- Create a short term, medium term, and long-term training plan.
- Develop a training program to enhance the technical skills of maintenance personnel and establish career development pathways.
- Develop (online) training materials for the management/maintenance of medical oxygen equipment.

Maintenance practices and standards:

- Develop of a set of best maintenance practices and maintenance standards for medical devices, aligned with international guidelines.
- Develop protocols for preventive maintenance, calibration, and quality assurance.

- Establish mechanisms for regular monitoring, data collection, and reporting on equipment status, maintenance activities, and equipment performance.

Health and safety plan and manual:

- Develop a comprehensive Health and Safety plan for medical (oxygen) equipment.
- Ensure that all maintenance technicians and clinicians receive comprehensive training on the safe use and maintenance of medical oxygen equipment. This should cover handling, troubleshooting, and emergency procedures.

Supply chain of spare parts:

- Examine the current supply chain for spare parts, pinpointing areas for enhancement. This analysis should encompass decisions on the extent to which activities should be managed in-house versus outsourced.
- Develop a strategy/plan to ensure the availability of high-quality spare parts and consumables for medical devices.
- Implement a spare part supply chain improvement plan.

Procurement of equipment/services and donations:

- Develop a procurement strategy for new medical devices, ensuring technical specifications meet the requirements of the MEMP (including harmonization of equipment purchases).
- Develop template tender documentation and procurement contracts.
- Develop protocols for the acceptance and management of donated medical devices.
- Develop protocols for contracting 3PL maintenance services.
- Design monitoring and evaluation mechanisms to ensure adherence to SLAs.

Equipment disposal:

- Develop guidelines for the safe disposal and replacement of medical equipment, adhering to environmental and regulatory requirements.

Monitoring and evaluation framework and indicators:

- Design of a framework to monitor and evaluate the implementation of the maintenance strategy.
- Develop key performance indicators (KPIs) to measure the performance of medical equipment management.
- Establish mechanisms for regular monitoring, data collection, and reporting on equipment status, maintenance activities, and equipment performance.

Emergency response plan development:

- Develop a detailed emergency response plan that outlines the procedures for prioritizing oxygen supply, coordinating with healthcare facilities, and responding to oxygen shortages. In anticipation of equipment failures or oxygen supply disruptions, the plan should include provisions for backup oxygen sources or alternative equipment to ensure patient safety during emergencies.

Financing and sustainability:

- Develop a long-term financial plan for the medical (oxygen) equipment management plan, long term investment plan and maintenance plan, including budgeting and resource mobilization strategies.

Development of yearly implementation and action plans:

- Develop yearly implementation plans, setting clear objectives, activities, timelines, and responsibilities.

Refer to Annex K for the proposed implementation calendar.

4: CONCLUSION

The effort to improve medical oxygen equipment management and maintenance in Mozambique, as discussed earlier, is a challenging, long-term initiative that requires the collaboration of a variety of experts and stakeholders. This comprehensive project will demand substantial financial investments and serious commitment from both the Mozambican government and donors. A key factor in its success is shifting from the traditional equipment acquisition approach to adopting a proactive equipment management mindset. It's clear that to make a lasting and meaningful impact in the management of medical oxygen equipment, we need to move beyond concentrating solely on one aspect, like maintenance in isolation. Embracing a more comprehensive lifecycle approach that takes into account all aspects of equipment management is essential. This approach ensures a more effective and sustainable management of medical equipment, from acquisition to maintenance and eventual disposal.

Historically, maintenance of medical equipment has not been a priority within the Ministry of Health (MOH), donors, and implementing partners This lack of attention is one of the key reasons why departments like the DIEH receive insufficient support both from within the MOH and externally and consequently suffer from chronic underfunding. The scope of this challenge is extensive, and there are no quick or easy solutions. One of the crucial tasks facing the Government of Mozambique (GoM) is to persuade donors and implementing partners to actively participate in this area. To transform the prevailing mindset and establish a new culture around medical equipment management, it is imperative for the GoM to lead by example and make a sincere and dedicated commitment to prioritize this activity. By doing so, the government can inspire others to invest their resources and efforts in improving medical equipment management in the country. To make these necessary changes will take considerable time, effort and funding.

