CASE STUDY

Moving Across Mountains: Enabling Medical Oxygen Availability in Hard-to-Reach Areas

Nearly 12% of the 3.29 million square kilometers of India's geography is covered by the mountainous terrain, which is administered by 13 Indian states and is home to 1 of every 30 Indians. While the whole country grappled with the effects of the second wave, it had more devastating effects on the hilly and hard-to-reach regions of India. As of January 22, 2022, the 13 mountainous states accounted for one of every five COVID-19 confirmed cases in the country.

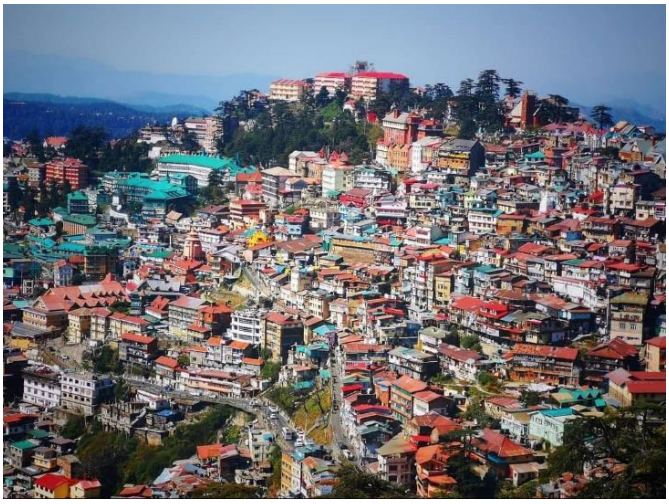
These undulating and often remote regions of the country present unique challenges to strengthening health infrastructure and improving access to healthcare. Many mountainous states in India have poor road connectivity despite high road density due to highly broken relief with vastly differing elevations, steep slopes, and deep gorges, among other factors. The population is spread sparsely or unevenly due to which often people have to walk long distances to even reach a primary health center (PHC) for health care. These regions often have extreme weather and geological conditions such as heavy rains, cloudbursts, snowfall, and landslides, among others. These result in roadblocks or frequent accidents on narrow windy roads, disrupting the normal movement of people and goods. In a few regions in India that are situated at an extremely high altitude, supplying even basic necessities remains challenging for some months in a year. Due to difficult terrain and extreme weather conditions, there is often low health-seeking behavior among the people in these areas.

PATH, with the support of Google and in partnership with Give India, initiated the setting up of 76 pressure swing adsorption (PSA) oxygen-generating plants across the country. Many health facilities in mountainous and hard-to-reach areas yet serving the communities vulnerable to COVID-19 were identified for setting up these oxygen systems.

This case study presents a glimpse of PATH's experience in proving respiratory support in three of the most hard-to-reach areas across India, namely, Shimla in Himachal Pradesh, Shillong in Meghalaya, and Kargil in Ladakh.

"*During COVID-19, hilly areas were worst hit with a shortage of medical oxygen. We worked with the health facilities in hard-to-reach locations in the hilly states on priority to make them self-sufficient in medical oxygen. Our experiences in these regions were unique, as setting up the PSA plant required different planning in constructing the plant site, moving the PSA plants, and commissioning them. Low atmospheric oxygen levels further magnified these challenges in some places with high altitude*."

Dr. Satish Tajne, Lead, Google Oxygen Project



Shimla, the state capital of Himachal Pradesh lies at an altitude of 2,206 m (7,238 ft)

PSA plant in Deen Dayal Upadhyay Hospital, Shimla: A case of constraint-based space planning

Deen Dayal Upadhyay Hospital: Shimla, the state capital of Himachal Pradesh situated at an altitude of 2,206 m (7,238 ft) and home to around 169,578 people, is also the location of one of the oldest hospitals in India, the Ripon Hospital. Founded by Lord Dufferin on May 14, 1885, and named after one of the Viceroys of India, Lord Ripon, the Ripon Hospital was renamed as Deen Dayal Upadhyay (DDU) Hospital and elevated to a zonal hospital by the Himachal Pradesh state government in memory of the late Deendayal Upadhyay, a prominent Indian political leader. The hospital got a newly constructed complex, which has a capacity of 256 general beds, 90 oxygenated beds, and 19 intensive care unit (ICU) beds. The hospital caters to a population of

PSA plant supported by Google installed in the existing PSA shed by extending the area to accommodate an 800 liter per minute (LPM) plant

approximately 2.5 including several nearby districts such as Mandi, Una, Kangra, Sirmaur, and Solan.

