SMART Logistic networks with Drones for TB care and management

Health Technology Assessment in India–

Regional HUB - Kalam Institute of Health Technology

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Study Title-

SMART Logistic networks with Drones for TB care and management

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Contents

Introduction

Tuberculosis (TB) is a treatable and preventable infectious disease primarily affecting the lungs, caused by Mycobacterium tuberculosis complex. It can impact various organs except hair and nails. While pulmonary TB is infectious, extrapulmonary TB is less common. Approximately 5-15% of individuals exposed to TB bacilli develop the disease. Despite being curable, comorbidities, extended treatment, and drug resistance contribute to treatment failures. In 2019, around 10 million people worldwide contracted TB, with many cases concentrated in high-burden countries including India, Indonesia, and China. TB control strategies aim to diagnose and treat infectious cases, while elimination strategies aim to address latent infection to prevent future cases. TB elimination is defined as reducing the incidence to less than one case per million population. However, TB's easy transmission, lack of natural immunity, difficulty in diagnosis, and reactivation potential hinder eradication efforts. Developed countries have implemented sustainable interventions, such as vaccination, treatment of latent infection, and integrated management. The World Health Organization (WHO) plays a crucial role in global TB elimination efforts, aligning with the End TB strategy focused on equitable, rights-based approaches. India, with a high TB burden, has implemented various control programs, including the National Tuberculosis Control Program and the current National TB Elimination Program (NTEP), to combat the disease. TB remains a global health challenge, with the WHO's End TB plan targeting significant reductions in incidence and mortality by 2035.

Tuberculosis (TB) has historically posed a significant threat to global health, ranking as the leading cause of death from a single infectious agent before the COVID-19 pandemic. In 2020, the World Health Organization (WHO) reported 5.8 million TB cases and 1.5 million TB-related deaths worldwide. While the pandemic influenced a decrease in new TB diagnoses, TB-related deaths increased compared to the previous year. The global TB incidence has seen an 11% cumulative decline from 2015 to 2020, yet the rate remains inadequate. TB incidence varies across countries, with significant societal and health costs. The WHO's End TB plan aims to reduce TB incidence to under 10 cases per 100,000 people and decrease fatalities by at least 95% by 2035. The plan advocates universal targets, including an 85% treatment success rate and comprehensive testing for drug resistance and HIV in TB-diagnosed patients. The ambitious plan seeks to eliminate TB as a global public health concern, necessitating tailored national targets and rigorous monitoring.

For effective implementation of the ETS, a tailored approach is necessary to monitor active TB cases, treatment follow-up, and case detection, considering each country's unique epidemiological characteristics related to TB incidence, prevalence, and risk factors. The WHO emphasizes the importance of conducting a thorough assessment of the national epidemiological and health system situation before executing the strategy. This evaluation should identify the groups most affected by and vulnerable to TB infection based on factors such as age, gender, comorbidities, nutritional status, tobacco, and drug use. (2)

Under the first pillar of the ETS, which focuses on integrated, patient-centred care and prevention, collaborative identification and management of HIV/TB cases are crucial. Additionally, the ETS highlights the need to prioritize groups at risk of poor treatment uptake and loss to follow-up. By addressing these aspects, the WHO's End Tuberculosis Strategy aims to combat TB effectively and reduce its burden on affected populations. (3)

Tuberculosis and India

For over five decades, India has been actively involved in tackling tuberculosis (TB), which remains a critical health concern for the country. India has made significant advancements in the diagnosis, treatment, and management of TB patients, employing advanced technologies and therapies. With the highest burden of TB globally, India witnesses approximately 2.6 million new cases and 400,000 deaths annually from the disease. The associated financial costs, in terms of lives lost, reduced income, and productivity, are substantial. To address this challenge, the Ministry of Health, and Family Welfare (MoHFW) has crafted an ambitious national strategic plan, aiming to eliminate TB by 2025. A multi-sectoral approach is essential to combat TB, addressing socio-economic factors and improving access to diagnostic and treatment services. Collaborative efforts are sought from various stakeholders, including cooperative societies, corporations, individuals, NGOs, and political parties. Drawing inspiration from successful polio eradication strategies, India's plan to eradicate TB involves strengthening the healthcare workforce, engaging private providers, fostering community involvement, enhancing surveillance systems, and introducing accurate diagnostic tools. Patient support, active case finding, and targeted preventive treatment for high-risk groups like household contacts, children, and PLHIV will be prioritized. Through these comprehensive measures, India aims to reduce the TB burden and ultimately achieve its eradication, mirroring the success of polio eradication efforts. (4,5,6)

TB medicines are given free of cost in India. Timely adherence to medicines is of outmost importance as the disease is completely curable. Hence ensuring the right TB medicines available for the right patient at right time for the right duration must be ensured to achieve the 2025 goals of TB elimination. (7)