A possible first step could be for the MOH to set up and lead a diverse project team to create and put into action the development Medical (Oxygen) Equipment Management Plan (MEMP). This could mark the beginning of meaningful work and improvements in this neglected area.

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WHO-UNICEF, *Technical Specifications and Guidance for Oxygen Therapy Devices, WHO medical device technical series*, Geneva, 2019.

6: ANNEXES

ANNEX A: OXYGEN QUANTIFICATION TOOLS

Estimating oxygen consumption is often based on various factors such as the number of beds, the availability of gas wall outlets, and historical usage patterns. However, it's important to note that these estimations come with significant limitations and face various challenges. Many facilities lack flow measurement systems, and even when they are present, they may not accurately reflect the actual oxygen requirements due to factors like waste, leaks, or rationing.

The following outlines descriptions of commonly employed tools for estimating oxygen consumption at different levels:

Bedside tools
Open Critical Care Oxygen Calculator
Link to latest version: https://www.oxygencalculator.com/cylinder/cylinderduration

Facility level tools
PATH Quantification and costing tool: oxygen delivery sources
PATH Oxygen Consumption Tracking Tool
Link to PATH O2 Toolkit: www.path.org/oxygen-delivery-toolkit

UNICEF Oxygen System Planning Tool (OSPT)
Link to latest version: https://www.unicef.org/innovation/oxygen-system-planning-tool

National planning tools
WHO COVID-19 Essential Supplies Forecasting Tool (ESFT)
Link to latest version: https://www.who.int/publications/i/item/WHO-2019-nCoV-Tools-Essential_forecasting-2022.1

ANNEX B: EQUIPMENT ACCEPTANCE AND COMMISIONING FORM

ACCEPTANCE FORM

Codes

Work order		Acceptance date	
PO#		Warranty expiry date	
Invoice#			
Supplier		Cost of the device	

Equipment data

Equipment Type		Health facility	
Category #			
Tag		Inventory tag	
Manufacturer		Address	
Model		Department	
Serial Number		Location	

ACCEPTANCE RESULT

	The equipment is correctly delivered, installed and ready to be used according to the manufacturer and international regulations		The equipment cannot be used for the reason described below in the FAULTY REPORT section

Health Technology Management Manager Name	
Signature	
Date	

COMMISSIONING FORM

Delivery

Received by		Delivery date	
Witnessed by		Packing list #	

Checklist	Yes	No	Comment
Packing list			
Correct number of boxes received?			
Visible damage to the boxes?			

Unpacking

Undertaken by		Unpacking date	
Witnessed by		Packing list #	

Checklist	Yes	No	Comment
Visible damage to the equipment?			
Equipment complete as ordered			
User manual as ordered? (English and Portuguese language)			
Service/technical manual as ordered?			
Power supply and plug comply the country standard and/or as ordered			
Accessories as ordered?			
Consumables as ordered?			
Spare part as ordered?			

*Register the Accessories, consumable and spare part in the dedicated form

Assembly/Installation

*Undertaken by		Installation date	
Witnessed by		*Work Order #	

*If Supplier or third company is responsible of the installation, register the name of the company and the Workorder number of its installation.

Checklist	Yes	No	Comment
Are all parts available?			
Do the parts fit together as intended?			
Is an inventory label placed?			
Is an Installation label placed?			
Is an maintenance label placed?			
Any visible damage to the equipment?			
Was the work carried out satisfactory?			

Commissioning/Performance test

*Undertaken by		Commissioning date	
Witnessed by		*Work Order #	

*If Supplier or third company is responsible of the installation/commissioning, register the name of the company and the Workorder number of its performance test.

Checklist	Yes	No	Comment
**Are the function verification / performance tests acceptable?			
**Are the Electrical safety tests performed?			
Is the Electrical safety test certificate present?			
Is the Performance test certificate present?			

**According to the manufacturer recommendation or international standards.

Training

*Undertaken by		Commissioning date	
Witnessed by		*Work Order #	

*If Supplier or third company is responsible of the training, register the name of the company and the Workorder number of program.

Checklist	Yes	No	Comment
**Was the training course given for medical staff?			
**Was the training course given for technical staff?			

