

Appendix

Appendix 1. Barriers and Facilitators of Oxygen Management

Factor	Description
Oxygen Purity	Ensuring high-purity medical oxygen (from producers, storage providers, logistics teams, and healthcare facilities) by adhering to WHO and pharmacopeia standards (1,2).
Medical Equipment and Maintenance	Effective use and upkeep of equipment like PSA plants, LMO tanks, and concentrators, supported by national staff training programs (1,3,4).
Production Capacity	Measures to increase production including upgrading plants, diverting industrial oxygen, and incentivizing private investment (1,5–7).
Regulatory Framework	Relaxed government regulations facilitated production, distribution, and fast-tracked approvals (1,8).
Oxygen Stewardship	Monitoring systems and protocols helped minimize wastage through audits and assigned personnel (1,9,10).
Network of Distribution Systems	Efficient supply ensured through optimized transport, subsidies, and hub-and-spoke logistics (11,12).
Procurement and Acquisition System	Diverse sourcing strategies and global donations (ADB, WHO, UNICEF, and USAID) supported procurement efforts (13).
Workforce Capacity and Training	Shortages addressed via private and volunteer engagement and extensive oxygen therapy training (14,15)
International Collaboration	Global partnerships with high-income countries, WHO, USAID, and others improved oxygen availability and coordination (1,16).

Public-Private Collaboration	State incentives encouraged private sector support in production, logistics, and supply (17,18).
Monitoring and Audits	Robust audit systems and digital tools like ODTS, ODAS, and OCMIS ensured real-time tracking and minimized inefficiencies (10,19).
Preparedness and Planning	Strategic planning, including digital forecasting, helped mitigate future oxygen crises (1,20–22).
Digital Technology	Tools like ODTS, ODAS, and IoT, GPS, GIS, and RFID-enabled platforms enhanced real-time monitoring of supply chains (1,23–25).
Oxygen Management	Strengthening the oxygen supply chain is critical to ensure timely access for critically ill patients (26–28).

Appendix 2 : Comprehensive Knowledge Base

Relationship	Interpretation of the relationship between factors	References
F1-F2	Setting up guidelines and protocols for well-functioning medical equipment to ensure safe and reliable oxygen therapy	(86–89)
F2-F1	Ensuring guidelines and protocols are in place for efficient and reliable performance of well-functioning medical equipment	(30–33)
F1-F5	Setting up guidelines and protocols for efficient use of medical oxygen to minimize wastage and prioritize critical patients	(1,34)
F5-F1	Ensuring guidelines and protocols are in place for the efficient use of medical oxygen to minimize wastage and prioritize critical patients	(1,34)
F9-F1	Leveraging expertise and resources to ensure the highest quality and purity for medical oxygen and medical equipment procured from other countries and international organizations	(1,35–37)
F10-F1	Leveraging expertise and resources to ensure the highest quality and purity for medical oxygen and medical equipment procured from private players	(1,35–37)
F1-F14	High technical standards essential for patient safety, efficacy, reliability, and standardization of oxygen therapy care	(26,38)
F9-F2	Address the global support for managing shortages in production and availability of medical equipment; international guidelines for usage and maintenance	(1,39,40)
F10-F2	Incentivize private players to address the shortage of medical equipment, improve accessibility and quality, enhance maintenance and repair services	(41,42)