The DDU Hospital faced an oxygen shortage when the pandemic hit the peak, as patients from nearby districts such as Mandi, Una, Kangra, Sirmaur, and Solan, which have a relatively limited health service, came to this facility seeking treatment and care. On a daily basis, the hospital was recording more than 65 cases every day during the second wave of the pandemic. The hospital tried to manage the oxygen demand with the 335 type B cylinders and 271 type D cylinders it had during the second wave, but it was inadequate as the hospital management faced significant challenges in getting the empty oxygen cylinders refilled in time. The nearest bottlers and refillers were available in Mandi district, which is about 150 kilometers by road from Shimla and required a 4-hour journey one way, or in Baddi district, which was also around 4 hours one way from Shimla.

During the second wave, a 300 -LPM plant was earmarked through the Prime Minister's Citizen Assistance and Relief in Emergency Situations Fund (PM CARES Fund) to DDU Hospital, but this capacity was not sufficient to cater to oxygen demand for a 109 oxygenated bed capacity s per the Government of India's formula of oxygen demand estimation, the maximum daily oxygen requirement in DDU Hospital was around 2.74 MT, but the 300-LPM plant would generate only around 0.56 MT of medical oxygen, even when operating at 100% production capacity.

Site where the PSA plant with support from PATH has been installed

Selection process:

PATH's respiratory care program team approached the state National Health Mission (NHM) Himachal Pradesh to offer the PSA plant of 800-LPM capacity with the aid of Google and Give India partnership in the state. The NHM recommended DDU Hospital situated in Shimla, and after a thorough assessment conducted by the PATH team, DDU Hospital was selected in discussion with state officials for PSA plant commissioning. Strengthening the support to DDU Hospital was crucial to meet its oxygen preparedness and make the health facility more self-sufficient in oxygen management. It also meant a reduction in the burden on Indira Gandhi Medical College & Hospital, another nearby health facility in Shimla, and thus expansion of the capacity in the state to manage COVID-19 cases requiring oxygen therapy.

"*The Indira Gandhi Memorial Hospital (IGMC) was catering to more than 100 patients at any given time during the pandemic. It could accommodate another 150 patients. In view of the surge in demand for medical oxygen, it was important to make DDU more self-sufficient in medical oxygen so that more patients could be referred to the health facility*."

Dr. Sulekha Sharma, Chief Medical Officer (CMO), Shimla

Challenges and how we resolved them:

Following a go-ahead from the NHM and aligning the hospital administration at the DDU Hospital, the PATH team initiated the preliminary actions required for the civil work at the hospital for PSA plant installation when the initial hurdles emerged.

a. **Lack of space for the new PSA plant:** The DDU Hospital did not have enough space in its premises to meet the standard specification for civil work requirements for installing an 800-LPM PSA plant. PATH's state staff held a series of meetings with the hospital authorities and conducted several site visits to address this issue.

"*The hospital already had a 300 -LPM PSA plant installed near its parking area. Besides this space, there was no other space in the facility for a new plant. Finally, it was agreed that the existing structure where the hospital had the PM CARES–supported 300-LPM PSA plant shall be extended to accommodate the new Google-funded 800-LPM PSA plant. This could be only done by making modifications in the parking space*."

Bikramjit Debnath, Technical Manager, PATH

The hospital officials got the required permissions from the civil surgeon of the district and the officials at the Municipal Corporation and Public Works Department (PWD) of Shimla to modify the space according to the

norms for further modifying the parking area to adjust the PSA plant.

"*There was good interdepartmental coordination between the various departments for the permissions required for the modification in the parking space and thus leading to completion of the civil works for the site. The PSA plant through PATH's support has been installed in the middle portion of the old and new DDU Hospital complex. The plant given by Google and Give India with PATH's support has been very timely as we are now able to deal appropriately with severe cases of COVID requiring medical oxygen*."