**According to the manufacturer recommendation or international standard.

Registration

Undertaken by		Registration date	

Checklist	Yes	No	Comment
Is an inventory label placed?			
Is an installation label placed?			
Is the maintenance label placed?			
Are the codes and equipment data registered in an electronic format (Excel or other application)?			
Have the accessories, consumables, spare parts, and manuals all been registered?			

**According to the manufacturer recommendation or international standard.

FAULTY REPORT

Name:
Date:
Signature:

ANNEX C: EXAMPLE OF AN INFRASTRUCTURE CHECKLIST FOR THE INSTALLATION OF A PSA

Facility Infrastructure					
Sequence	Description	Acceptable	Unacceptable	Target	Comments
1	Facility Location	The location for the Oxygen Plant (PSA / VSA) is acceptable; A. Within the hospital. B. Not in a flood zone. C. Away from pedestrian traffic. D. On a Sturdy surface. E. Away from open flames. F. Away from trash and garbage.	The Oxygen Plant potential location is unsafe for staff, visitors, and community.	The location of the oxygen plant meets the location where it's safe for staff, visitors, and community.	
2	Building Condition for Oxygen Plant	The building has the basic infrastructure to implement an PSA / VSA, electrical, piping, fire suppression, and the appropriate climate / environmental controls.	The building does not have the basic infrastructure to install the PSA / VSA.	The facility meets the basic infrastructure to install an PSA / VSA.	
3	Oxygen Plant Available Space	There is ample space to install an oxygen plant.	There is no space within the facility to install a PSA / VSA.	There is ample space to install an oxygen plant.	
4	Concrete screed / Pad / Building for Oxygen Plant	The oxygen plant will be installed on a solid foundation such as concrete.	The location for the oxygen plant is unstable.	The foundation is level, stable, and approved for the weight of the PSA / VSA.	
5	Roofing appropriate	If the Oxygen plant is located within a separate building, the roofing must be free of leaks, holes, and has an appropriate covering.	The roofing is defective.	The roofing is secure, non-leaking, free of holes, and provides adequate thermo-isolation. The roofing must have adequate ducts and piping for ventilation.	
6	Ventilation - HAVC	The storage room where the PSA / VSA will operate, there must be adequate ventilation within the room before installation of the oxygen plant.	No ventilation within the location where the PSA / VSA will be located.	The storage room where the PSA / VSA will operate, there must be adequate ventilation within the room before installation of the oxygen plant.	
7	Electricity supply	There is an adequate and constant electrical supply.	The electrical supply is inconsistent, not constant, and unreliable.	There is an adequate and constant electrical supply.	
8	Alternative Power Supply	There is a backup electrical power source.	The facility has no backup electrical power source.	The facility has redundant backup electrical power sources.	
9	Piping connection to the main building	The external piping meets the quality standards to supply oxygen.	The external piping does not meet the quality standard to supply oxygen. There is no external piping to supply oxygen.	The external piping meets the quality standards to supply oxygen.	
10	Oxygen System Pressure	The current internal oxygen system has regulators to control the flow of oxygen.	The Facility has no regulators to control oxygen flow.	The current internal oxygen system has regulators control the flow of oxygen.	
11	Three Prong Safety Plugs	The electrical outlets within the facility are Three -prong safety plugs.	The electrical outlets are not grounded with three prong plugs.	The electrical outlets within the facility are Three -prong safety plugs.	

ANNEX D: OUTLINE OF MEDICAL (OXYGEN) EQUIPMENT MANAGEMENT PLAN (MEMP)

Efficient management of medical (oxygen) equipment is pivotal in establishing an effective medical equipment program. This planning entails the consideration of financial, physical, and human resources essential for the selection, procurement, installation, maintenance and finally disposition of the equipment. Once the program/plan is defined, ongoing evaluation and management of the financial, personnel, and operational aspects are necessary for its continuous advancement and required enhancements. A Medical Equipment Management Plan (MEMP) typically includes several key chapters or sections, each addressing specific aspects of the plan.