Tuberculosis medicine distribution in India

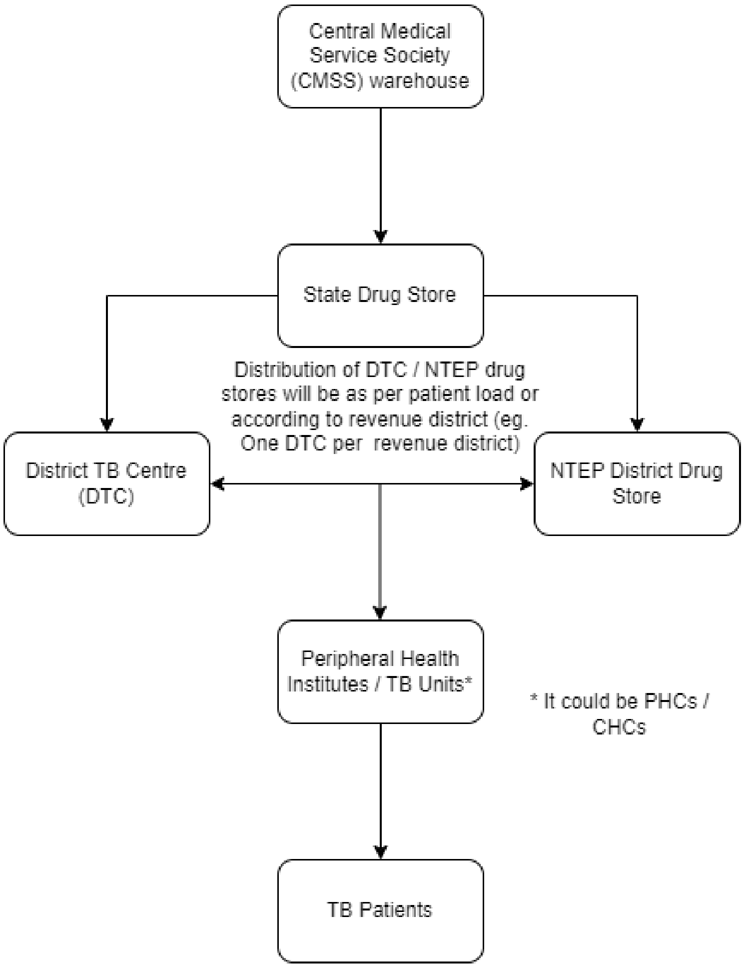


Figure 1: Conventional TB drug distribution system in India

The TB drug purchase has been done through central purchasing scheme, where the CMSS will call for tender followed by distribution of the purchased medicines to the stares based on their need. However, recently the purchasing has been given to states. This has resulted in an acute shortage of drugs across the country as the state purchasing receives less interest from TB drug manufactures.

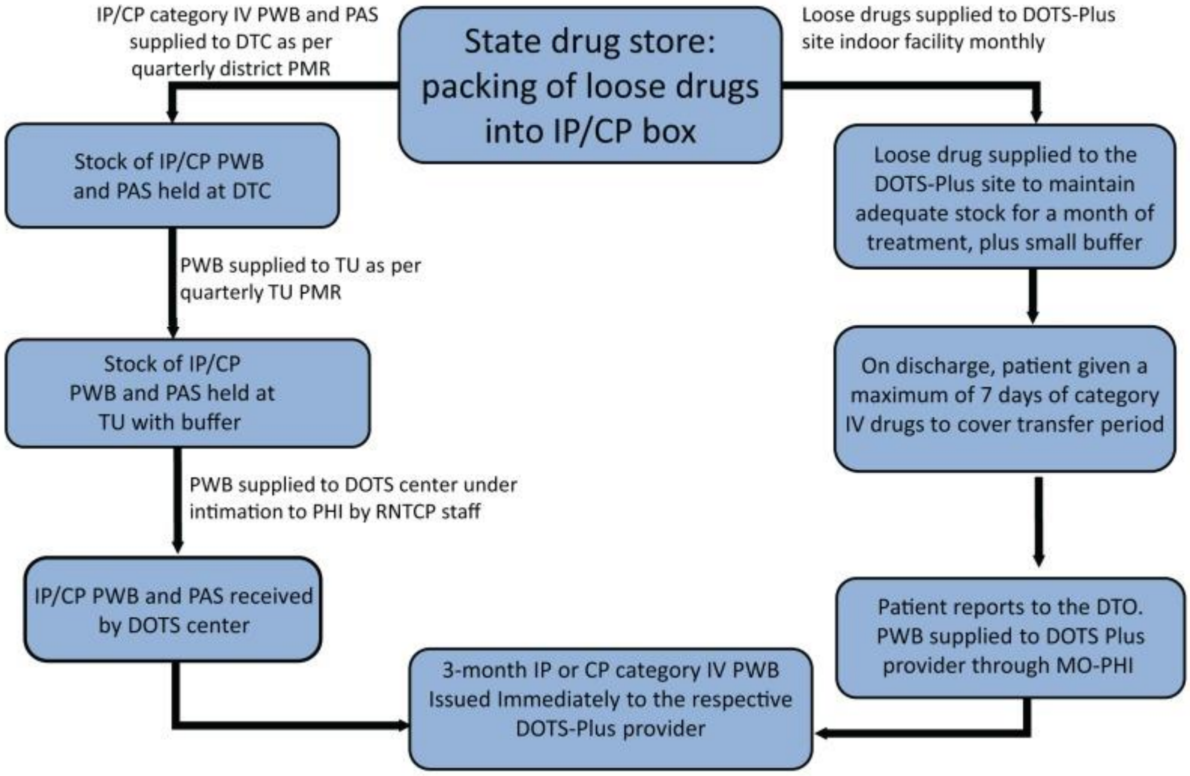


Figure 2 : Distribution of second line TB medicines (Injections) (8)

Health system supply chain challenges in India

India's healthcare system faces considerable challenges in ensuring adequate coverage, particularly in remote and rural regions. With 28,863 primary healthcare centers responsible for vaccine distribution, covering vast areas averaging 44.46 square miles each, last-mile delivery becomes a significant hurdle. Geographical complexities, such as mountainous terrains, jungles, and deserts, coupled with mobile populations, make it difficult for health workers to reach and vaccinate everyone effectively. This leads to incomplete vaccinations among rural children. The lack of proper infrastructure exacerbates these challenges, with poor roads, monsoon-related supply route disruptions, and electricity shortages impacting medical supply chains. The decentralized distribution process, involving multiple levels of facilities and irregular restocking schedules, further complicates inventory management. Consequently, healthcare facilities often face shortages and resort to alternative procurement methods. Inadequate blood logistics also pose a critical problem in several Indian states, leading to preventable deaths and increased financial burdens. Innovative solutions, such as drone delivery, are urgently needed to overcome these obstacles and enhance vaccine access, ensuring the availability of essential medical resources in remote areas while addressing the broader complexities of healthcare logistics.(8)