F2-F14	Sufficient availability and proper functioning of medical equipment required for ensuring safe, efficient, and timely access to medical oxygen to patients	(43,44)
F4-F3	Keeping a check of licensing and permits, imports and exports, quality of medical oxygen, pricing, and other aspects to ensure oxygen is available to those in need	(45,46)
F3-F6	Reduce delays, wait times, and disruptions in the supply chain of medical oxygen that is produced	(1,47,48)
F3-F7	Minimize inefficiencies, mismanagement, and disparities in oxygen management by acquiring oxygen supplies when existing capacity is insufficient	(1,48,49)
F11-F3	Accurate and real-time understanding and information about the demand and supply of medical oxygen required and available	(12,50)
F3-F12	Keep a check on existing capacity to plan and prepare for any unforeseen increase in oxygen demand in the future	(33,51,52)
F12-F3	Necessary oxygen supply in place to ensure to meet the steep rise in demand for oxygen therapy during the crises and in future contingencies	(89,101,102)
F4-F11	Information and guidance about the standards for the quality, safety, and efficacy of oxygen supplies as well as monitoring to respond effectively in a crisis	(53,54)
F11-F4	Ensuring compliance with guidelines, protocols, and regulations to be prepared and equipped to deal with contingencies and crises	(1,53,54)
F4-F12	Safe and effective management of oxygen to reduce shortages, contingency planning to be prepared to respond to any steep rise in demand	(55,56)

F4-F13	Rapid deployment of digital technologies for implementation, management, and monitoring of oxygen therapy	(35,54)
F10-F5	Ensure availability of oxygen to reduce the burden on the public healthcare system's oxygen supplies; pool resources, expertise, and knowledge to improve the availability and distribution while minimizing wastage	(1,57)
F5-F14	Prioritize oxygen allocation to critical cases and minimize wastage of medical oxygen	(9,10)
F6-F7	Effectively and efficiently secure and distribute essential oxygen supplies that need to reach the final health facilities in a cost-effective and timely manner	(3,4,98)
F7-F6	Ensure that the logistics network is well-stocked with the required resources and supplies in a cost-effective manner	(1,43,48)
F6-F8	Providing resources, supplies, and training needed by frontline workers to perform their jobs effectively	(58–60)
F8-F6	Capacity building and training programs for frontline workers to ensure staff has sufficient skills and knowledge to manage the distribution of oxygen supplies in crises	(58,59)
F6-F9	More international collaborations to develop new distribution systems to improve the efficiency and speed of oxygen delivery. Eg. Air bridges, solidarity oxygen express	(1,49)
F6-F10	More PPP to manage logistics; more effective response in logistics management by the private sector	(49,61)
F12-F6	Planning and forecasting oxygen demand for drawing up an elastic oxygen supply chain and distribution system	(62,63)
F13-F6	Plethora of digital tools and platforms to map and distribute oxygen supplies	(1,47)

F7-F9	Procurement and acquisition strategies for acquiring oxygen generation and storage capacity from other countries through imports or donations	(64,65)
F7-F10	Procurement and acquisition strategies for acquiring oxygen generation and storage capacity within the country through private sources; incentivize MSMEs and private players	(64,66)
F12-F7	Track, identify, and forecast procurement needs for medical oxygen, equipment, and consumables (vis a vis existing capacity)	(1,67)
F8-F10	Collaborations with the private sector to ensure healthcare workers have the skills, knowledge, and resources required to manage oxygen supplies effectively	(1,68)
F12-F8	Training staff for any future crises, oxygen therapy ecosystem, SOPs, and guidelines on various aspects of clinical treatment of patients on oxygen therapy	(62,69)
F13-F8	Medical and paramedical staff and volunteers provided training through digital tools and learning management systems; to have appropriate knowledge and skills to treat patients requiring oxygen therapy	(70,71)
F9-F10	Bringing together the resources, expertise, and knowledge of both public and private sector organizations and other countries as well as international organizations	(1,72,73)
F10-F9	Bringing together the resources, expertise, and knowledge of both public and private sector organizations and other countries as well as international organizations	(1,73,74)
F11-F12	Early detection of oxygen needs will help in proactive planning and management of the contingencies; and allow more response time to mitigate the impact	(75–77)
F11-F13	Setting up digital tools to enable active monitoring of oxygen demand and supply	(77,78)

F12-F13	Setting up digital tools to enable a more strategic and effective oxygen response	(79,80)
F13-F12	Effective planning and forecasting of oxygen demand and landscaping oxygen production capabilities; active monitoring of essential commodities	(79–81)

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