- **Introduction:** Provides an overview of the MEMP and its purpose, as well as the scope and objectives of medical equipment management within the organization.
- **Policy and Purpose:** Outlines the policies, goals, and objectives related to medical equipment management, emphasizing the importance of safety and quality of care.
- **Regulatory Compliance:** Addresses how the DIEH adheres to local, national, and international regulations and standards governing medical equipment management.
- **Roles and Responsibilities:** Details the roles and responsibilities of various personnel involved in equipment management, such as biomedical engineers, clinicians, administrators, and procurement staff.
- **Inventory and Asset Management:** Covers the processes for maintaining an accurate inventory of medical equipment, tracking asset information, and ensuring that equipment is properly tagged and labeled. This would ideally be performed by using a CMMS.
- **Maintenance and Inspection:** Describes the procedures for preventive maintenance, scheduled inspections, and equipment testing. It may also include guidelines for troubleshooting and corrective maintenance.
- **Training and Competency:** Outlines the training requirements for staff who interact with medical equipment and ensures that they are competent in their roles.
- **Safety and Risk Management:** Addresses strategies for ensuring the safety of patients and staff when using medical equipment. This includes risk assessment, incident reporting, and safety protocols.
- **Equipment Acquisition and Disposal:** Details the processes for procuring new equipment, including vendor evaluation, and guidelines for the decommissioning and disposal of equipment that is no longer in use.
- **Documentation and Record Keeping:** Explains the importance of maintaining accurate records for each piece of equipment, including service histories, maintenance records, and incident reports.
- **Quality Assurance and Performance Improvement:** Describes the methods for monitoring and improving the quality of medical equipment management services, including the use of Key Performance Indicators (KPIs).
- **Emergency Preparedness:** Addresses how the organization plans for and manages medical equipment during emergencies or disasters.
- **Budget and Resource Allocation:** Provides insights into how financial resources are allocated for equipment management and outlines budget considerations.
- **Long term equipment replacement plan:** Is a structured strategy that outlines the process and timeline for replacing and upgrading medical oxygen equipment in a healthcare facility or at the national level when the existing equipment becomes outdated, damaged, or no longer meets safety and performance standards.
- **Appendices:** Includes supporting documents, forms, templates, and additional resources that are referenced in the MEMP.

ANNEX E: LIST WITH BASIC SET OF TOOLS AND TESTING EQUIPMENT

- Electrical tape
- Zip tight straps
- Super glue, epoxy glue
- Sandpaper
- Permanent markers
- Scissors
- Knife
- Hex wrench set (Allen wrenches)
- Crescent wrench
- Tape measure
- Multi-meter
- Small tube or roll of solder,
- Solder sucker and/or desoldering wick,
- Soldering iron
- Wire cutters
- Wire strippers
- Screwdrivers (#1 and #2 Phillips and small, medium flat head)
- Jewel screwdrivers
- Needle nose pliers
- Flashlight
- Small plastic cup measure
- Latex gloves
- WD-40
- Ziploc bags
- Batteries (AAA, AA, 9V),
- Fuses (250 v, 0.5, 1.0 and 1.5 a glass tube type)
- AC outlet analyzer/tester
- AC-to-DC universal adapter
- Extension cords
- Hemostats
- Forceps (small clamps and tweezers)
- Wire crimp/fasteners

Oxygen/Gas specific equipment:

- Gas flow meter
- Oxygen Analyzer
- Pressure meter

ANNEX F: TYPICAL MAINTENANCE ACTIVITIES FOR OXYGEN CONCENTRATORS

Weekly maintenance is the responsibility of the clinical staff:

Clean the external filter:

- Remove the filter.
- Wash the filter with water and dry it very well.
- Reposition the filter and in the correct position.

Cleaning the humidifier:

- Remove the humidifier and wash with dish detergent and dry.
- Reposition the humidifier in the correct position (use two hands).
- Fill the humidifier with distilled water.

Clean the outside of the device:

- With a clean, damp cloth, wipe the outside of the device.
- Monthly maintenance is the responsibility of Maintenance personnel

Monthly PM by the hospital technician:

Perform the weekly maintenance of the clinical staff and verify that it is performed correctly by the staff. (through the maintenance sheet on the side of the device)

- Check the internal modular filter
- Remove the main filter, grille and modular filter
- Check the filter that is not dark brown in color
- In case the filter is too dirty, replace it with a new filter
- Reposition the filters and the grid in the correct position.
- Check that the power cable is not damaged.
- Check the alarms according to the basic inspections during installation.
- Record the hours of operation and the maintenance performed.