Dr. Rana, Nodal Officer, Oxygen, DDU Hospital

With the necessary approvals in hand, the PATH team initiated the civil work for the new PSA plant installation at the DDU Hospital premises.

b. Location of the DDU Hospital:

The location of the DDU hospital presented another set of distinct challenges. The large truck (around 40 feet) used to transport the PSA plant from Bengaluru to Shimla could not be used for delivering the PSA plant to the hospital as the roads in Shimla are too narrow for the large truck to navigate, causing traffic jams and minor accidents due to the winding nature of the roads. Therefore, the PSA plant parts had to be shifted into three small trucks so that the plant could safely be transported to the site. Furthermore, the traffic police had to be informed prior to the trucks entering the city as narrow roads could also create traffic jams. The last few meters of road connecting the main road to the facility was a very narrow and steep slope. It took the three trucks over 4-6 hours to carry parts of the PSA plant up on this steep and narrow slope to the location designated for the installation of the plant.

c. Modification in the existing shed:

The existing shed that the Hospital had for the government-supported 300-LPM plant was made to accommodate only one plant. The modification was done to accommodate both the plants, and an additional space of 9 m x 6 m.

Additionally, since now two plants would run in the same shed, it was observed that there was a lack of sufficient ventilation. Therefore, air passage was increased in the shed by making further space for windows from the existing walls for cross-ventilation.

d. Moving PSA parts from the crane: During the installation, fencing of the parking area had to be cut down so that the crane could come inside. Furthermore, it took the crane almost 1 hour to move the parts from each truck to the site due to the narrow space available to the crane.

The Google-supported 800-LPM PSA plant at the DDU Hospital was installed, connected to the medical gas pipeline system of the hospital, and commissioned successfully with technical support from the PATH team in October 2021.

The slope leading to the DDU Hospital

Nitin, a shopkeeper living in Shimla expressed, "*I have never seen so much hardship in my town. I cannot recollect how many, but there were so many deaths in my city due to COVID-19. Only the affluent could spend Rs. 30,000 or more to purchase oxygen concentrators to save their near and dear ones. There is a sense of security and well-being now as my town is better prepared for managing COVID-19 cases as both IGMC and DDU Hospital are well equipped*."

The facility is now prepared for any future anticipated wave of a pandemic with an oxygen generation and delivery capacity of at least 1,100 LPM and a dedicated ICU facility. It is less dependent on refilling oxygen cylinders. At a given point in time, it can cater to more than 90 patients with respiratory issues. It will be catering to a population of more than 2.5 lakhs from Shimla and nearby districts and will thus act as a nodal center for respiratory care besides the IGMC. According to the State Nodal Officer, Dr. Jitender Chauhan,

"*Today, the Himachal Pradesh has an oxygen capacity of producing 100 MT of oxygen from various oxygen sources such as cryogenic liquid medical oxygen (LMOs), PSA plant donated by PM CARES, Corporate Social Responsibility (CSR) donations, and foreign donations*."

Installing an 800 LPM PSA plant at the Nazareth Hospital, Shillong, Meghalaya: Fast-tracking along the hilly tracks

Nazareth Hospital, Shillong

Shillong, the capital of Meghalaya state and referred to pre-independence of India by the British as the "Scotland of the East," is a hill station in the northeastern part of India. The state saw an unprecedented wave of the pandemic when the second wave of COVID-19 hit. In May 2021, the state has reported 21,576 COVID-19 cases and 268 deaths. In East Khasi Hills alone, where Shillong is located, the maximum number of active COVID-19 cases had reached 2,121 out of a total of 3,726 active cases. The state government brought in all public and private health facilities in the state, including the Nazareth Hospital, under the ambit of its oxygen management plan.

Started in 1959, the Nazareth Hospital in Shillong is a voluntary, non-profit organization administered by the sisters of the Holy Cross Menzingen. The Nazareth Hospital is a 400-bedded charitable hospital, with 20 ICU beds, 6 dialysis units, and 100 oxygen beds. The hospital caters to a population of more than 100,000 people from Shillong and adjoining areas and other districts of the state.

The facility managed the COVID-19 cases during the second wave with the 60 type D cylinders it had.


PSA plant being installed in Nazareth Hospital

"*Our health facility was just not prepared to handle the financial burden which came along with the pandemic.*

Mostly, the health facility was managing by using type D cylinders. Our vehicles were travelling long distances from Shillong to Guwahati in the adjoining state of Assam, navigating over 100 kilometers and around 3-4 hours one way for the refilling of the cylinders. We were spending about Rs. 10,000 including the vehicle cost, driver payment, loading, unloading charges, etc. We had to wait for long hours to get the cylinders refilled. The entire process was very cumbersome for us. Furthermore, we were buying the type D cylinders at a cost of more than Rs 530 per cylinder. We were also exploring any donor contribution for the PSA plant for our region. With the availability of the PSA plant, the costs for procurement of oxygen cylinders, which also includes their transportation costs, has greatly reduced."