Supply chain challenges in TB medicines

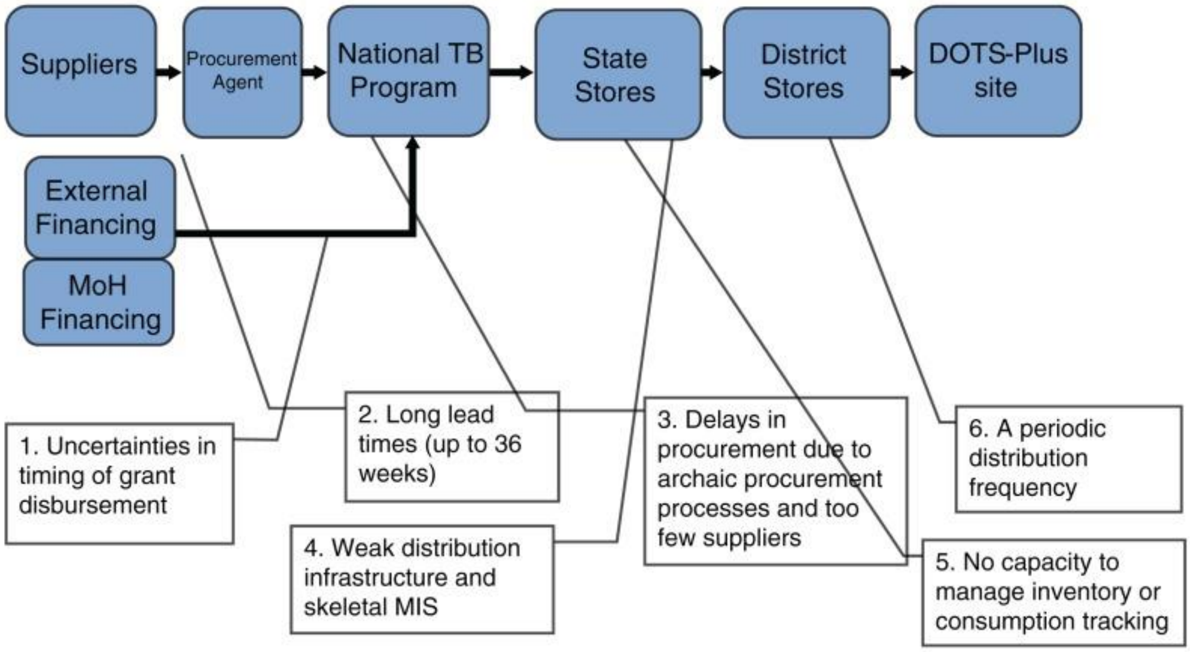


Figure 3 : Challenges in the TB medicine distribution system (8)

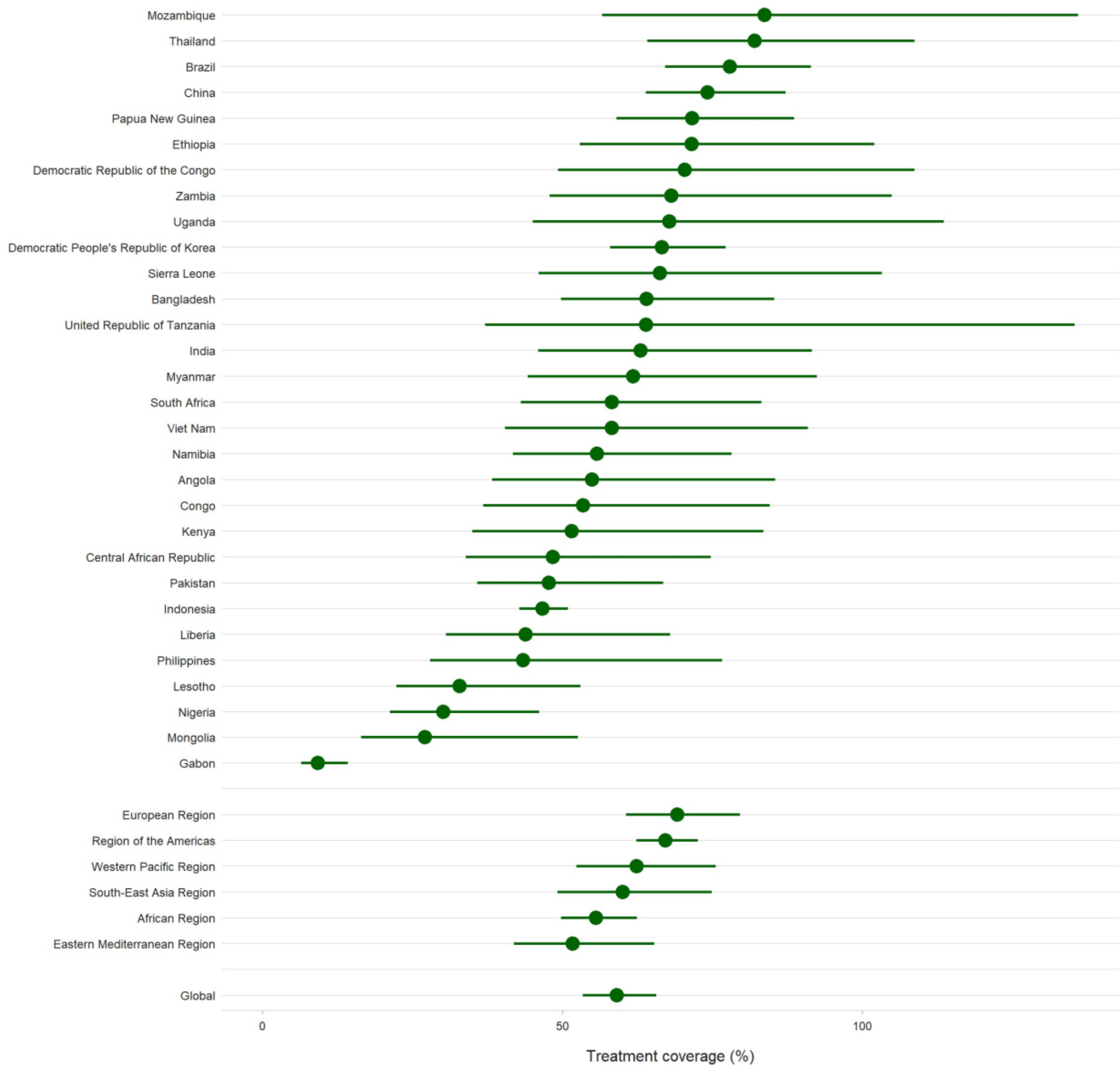


Figure 4:TB treatment coverage in 2020 for 30 high TB burden countries

Figure 1 depicts that there exists a big gap exists in the coverage of TB treatment in the high burden countries. India, accountable to contribute nearly 28% global TB cases coverage ranges between 60 and 65%. The global TB strategy states coverage is a critical indicator in tracking the implementation of the End TB Strategy, with a recommended target of at least 90% coverage by 2025. This indicator serves as a key measure to evaluate the progress made in combatting TB and ensuring effective treatment for those affected. Moreover, TB treatment coverage is among the 16 indicators employed to assess advancements towards achieving Universal Health Coverage (UHC) as part of the United Nations' Sustainable Development Goals (SDGs). By including TB treatment coverage in the UHC target, the global community aims to address TB as a public health concern and enhance access to comprehensive healthcare services for all populations, fostering progress towards sustainable development. (9)

Measures taken by Government of India to combat supply chain issues for TB medicines.