Annual maintenance is the responsibility of DIEH maintenance personnel.

Perform the weekly maintenance of the clinical staff and verify that it is performed correctly by the clinical staff. Perform monthly Maintenance and check if was done correctly by the hospital technician.

- Replace the internal main and modular filters, if necessary.
- Open the device and clean with brush and compressed air (optional) the inside of the device.
- Replace the internal anti-bacterial filter paying attention to the indicated flow direction
- Record the type of maintenance.
- Check oxygen purity.

ANNEX G: TYPICAL PREVENTIVE MAINTENANCE/INSPECTION ACTIVITIES FOR OXYGEN RAMPS, OXYGEN CYLINDERS, AND PIPED OXYGEN SYSTEMS

Medical Oxygen Cylinders:

- Visual Inspections: Regular visual checks for physical damage, corrosion, or leaks on the exterior of the cylinders.
- Valve Inspections: Ensure the valve is in good condition and properly functioning.
- Pressure Testing: Periodic hydrostatic testing to assess the integrity of the cylinder and detect potential weaknesses.
- Cleaning: Regular cleaning and removal of contaminants from the cylinder's exterior.
- Valve Maintenance: Lubrication and maintenance of cylinder valves.

Oxygen Ramps:

- Structural Inspections: Regular inspections for signs of damage or structural issues.
- Surface and Piping Integrity: Ensuring that surfaces are free from corrosion or contaminants and that the piping is securely connected.
- Safety Systems: Testing of safety systems, such as pressure relief valves and alarms, to ensure they function correctly.

Internal Piping Systems:

- Pressure and Leak Testing: Periodic testing to identify any leaks or pressure issues within the piping system.
- Clog Prevention: Regular checks to ensure that the piping is free from obstructions or blockages.
- Quality of Gases: Monitoring and testing the quality of gases delivered through the piping system.

ANNEX H: TYPICAL PREVENTIVE MAINTENANCE/INSPECTION ACTIVITIES FOR PSAS

The type and frequency for preventive maintenance activities for PSA (Pressure Swing Adsorption) systems can vary based on manufacturer recommendations, usage conditions, and the specific equipment in use. Typically, these activities are performed quarterly, semi-annually, or annually. Here's a general guideline:

1. Quarterly:
    - Visual inspections of the entire PSA system to check for signs of wear, damage, or corrosion.
    - Checking the condition of pipes and tubing for any leaks, blockages, or damage.
    - Ensuring that valves and fittings are properly tightened and functioning correctly.
    - Monitoring and maintaining the proper pressure levels throughout the PSA system for efficient operation.
    - Calibrating sensors and controls to ensure accurate readings and proper system operation.

2. Semi-Annually:
    - Replacement of inlet and outlet filters to ensure the air entering the PSA system is clean and the oxygen output remains pure.
    - Checking the condition of the adsorbent beds to ensure they are functioning properly and replacing the beds when they become saturated.
    - Analyzing the oxygen purity to ensure it meets the required medical standards.

3. Annually:
    - Verification that the alarm and safety systems are in good working order and responding to any potential issues.
    - Maintaining the compressor as per the manufacturer's recommendations (relevant to Mozambique's case, where all PSAs have a compressor and filling ramp).
    - Comprehensive inspection, including documentation review and record-keeping of all maintenance and inspection activities for compliance and troubleshooting purposes.

It's important to note that these are general guidelines, and specific maintenance schedules may vary based on the manufacturer's recommendations, local regulations, and equipment usage.

ANNEX I: TYPICAL PREVENTIVE MAINTENANCE FOR LOX EQUIPMENT

The frequency of preventive maintenance for LOX (Liquid Oxygen) equipment can vary depending on several factors, including the specific type of equipment, manufacturer recommendations, and usage conditions. It's essential to follow the manufacturer's guidelines and best practices for maintenance schedules.

Typically, preventive maintenance activities should be performed on a regular basis, which often includes quarterly, semi-annual, or annual maintenance checks. Some maintenance tasks may need to be conducted more frequently, while others can be less frequent. Here's a general guideline:

1. Quarterly preventive maintenance activities:
    - Check the pressure levels to ensure they are within the specified range. This can be done quarterly.