Mr. Rethu Krishna, Maintenance Manager, Nazareth Hospital

Selection process: When the PATH respiratory care team approached the state of Meghalaya, the NHM Meghalaya recommended the state government identified Nazareth Hospital situated in Shillong for receiving the PSA plant. It is one of the priority facilities in the state to manage the high caseload and was notified as a dedicated COVID facility during the second wave, as it was catering to COVID-19 cases from all the nearby districts such as West Khasi Hills District, West Jaintia Hills District, East Jaintia Hills District, and East Garo Hills District.

Training of the technicians at Nazareth Hospital with PATH team support

Challenges

a. **Weather conditions:** When the PATH team initiated the site assessment work, the major challenge came in the form of climatic conditions. The region is known for continuous rainfall, and, therefore, it was challenging to complete the site assessment. With continuous efforts by the PATH team and hospital facility staff, this challenge was overcome.

b. **Transporting the 800 - LPM PSA plant to Nazareth Hospital:** Once the truck carrying the PSA plant parts reached the outskirts of the city, the regulations regarding traffic movement and movement of heavy vehicles restricted its entry. As per the state's regulations, the truck could not enter the city between 8 a.m. and 8 p.m. Furthermore, the roads leading to the Nazareth Hospital were narrow and winding, impacting the easy mobility of the truck and presenting another challenge to transporting the PSA plant. After completing the long and arduous journey, the truck was held up around 13 km from the hospital. The Nazareth Hospital administrators and the PATH team decided to transfer the PSA plant components from one large truck to smaller trucks. The PATH team in Meghalaya facilitated the transportation of the PSA plant to the Nazareth Hospital. It hired three smaller trucks and a crane to move the PSA plant components in parts from the trucks for this purpose and worked overnight to complete the offloading of the PSA plant at the hospital site in the wee hours of the morning. When the PSA plants arrived at the health facilities, new sets of challenges emerged, as the hospital did not have prior experience of installation in such difficult geography. Diligently, the PATH team further handheld the team and provided the required support. The PSA plant of 800 LPM capacity was commissioned in Nazareth Hospital in November 2021.

"*This will be the first hospital in Meghalaya to have been supported by PATH in partnership with Google and Give India with the provision of the 800 -LPM PSA plant. It will be a great significant achievement for the health facility, taking into account that this is one of the facilities in the state with a high caseload of COVID-19 patients during the second wave*."

Mission Director of NHM, Shri Ram Kumar

Traversing across nine states to install PSA plant in District Hospital, Kargil, Ladakh

Kargil, nestled in the western Himalayas, is one of the most isolated districts of the country. It became famous during the armed conflict between India and its western neighbor Pakistan in 1999. It is a remote, inaccessible, and high-altitude area that is the gateway to Ladakh from Kashmir. It is one of the two districts (the other being Leh) and the joint capital of Ladakh, the newly created Union Territory of India. Located at an altitude of 8,780 feet above sea level and spread over an area of 14,036 square kilometers, Kargil is home to nearly 141,000 people and is very thinly populated—just 8.3 people per square kilometers.

Many of the villages in Kargil are without motorable roads and get merely 3-4 hours of electricity in a day. More than 27 villages out of 127 inhabited villages in Kargil are without electricity. People are constrained to use mostly kerosene lamps to meet their extra energy demand. People living here bear the harshest of weather conditions such as extreme cold and nearly freezing temperatures dropping to -40°C, dryness, high radiation, low humidity, low oxygen, desert landscape, and limited water sources.

Speaking on the challenging conditions in Kargil, Dr. Phuntsog Angshuk, Former Director Health, Union Territory Ladakh said, "*The district is among the less developed districts of the country, ranking at the bottom in infrastructural facilities and overall socio-economic development. For almost six months, life in Ladakh comes to a standstill as the temperature dips down to -40°C, roads get covered with ice due to snowfall, and they become slippery. The region is often completely disconnected from nearby areas such as Srinagar and Himachal Pradesh*."