To enhance supply chain efficiency and address existing challenges, several innovative strategies were adopted. Delayed payment issues affecting drug production and shipment, especially for second-line drugs, were mitigated through short-term solutions like bridge financing. Novel approaches such as initial up-front deposits, guaranteed order volumes, options pricing, and deferred purchasing contributed to resolving supply chain financing problems. Improved forecasting, driven by data-driven state-level micro-planning, along with the expansion of services based on DOTS-Plus geographic and time-based considerations, enhanced supply chain performance. Laboratory capacity was elevated, and transparent information exchange with suppliers ensured cost reduction. The standardization of quality norms across the supply chain created a uniform marketplace, fostering demand for quality products. Risk aggregation through global ordering rather than country-specific ordering revolutionized drug procurement methods. A virtual rotating stockpile was introduced to prevent stockouts, and effective forecasting aided in quantifying and managing risk factors. (8)

SMART Logistics criteria

The term "SMART" is often used as an acronym to represent the following attributes: Specific, Measurable, Achievable, Relevant, and Time-bound. It is commonly used in goal setting and project management contexts to create well-defined and attainable objectives.

In the logistics industry, the term "SMART" could potentially be used to describe an approach or network that incorporates the SMART principles into its operations and strategies. For example:

Specific: Clearly defining the logistics objectives, tasks, and responsibilities.

Measurable: Establishing key performance indicators (KPIs) to monitor and evaluate the efficiency and effectiveness of the logistics network.

Achievable: Ensuring that the logistics network's goals are realistic and feasible given available resources.

Relevant: Aligning the logistics network's objectives with the overall business goals and customer needs.

Time-bound: Setting deadlines and timeframes for the achievement of logistics milestones and targets.

Smart Logistics integrates cutting-edge technologies to address challenges and create innovative solutions within the logistics sector. Leveraging real-time data and predictive analytics, the approach emphasizes proactivity in problem-solving and decision-making. Central to this approach is the vital role technology plays in enabling efficient and effective supply chain management within a Smart Logistics system. As technologies continue to advance, their integration will further enhance the responsiveness and efficiency of logistics networks, shaping the future of the industry and driving it towards improved outcomes. (10)

SMART Logistics using drones.

Drones have emerged as a transformative solution in delivering medication and medical supplies to remote and rural areas, effectively overcoming barriers to healthcare access. Partnerships between companies like Zipline and Novartis in Ghana and Swoop Aero in Malawi and the DRC have demonstrated the significant reach and impact of drone delivery. Patients with conditions like sickle cell disease and those needing HIV medicines benefit from timely and efficient deliveries, eliminating the need for long and arduous journeys to healthcare facilities. Moreover, drones play a crucial role in swiftly transporting lab samples to testing centers, contributing to disease surveillance and control efforts. Overall, the use of drones in healthcare showcases their potential to revolutionize medical supply chains and enhance healthcare access, particularly in underserved regions, ultimately improving patient outcomes and public health. (11)

The transportation of biological samples, such as blood units and organs, is critical, as the quality and stability of these samples are highly sensitive to transit time. However, geographically challenging areas with long and circuitous routes and urban locations facing unpredictable journey times due to rush-hour congestion pose significant difficulties in ensuring timely delivery of these samples. To overcome these barriers, uncrewed aerial vehicles (UAVs) or drones emerge as a potential solution, offering a promising option for swift and efficient transportation of clinical samples, even in challenging and time-sensitive situations. (11)

The rapid development of drone technology necessitates the establishment of a robust framework and tools to ensure safe and effective use for the delivery of medical products. Traditional stability testing methods need expansion to encompass the unique stresses experienced during drone transportation, such as vibration, g-forces, pressure changes, humidity, and temperature fluctuations, which can impact the integrity of medicines. Cutting-edge technology allows UAVs to be flown beyond the visual line of sight (BVLOS) with communication between ground pilots and the vehicle. However, existing civil aviation regulations are not keeping pace with these advancements, and only a few exceptional cases have allowed pilot studies to demonstrate the full potential of over-the-horizon delivery missions. Addressing regulatory challenges is imperative to unlock the true capabilities of drones in medical product delivery. Advanced economies such as UK are considering using drones to overcome the recent geopolitical transitions in Europe such as Brexit.

Drones, or Unmanned Aerial Vehicles (UAVs), have emerged as a transformative technology in logistics with vast potential. They offer unique capabilities that address diverse challenges and create new opportunities for innovative and efficient logistics operations. Notably, drones excel in last-mile deliveries, reducing delivery times and costs by bypassing road congestion and directly reaching customers' doorsteps, particularly advantageous in urban areas. Their efficiency in catering for disaster relief measure were extensively being utilised. The ability to swiftly assess and deliver critical supplies to hard-to-reach areas due to their ability to access hard-to-reach locations has yet to be completely exploited efficiently. In logistics and warehousing, drones automate inventory management tasks, optimizing storage arrangements and streamlining processes. Their high-resolution cameras and sensors enable remote inspections of infrastructure assets, reducing risks and facilitating maintenance.