2. Semi-Annual preventive maintenance activities:
    - For equipment not checked quarterly, semi-annual pressure checks are recommended to ensure they are within the specified range.
    - Leak Detection: Conduct leak tests semi-annually to identify any gas or liquid leaks and address them promptly.

3. Annual Maintenance Activities:
    - Filter Replacement: Replace filters as recommended by the manufacturer annually to maintain the purity of the LOX.
    - Lubrication: Apply lubricants to moving parts annually to prevent friction and ensure smooth operation.
    - Valve Inspection: Examine valves for proper functioning and make any necessary adjustments or replacements annually.
    - Alarm Testing: Test and calibrate alarms annually to ensure they are functioning correctly and can alert personnel in case of any issues.
    - Safety Checks: Verify that safety mechanisms and emergency shutdown systems are operational annually.
    - Piping and Tubing Inspection: Inspect the condition of the pipes and tubing for any signs of wear or damage annually.
    - Oxygen Sensor Calibration: Calibrate oxygen sensors to maintain accurate readings and safety annually.

4. Regular and ongoing preventive maintenance activities:
    - Visual Inspection: Regularly inspect the LOX tank and associated equipment for any visible signs of wear, damage, or corrosion. This should be conducted weekly or as needed, depending on the environment and usage.
    - Cleaning: Keep the equipment clean to prevent the buildup of dirt and debris that could impede its operation. This should be part of routine maintenance and performed regularly.
    - Valve Inspection: Regularly examine valves for proper functioning and make any necessary adjustments or replacements during routine maintenance.
    - Piping and Tubing Inspection: Regularly inspect the condition of the pipes and tubing for any signs of wear or damage during routine maintenance.
    - Documentation Review: Maintain detailed records of all maintenance activities, inspections, and repairs during routine maintenance.
    - Ventilation System Inspection: Ensure that ventilation systems are clear and functioning correctly to maintain a safe environment. Ventilation system inspection should be conducted regularly.
    - Maintain detailed records of all maintenance activities, inspections, and repairs.
    - Provide training for personnel responsible for equipment maintenance to ensure proper procedures are followed. Training should be conducted initially and periodically as needed.

ANNEX J: PROPOSED MAINTENANCE STRATEGIES FOR PRIORITY MEDICAL OXYGEN EQUIPMENT

PSA Plants:

In the Mozambican Public Health System, it makes sense to consider using a Third-Party Logistics (3PL) maintenance provider for both preventive (PM) and corrective (CM) maintenance PSA systems. These systems are quite complex, and the Ministry of Health (MOH) currently lacks the specialized maintenance skills required for effective PM and CM. A 3PL provider, whether it's the original equipment vendor or a general maintenance provider, brings the necessary expertise to ensure these systems run smoothly. When managed well and chosen carefully, they can address issues quickly reduce downtime, and provide cost-effective solutions. This approach allows the MOH to focus on patient care while transferring the challenging task of PSA maintenance to the 3PL provider.

Moreover, selecting a generic 3PL maintenance provider offers the advantage of consolidating equipment from various brands and sources under one contract, simplifying the maintenance process for a diverse range of PSA equipment. However, it's important to balance this advantage with the quality-of-service delivery. Currently, two of the MOH's PSA systems (Monapo and Mocuba) are covered by a Service Level Agreement (SLA) contract provided by the official representative of the vendor, funded by USAID and managed by the MOH/DIEH. These contracts have a duration of two years from equipment arrival in country. To safeguard continuation of maintenance services the MOH needs provide budget after the current SLAs are ending

The Ministry of Health (MOH) has recognized the challenges in handling the in-house maintenance and repair of Pressure Swing Adsorption (PSA) systems and is actively seeking a third-party logistics (3PL) provider to extend their services to the remaining PSA systems across the country. This provider will not only take care of preventive maintenance (PM) and corrective maintenance (CM) but also offer external staff to assist in filling oxygen cylinders at the PSA filling ramp. This collaborative approach aims to enhance the overall reliability and functionality of the systems, allowing the MOH to focus on its core mission of delivering healthcare services.