Even this remote region was not left untouched by the COVID-19 pandemic. When the COVID-19 cases started increasing during the second wave, the 180-bedded Kargil District Hospital with 40 ICU beds was identified as a dedicated COVID facility. The hospital was getting more than 410 admissions of COVID cases during the second wave. Although the facility had around 300 type D cylinders and 69 type B cylinders, it was not connected

well enough to ensure a steady supply of medical oxygen. Moreover, the peak demand for oxygen was very high (around 4,500 M3), which became a challenge for the hospital to manage.

"*We made efforts to facilitate the process of the PSA plant assessment, installation and commissioning in both Shimla and Kargil. There was continuous coordination required with the hospital administration, state nodal officers, and electricity departments for both the sites. A number of challenges emerged, such as the unavailability of electricians at the site and power issues, but we were determined to get the work done amid all the challenges that these hard-to-reach areas offered us*."

Mr. Anil Sharma, State Lead, PATH

PATH respiratory team which was focusing on reaching the hard-to-reach areas approached the NHM Ladakh for providing support of the PSA plant. PATH in partnership with Google and Give India supported the health facility with an 800 - LPM PSA plant.

"*The experience of providing PSA plant to an area like Kargil was different as Kargil is located at one of the highest altitudes of 8,780 feet and is having one of the toughest terrains in India. The transportation was done across nine states, namely, Karnataka to Ladakh via Andhra Pradesh, Telangana, Maharashtra, Haryana, Punjab, Himachal Pradesh, and Jammu and Kashmir, crossing a distance of 3,200 km and crossing many plains, deserts, and the Himalayan region to reach the health facility in a span of 10 days*."

Dr. Jayendra Kasar, Senior Program Officer, PATH

Map showing the distance traveled by the track to reach Kargil

Dr. Satish Tajne, further added on the importance of the support given in this health facility, "*Once set up, the oxygen plant in Kargil can meet the medical oxygen needs of not only the local population but also the injured personnel of the armed forces and tourists who may suffer from low oxygen conditions at such high-altitude locations*."

Challenges

Long border delays with limited road infrastructure: The roads were snow-covered and had become slippery. To avoid accidents, the drivers many times had to halt and wait till the roads became manageable for travel. In one instance, the drivers had halted for five days at the Kashmir border due to snow-covered roads.


The truck carrying PSA plant halted at Srinagar road

No internet for accessing GPS: There is a lack of GPS communication and information on the whereabouts of the vehicle location in such locations.

Climate poses a challenge for PSA plants: The oxygen level was very low in this region about 14.2% due to which an additional air compressor has to be provided for maintaining productivity. This is recommended by PATH, and with the support of Give India, it is being arranged.

Driving was challenging: Maneuvering the truck was challenging for the drivers as this was the first time some of them were driving in such a high-altitude region. Moreover, continuous driving made the drivers face driving fatigue.

Extreme temperature: Extreme cold weather conditions posed a challenge for the drivers. Kargil had an extreme temperature of -40°C at the time the truck reached the health facility in Kargil. Furthermore, fuel and lubes became thick due to the extreme weather and further posed a challenge in transportation.

The PSA plant in Kargil was commissioned in December 2021.

"*Now we are not dependent on only cylinders. Including the Google PSA support, our facility has 2,700 LPM to manage oxygen crises in the future. We are much better prepared to handle the third wave now*."

Dr. Munawar Hussain Wazir, CMO

Lessons

1. Health facilities in mountainous and hard-to-reach areas need captive oxygen generation and delivery capacity: PSA plants and oxygen concentrators are best suited to reduce dependence on cylinders, which are unreliable in cases of emergency or high demand.
2. Delivery of heavy machinery to hard-to-reach areas will require a different logistics arrangement, where the plant is delivered in one shipment up to a certain point and then transferred to smaller trucks for the final leg.
3. Health facilities in mountainous locations will have space constraints for infrastructure expansion. It will need different space modifications while also adhering to the standard specifications.
4. As these regions also have poor infrastructure, such as lack of electricity and access to fuel (such as diesel), it would require further planning or alternate, greener, more sustainable, and reliable options.

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PATH is a global nonprofit dedicated to achieving health equity. With more than 40 years of experience forging multisector partnerships, and with expertise in science, economics, technology, advocacy, and dozens of other specialties, PATH develops and scales up innovative solutions to the world's most pressing health challenges.

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