Maximizing the benefits of drone delivery in medical supply chains requires a collaborative effort from technologists, government leaders, and healthcare and social advocates. To ensure the successful integration of drone technology, it is essential to prioritize public safety, represent community interests, and consider cost-effectiveness without diverting investment capital from other critical aspects of the system. In transitioning from theoretical principles to practical implementation, this briefing paper aims to provide an overview of key considerations for designing medically oriented drone delivery deployments. It addresses the following aspects:

Challenges in Medical Supply Chains

Identifying and addressing specific challenges in medical supply chains that can be effectively tackled by incorporating drone delivery. These challenges may include last-mile delivery issues, access to remote areas, emergency response, and ensuring timely and efficient delivery of critical medical commodities.

Framework for Evaluation: Developing an initial framework to assess potential drone delivery projects in the medical field. This evaluation process should consider factors such as geographical terrain, infrastructure, regulatory environment, logistical complexities, and anticipated benefits.

Trade-offs in System Design: Recognizing the trade-offs between various system designs and technologies used in medical drone delivery. This involves weighing factors like drone capabilities, payload capacity, range, reliability, cost, and the level of human involvement in the process.

By addressing these fundamental issues, stakeholders can pave the way for successful and impactful drone delivery deployments in the medical sector, ultimately improving healthcare access, patient outcomes, and the overall efficiency of medical supply chains. (11)

Transport of medicines using drones

The transportation of medicines using drones involves two main propulsion designs: rotor (vertical take-off and landing - VTOL) and fixed-wing variants. Technical advances are blurring these distinctions, leading to new hybrid designs that combine both functionalities. The choice of drone design can impact the stability of the medicines being transported. The scenarios where drone delivery of medicines has the greatest impact include emergency situations, urban environments, and geographically challenging locations. Drones offer speed, cost-effectiveness, and the ability to overcome physical barriers in these scenarios. For emergency deliveries, speed and precision are crucial, and the ability to hover and assess the situation can be vital. Ensuring medicine quality and patient safety in case of drone failure is essential, especially for sensitive biopharmaceuticals like antivenom injections. In urban environments, drone deliveries can be part of the final-mile delivery approach, reducing transport time and offering the possibility of delivering personalized medicines prepared at local pharmacies. However, security concerns may arise in this context, necessitating additional protective measures for the supply chain. Transporting medicines to geographically challenging locations requires careful consideration of factors like safe flight time, range, on-board conditions, and post-flight medicine quality testing. Vaccines, antimalarials, and blood products are particularly sensitive to environmental factors, and their quality must be closely monitored during transportation. Despite concerns, successful pilot projects have demonstrated the potential of drones in transporting medicines and medical products, offering a promising solution to enhance healthcare access in diverse scenarios. (11)

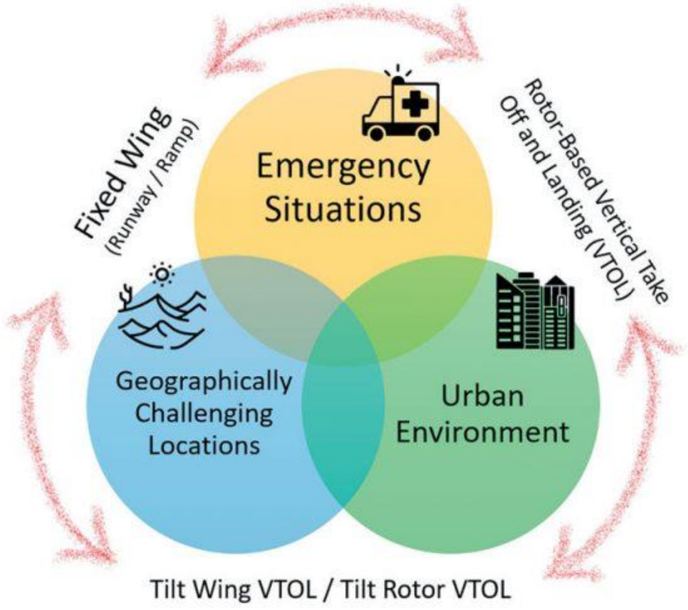


Figure 5: Types of drones and their potential service areas (11)

Usage of drones across the globe

In the quest to address the challenges of accessing remote communities around Kerema town, the collaboration between MSF (Médecins Sans Frontières) and US Company Matternet introduced innovative technology as a solution. They conducted trials using small quadcopter Unmanned Aerial Vehicles (UAVs) to transport sputum samples of patients with suspected Tuberculosis (TB) from remote health centers to Kerema general hospital for testing. Additionally, the UAVs were considered for transporting test results and treatments back to the remote facilities. This initiative aimed to bridge the gap in healthcare access and improve TB diagnosis and treatment in hard-to-reach areas, demonstrating the potential of cutting-edge technology to revolutionize healthcare delivery in remote regions. (12)

Rwanda has emerged as a pioneering user of drone technology since 2016, when it embraced drones for the crucial task of transferring blood supplies between medical facilities. This innovative drone network is operated in collaboration with Zipline, a California-based robotics company that oversees the design and management of the drone fleet and launch sites. The initiative is made possible through a partnership between Gavi, the Vaccine Alliance, which focuses on expanding access to vaccines in low-income countries, and UPS, the renowned international package delivery and supply chain management company. By leveraging drone technology for the efficient and timely transportation of blood supplies, Rwanda has demonstrated its commitment to improving healthcare services and saving lives, making drones an integral part of the country's medical infrastructure. (13)

A study from Europe on effectiveness of biomedical sample transportation within a specified period showed drones offer a time-efficient and cost-effective solution for transporting biomedical samples in time-critical healthcare operations. Traditional services often cause delays due to minimum volume requirements and variable delivery times affected by traffic conditions. In a cost assessment analysis, drones were found to deliver biomedical samples three times faster and at 60% lower cost compared to electric vans. The drone delivery scenario involved fixed routes between hospitals, ensuring reliability and independence from traffic conditions. For time-sensitive operations of less than 60 minutes, the speed and reliability of drone delivery make it highly advantageous. In less time-sensitive situations, e-vans may be more cost-effective due to their larger volume capacity. Overall, drones prove to be an efficient and dependable option for ensuring timely delivery of critical medical samples. (14)

Table 1: Snapshot of trials conducted using drones for distributing medicines and medical products (14)