Oxygen Concentrator:

The concentrator typically has a lifespan of 8-10 years when used and maintained correctly. Basic actions are necessary to ensure its efficient operation to ensure it can reach the expected lifespan.
Clinic staff should perform daily inspections and cleaning tasks, like checking filters and visual checks. Technical staff should support clinical staff by conducting periodic inspections, filter cleaning, and replacement of internal filters as outlined in the concentrator manual. Additionally small repairs like replacement of the electrical plug, replacement of broking humidifiers should also be executed by the hospital technical staff. For a detailed overview of PM responsibilities and activities see Annex F.
To keep the concentrator working properly and safely, each health facility's maintenance department should maintain a level 1 spare parts kit on-site. This kit includes filter replacements (main filter, microfilter, and bacteria filter). Major repairs on this relatively low-cost equipment in remote locations are discouraged; instead, a "Run-to-Failure" strategy is recommended. To implement this, having similar equipment in stock at the national or provincial level for quick replacements is crucial. Any faulty oxygen concentrator should be taken out of service and decommissioned according to agreed-upon procedures and replaced almost immediately. In the case of concentrators, it is more cost effective and efficient to keep the responsibility for maintenance inhouse.

Oxygen cylinders, ramps and internal piped oxygen systems

Regular maintenance and inspections are vital to ensure the safe and dependable supply of medical oxygen in healthcare settings. The frequency of these tasks can vary based on regulations, equipment types, and local policies, but they are typically performed periodically, often annually, in accordance with relevant guidelines. It's crucial to adhere to manufacturer recommendations and any local regulations when setting up maintenance schedules and procedures.

These inspections require a range of tools, from basic items like mirrors and flashlights to non-destructive testing (NDT) equipment like ultrasonic testing and radiography, which assess the material integrity of piped systems. Specialized testing equipment, such as hydrostatic testing devices for pressure cylinders, is used to confirm the safety and functionality of cylinders under high pressure. Given the requirements in terms of human resources and equipment, it is advisable for the Ministry of Health (MOH) to consider outsourcing these tasks to a qualified organization or 3PL provider.

Liquid Oxygen tanks (LOX)

When it comes to LOX (Liquid Oxygen) tanks, there are two primary ownership and maintenance models to consider. In the first model, the Ministry of Health (MOH) is the owner of the equipment, which grants the government of Mozambique greater flexibility in choosing LOX suppliers and the option to switch between them as needed. However, this approach places the responsibility for equipment maintenance squarely on the shoulders of the MOH.

Conversely, the second option involves the supplier being the equipment owner, responsible for installing and maintaining the tank as part of the LOX gas supply agreement. This arrangement reduces the MOH's direct involvement in equipment maintenance but makes the government more dependent on the supplier. It also provides the supplier with more leverage in setting prices, as changing suppliers becomes significantly more complex under this model. Each option has its advantages and disadvantages, and the choice between them should be made carefully, considering factors like flexibility, control, and long-term dependencies.

In the scenario where the Mozambican Ministry of Health (MOH) assumes ownership of the LOX tank and its related equipment, it becomes essential for them to consider outsourcing the preventive and corrective maintenance of the equipment to a Third-Party Logistics (3PL) provider. This decision is primarily driven by the MOH's limited in-house capacity to carry out these maintenance activities efficiently themselves.

ANNEX K: TENTATIVE IMPLEMENTATION SCHEDULE

	MEMP Roadmap		2024				2025				2026				2027				2028			
#	**Main Activity**	**Sub Activities**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Create multidisciplinary project team	Create multidisciplinary project team to develop and implement a medical (oxygen) equipment management plan (MEMP)																				
		Identify key stakeholders from various departments and healthcare facilities who should be included in the project team																				
		Define the roles and responsibilities of team members and establish clear lines of communication and reporting																				
		Establish the project team's Technical Assistance (TA) budget																				
		Facilitate coordination and negotiations with stakeholders and donors regarding the technical and financial backing of the implementation plan																				
2	Perform a medical oxygen capacity analysis	Oxygen supply assessment																				
		Oxygen demand assessment																				
		Future demand estimation																				
		Gap identification																				
		Recommendations and action plan																				
3	Development of an inventory system	Develop guidelines and standard operating procedures (SOPs) for medical equipment inventory management																				
		Prioritize key medical equipment to be included in inventory																				
		Establish a comprehensive medical equipment inventory system to track and monitor/update equipment across healthcare facilities																				