Site	Company	Product	Flight duration	Distance	Maximum	Safety device
Vanuatu S. Pacific	Swoop Aero, Wingcopter	Vaccines	30 mins	45km	6kg	Teardrop shape, remote control dropping, ice, temperature sensor

Rwanda and Ghana	Zipline	Blood	30 mins	80km	1.8kg	Redundant systems: parachute landing, communication
Tanzania	DHL, GIZ &Wingcopter	Snake venom antiserum, etc.	40 mins	60km	6kg	Thermally insulated box
Urban Switzerland	Swiss Post, Matternet	Blood, test specimen	10 mins	3km	2kg	QR code for opening the case, parachute landing
Rural Virginia	Flirtey	Drug	3 mins	Not mentioned	5.5kg	Anti-drone collision system (NASA), parachute landing
Rural Madagascar	Vayu	Blood and faeces test specimen	Not mentioned	Up to 60km	2kg	Lock
Rural China	SF Technology	Injection	Not mentioned	Up to 15km	8kg	Ice

The Unmanned Aircraft System Rules (UAS Rules) 2021 - India

The Unmanned Aircraft System Rules (UAS Rules) 2021 were introduced by the Ministry of Civil Aviation in India to govern the usage and operation of drones in the country. Issued in March 2021, these rules categorize drones based on their maximum take-off weight and lay down specific requirements and restrictions for each class. All drone operators are mandated to register their drones and obtain necessary permits or approvals from the Directorate General of Civil Aviation (DGCA) before flying them in Indian airspace. The rules establish "No Drone Zones" around sensitive areas, including airports and military installations, where drone operations are prohibited. Additionally, operational limitations such as flight altitude, distance from aerodromes, and restrictions during night operations are stipulated. Drone pilots must obtain a Remote Pilot License (RPL) and adhere to prescribed safety features like 'No Permission-No Take off' capability. The Digital Sky Platform, an online portal developed by the DGCA, facilitates the registration and approval process for drone operations. The UAS Rules 2021 seek to regulate drone usage while ensuring safety, security, and privacy considerations are met, and they encourage responsible drone operations in India. (15)

Meghalaya Drone Delivery Network: A successful intervention by using drones for medical use.

In the hilly state of Meghalaya, where reaching remote health facilities has long been a logistical challenge due to rugged terrain and inadequate road infrastructure, the government's Meghalaya Health Systems Strengthening Project (MHSSP) has embraced an innovative solution – the use of drones. Expected to revolutionize medical supply transportation, drones are envisioned to efficiently deliver vaccines, medicines, diagnostic samples, blood units, and other crucial medical commodities to remote areas. Recently unveiling India's first drone station at Jengjal Sub-divisional Hospital in West Garo Hills, this pioneering initiative will cater to hard-to-reach health facilities within a 50 km radius, significantly reducing delivery times and facilitating both routine and emergency supply transfers. With plans for further expansion and integration into the existing public health supply chain, this forward-looking endeavour aspires to ensure equitable access to quality healthcare for all residents of Meghalaya. (16)

Health implications of TB medicine distribution using drones.

Need for the Study

The integration of drone technology holds immense promise in addressing the challenge of reaching populations that remain beyond the reach of conventional transportation methods, particularly when it comes to delivering essential TB medicines. This innovation could potentially bridge the geographical gaps that have hindered the efficient distribution of TB medications, thereby enhancing the coverage and accessibility of treatment to remote and underserved areas.

In gauging the health impact of such an intervention, a feasible approach could involve monitoring the number of individuals who successfully receive the prescribed TB medication through drone-assisted delivery. This metric would provide an indirect yet valuable insight into the effectiveness of the intervention, as a higher medication coverage rate would signify a more comprehensive approach to tackling the burden of TB within these populations.

The benefits of improved medication coverage extend beyond mere numbers. An elevated coverage rate has the potential to translate into tangible health outcomes, including a notable reduction in TB-related morbidity and mortality. By ensuring a wider and more equitable access to essential TB medicines, drone-enabled delivery has the capacity to contribute significantly to curbing the impact of this infectious disease.

A comprehensive assessment of the intervention's cost-effectiveness would ideally involve the incorporation of disability-adjusted life years (DALYs) – a comprehensive metric that captures both the burden of morbidity and mortality. DALYs provide a standardized means of quantifying the overall health impact of various interventions, allowing for meaningful comparisons with other healthcare initiatives. By employing DALYs as a measuring tool, decision-makers can gain valuable insights into the potential value and efficiency of utilizing drones for TB medicine delivery, thus informing resource allocation and policymaking for optimal public health outcomes. (17)

The utilization of drones also brings about notable environmental benefits. One significant advantage lies in the eco-conscious nature of many drones, as a considerable portion of them operates without the need for conventional fuels. A particularly noteworthy environmentally sustainable facet is the ability to charge drone batteries using solar energy, thus aligning with eco-friendly practices. By employing drones, a tangible reduction in carbon emissions can be achieved, especially when contrasted with the carbon footprint associated with diesel-powered cars or motorcycles typically employed for last-mile delivery purposes.

Moreover, the consideration of product quality constitutes another vital aspect. The stringent quality demands of most vaccines necessitate continuous refrigeration throughout the entirety of the supply chain, from initial manufacturing to final service delivery, to ensure the product's integrity. In this context, the expedited drone delivery window offers a distinct advantage. Unlike traditional transportation methods, where the assurance of refrigerated conditions is required over extended periods, drones enable a significantly shorter time frame for delivery. This condensed timeline, combined with the potential for precision logistics, contributes to minimizing the risk of compromising product quality. Thus, the utilization of drones not only enhances efficiency but also safeguards the quality and efficacy of vital medical supplies throughout their journey to the intended recipients.

However, there is a need for a more integrated approach to user experience and engagement in the drone delivery process to ensure it remains user focused. Implementing a new delivery system like medical delivery with drones raises various interaction issues with medical and nursing staff, pharmacists, dispatchers, and patients. As the field lacks user-centered research, further studies are required to investigate human-drone interaction, including both demand- and technology-driven aspects. A mixed-method approach can be valuable in assessing the usefulness and usability of drones, considering the needs of all users, and translating them into functional requirements and design guidelines. (18)

The integration of drones into medical supply chains offers potential cost savings in various scenarios, including complementary use alongside existing transport options and deliveries within specified flight range and payload limits. These cost benefits arise from reduced operational and personnel expenses, the possibility of minimizing inventory holding time and waste, and the increased frequency of deliveries. Drones also bring notable performance improvements, such as enhanced speed for emergency shipments, increased flexibility to reach remote areas, and higher delivery frequency to prevent stock-outs. Collectively, the use of drones not only promises economic advantages but also contributes to improved healthcare supply chain efficiency and accessibility.

Objectives

1. To determine the effectiveness in terms of health benefits while using drones for TB medicine distribution
2. To evaluate the supply chain effectiveness of drone-based TB medicine distribution in India
3. To evaluate the feasibility for using drones as standard supply chain for the medicines and biomedical sample transportation in different geographical terrains.

Inclusion criteria

1. Tuberculosis patients requiring drug delivery for treatment.

2. Studies conducted in distant or underserved locations, resource-constrained settings, or regions lacking healthcare infrastructure.
3. Studies focusing on the use of drones for medicine delivery in tuberculosis treatment.
4. Studies comparing drone-based medication delivery with traditional ground conveyance or manual distribution strategies for tuberculosis treatment.
5. Investigation of how access to medications, delivery timeliness, treatment compliance, and overall treatment outcomes affect tuberculosis patients.
6. Consideration of randomized controlled trials (RCTs), quasi-experimental studies, observational studies, economic evaluations, or systematic reviews/meta-analyses.
7. Studies published in peer-reviewed journals or conference proceedings.
8. Studies conducted in the English language between the years 2000 and 2023.

Exclusion criteria

1. Studies that do not specifically address drug delivery aspects of tuberculosis treatment or do not involve diagnosed tuberculosis patients.
2. Research not focusing on using drones for delivering medications in tuberculosis treatment.
3. Studies not comparing traditional medicine delivery methods with drone-based medication delivery for tuberculosis.
4. Non-original works, such as editorials, essays, or letters, without a well-defined methodology or insufficient information to evaluate result reliability.
5. Non-English studies unless accompanied by an English translation or summary.
6. Studies outside the designated time frame (2000-2023) and duplicate studies.

Assessment of effectiveness

Methodology

Search strategy

We would be following three step method for searching studies. The prelim search would be conducted on PubMed, Google Scholar, and Cochrane, where we would identify the keywords from the titles and abstracts of initial few articles and the index terms used to describe the article. The second search would be based on all the identified keywords based on the first search in all the databases. Thirdly, the reference list of all identified reports and articles will be searched for additional studies. We would be searching both published and unpublished data for the review and would include English and other language studies if translation is possible.

Table 2: Search terms used.

Drone related terms	Drone Drone aircraft UAV UAS Unmanned aerial systems
Health-related terms	Medical application Surgical application Vaccines Medicines Medical devices Blood Blood products Samples
Delivery-related terms	Medical delivery Medical transport Delivery Support
User-related terms	User group Human drone interaction User experience User feedback User acceptance

Frame PICO

Table 3: PICO Criteria

Criteria	Response
Patient/ Population (P)	Patients diagnosed with tuberculosis.
Intervention (I)	The use of drones for medicine delivery in the treatment of tuberculosis.
Comparator (C)	Traditional methods of medicine delivery like ground transportation or manual distribution.
Outcomes (O)	Enhanced treatment adherence, accessibility, timeliness, and efficiency of pharmaceutical delivery, as well as potential effects on treatment outcomes and disease control.

Information sources

The database for the published and unpublished studies search would include PubMed, MEDLINE, CINAHL, google scholar, Cochrane central register of controlled trials, Embase.

Screening Process

All articles identified by the search will be entitled to titles and abstracts screening. The screening will be performed by two independent reviewers for assessment against the inclusion criteria for the review. Potentially relevant studies will be retrieved in full, and their citation details will then be exported to the reference management software EndNote X7. Duplicate articles will be removed, and full text of selected citations will be assessed in detail against the inclusion criteria by two independent reviewers. Any disagreements that arise between the reviewers at each stage of the study selection process will be resolved through discussion or with a third reviewer. The results of the search and study selection and inclusion process will be reported in full in the final systematic review and presented in a Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram.

Assessment of methodological quality

Full studies selected by the primary researcher will be given for independent second review to check if studies are selected as per the inclusion and exclusion criteria. Once selected two independent reviewers would check the quality of the selected study's methodology with the help of a critical appraisal checklist as per Joanna Briggs Institute guidelines for quantitative research. The result of critical appraisal would be explained in the tabular form.

Data Extraction

From the selected study data would be extracted using the JBI standard tool. Two independent reviewers would extract the data. The data extracted would include details like author name, year of publication, total no. of participants, study method, detail of intervention and comparator, study outcome, etc. The author of the selected studies would be contacted if data found incomplete.

Data Synthesis

Studies will, where possible, be pooled with statistical meta-analysis, using RevMan 5.3. Effect sizes will be expressed as either odds ratios (for dichotomous data) or weighted (or standardized) final post-intervention mean differences (for continuous data) and their 95% confidence intervals will be calculated for analysis. Heterogeneity will be assessed statistically using appropriate statistical tool. Effect size would be expressed in terms of weighted mean and with 95% confidence interval would be calculated for the analysis. Where statistical pooling is not possible the findings will be presented in narrative form including tables and figures to aid in data presentation, where appropriate.

Critical Appraisal

Risk of bias summary and Risk of Bias Graph of review authors' judgements about each risk of bias item for each study will be included.

Cost effectiveness analysis of medicine distribution using drones in comparison with conventional delivery system.