	MEMP Roadmap		2024				2025				2026				2027				2028			
#	**Main Activity**	**Sub Activities**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
4	Implementation of a CMMS	Perform needs assessment and requirements gathering.																				
		Selection and procurement of software solution.																				
		Procure and distribute hardware.																				
		Implement system (configuration and customization).																				
		Execute CMMS training and capacity building.																				
		Implement a pilot and perform system testing.																				
		Execute a nationwide rollout.																				
5	Develop a policy and regulatory framework	Review existing policies, regulations, and guidelines related to medical equipment management																				
		Identify gaps and propose necessary updates and additions to align with international best practices																				
		Define equipment policy by level of care																				
		Develop policies and procedures that cover the entire lifecycle of medical equipment, including procurement, installation, maintenance, and disposal																				
6	Human Resources and capacity building	Perform a skills and gap analysis																				
		Create a short term, medium term, and long-term training plan																				
		Develop a training program to enhance the technical skills of maintenance personnel and establish career development pathways																				
		Develop (online) training materials for the management/maintenance of medical oxygen equipment																				

	MEMP Roadmap		2024				2025				2026				2027				2028			
#	**Main Activity**	**Sub Activities**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
7	Maintenance practices and standards	Develop of a set of best maintenance practices and maintenance standards for medical devices, aligned with international guidelines.																				
		Develop protocols for preventive maintenance, calibration, and quality assurance.																				
		Establish mechanisms for regular monitoring, data collection, and reporting on equipment status, maintenance activities, and equipment performance.																				
8	Health and safety plan and manual	Develop a comprehensive Health and Safety plan for medical (oxygen) equipment																				
		Ensure that all maintenance technicians and clinicians receive comprehensive training on the safe use and maintenance of medical oxygen equipment. This should cover handling, troubleshooting, and emergency procedures																				
9	Supply chain of spare parts	Examine the current supply chain for spare parts, pinpointing areas for enhancement. This analysis should encompass decisions on the extent to which activities should be managed in-house versus outsourced.																				
		Develop a strategy/plan to ensure the availability of high-quality spare parts and consumables for medical devices.																				
		Implement a spare part supply chain improvement plan.																				
10	Procurement of equipment/services and donations	Develop a procurement strategy for new medical devices, ensuring technical specifications meet the requirements of the MEMP (including harmonization of equipment purchases)																				

	MEMP Roadmap		2024				2025				2026				2027				2028			
#	**Main Activity**	**Sub Activities**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
		Develop template tender documentation and procurement contracts																				
		Develop protocols for the acceptance and management of donated medical devices																				
		Develop protocols for contracting 3PL maintenance services																				
		Design monitoring and evaluation mechanisms to ensure adherence to SLAs																				
11	Equipment Disposal/Condemnation	Develop guidelines for the safe disposal and replacement of medical equipment, adhering to environmental and regulatory requirements																				
12	Monitoring and evaluation framework and indicators	Design of a framework to monitor and evaluate the implementation of the maintenance strategy																				
		Develop key performance indicators (KPIs) to measure the performance of medical equipment management																				
		Establish mechanisms for regular monitoring, data collection, and reporting on equipment status, maintenance activities, and equipment performance																				
13	Emergency response plan development:	Develop a detailed emergency response plan that outlines the procedures for prioritizing oxygen supply, coordinating with healthcare facilities, and responding to oxygen shortages. In anticipation of equipment failures or oxygen supply disruptions, the plan should include provisions for backup oxygen sources or alternative equipment to ensure patient safety during emergencies																				

	MEMP Roadmap		2024				2025				2026				2027				2028			
#	**Main Activity**	**Sub Activities**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
14	Financing and sustainability	Develop a long-term financial plan for the medical (oxygen) equipment management plan, long term investment plan and maintenance plan, including budgeting and resource mobilization strategies																				
15	Development of yearly implementation and action plans:	Develop yearly implementation plans, setting clear objectives, activities, timelines, and responsibilities.																				

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