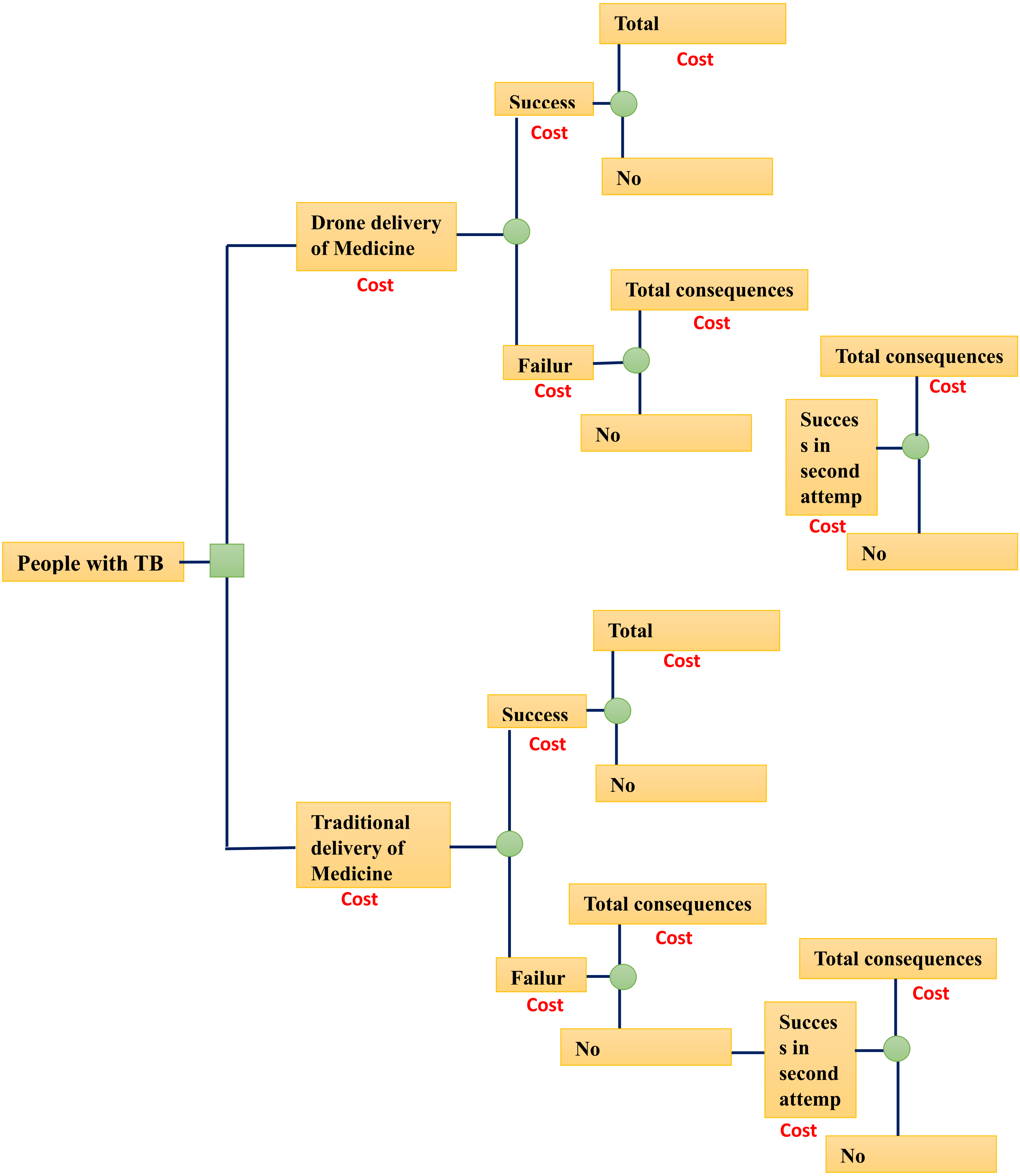
Objective:

1. To determine the cost effectiveness of using drones for Tuberculosis medicine distribution in comparison with conventional supply chain measures.

Table 4: PICOT Criteria

Criteria	Response
Patient/ Population (P)	Patients diagnosed with tuberculosis (TB)
Intervention (I)	Medicine delivery using drones
Comparator (C)	Conventional medicine delivery methods
Outcomes (O)	Reduction in average cost per delivery (operational cost of traditional supply chain) Reduction in average time of delivery Uninterrupted distribution of medicines / Reduction in frequency of stockouts Performance improvement in supply chain Reduction in inventory holding time. Reduction in medicine wastage due to non-utilisation of medicines
Time Horizon (T)	Long-term impact assessment (i.e., 5-year period)

Decision tree



Costing

The costing for this study will be done using the Time Driven Activity Based Costing (TDABC) method, which was developed by Kaplan and Anderson.(19) It is a bottom-up accounting system that needs two parameters, like the quantity of time (capacity) and the capacity cost rate for each resource the patient utilises at each process.(20) This technique helps us to allocate the accurate costs to each step of the processes. The TDABC approach may be useful for bundled payment cost assessment (21), as well as for resource allocation in the most effective manner with the least amount of wastage. (22) We aim to perform the costing based on either societal or patient perspective.

Possible cost parameters

- Drone acquisition, maintenance, and Operator Training
- Infrastructure Setup (such as drone charging stations or landing zones, mobile clinic facilities or community health worker offices)
- Inventory holding cost.
- Landing area facilitation cost
- Training and Education (for patients or healthcare providers about the use of drones or conventional methods for medicine delivery)

Sensitivity Analysis

The robustness of our research will be evaluated using sensitivity analysis to account for various structural, model, and parameter uncertainties. A probabilistic sensitivity analysis (PSA), based on the HTA_In reference example, will be performed to investigate the effect of joint parameter uncertainty. Additionally, log-normal, beta, and gamma distributions of the parameters in our study, will be used for the PSA. Upper and lower bounds will be computed under the assumption that there is a reasonable deviation on either side of the base estimate for the input parameters. Then, using the Monte Carlo method, the findings of the analyses will be simulated for at least 1000 times.

Conclusions:

This proposal was presented in the 37th Technical Appraisal Committee Meeting held on 8th of August 2023 and following recommendations were suggested:

- Even though the effectiveness of drones is well ascertained in remote areas the cost-effectiveness analysis could not be undertaken due to lack of data. It may be undertaken once the data is available.
- A Systematic review couldn't be an option since data is sparse and heterogeneity would be high.
- A pilot proposal specific to a remote area may be undertaken that may include Cost-analysis/ Program Development/ Cost Implementation Study Specific To Remote Locations etc.

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