

Medicine from the Sky



Overview

The Fourth Industrial Revolution provides new opportunities to ensure that all people have access to high-quality medical care. While the challenges in connecting rural and poorer communities are significant, with greater access to blood, vaccines and even organ transplants, rural communities can experience a level of health otherwise possible only in the urban core of many countries. Drones, an emerging technology, are improving the delivery of vital goods, opening up the possibility of medicine delivered from the sky, and can be an important component of this future-focused health system.

Delivering medical goods using drones has now been an option for at least five years. Doctors Without Borders began testing the transport of diagnostic samples between remote clinics and central testing facilities during a tuberculosis outbreak in Papua New Guinea as early as 2014.¹ As other countries witnessed the possibilities, the first big leap forward took place in Rwanda, where experiments, or pilot projects, matured into national-scale implementations outside of the urban core – delivering blood on demand and at scheduled intervals. Garnering significant international attention, it led to international bodies, governments and healthcare systems now beginning to consider the impact drone delivery may have on their own logistics networks.

While plenty of tests and some at-scale implementation in Africa have increased awareness of the opportunities provided by drones, service providers, government officials and local communities must consider how their populations will be affected and what policies need to evolve for people to reap the benefits. As it stands, it is still difficult to find trusted sources of data, real economic analysis or comparisons between operational models beyond what appears in the press or is

offered by the service providers; policy-makers need a trusted source to turn to. The World Economic Forum's Medicine from the Sky project is developing source materials to assist policy-makers and health systems in analysing the opportunities and challenges of drone delivery as well as competing delivery models and technologies.

Capturing maximum value from drone delivery requires a combined effort from technologists, government leaders and healthcare and social advocates to ensure systems are designed in a way that protects public safety, ensures community interests are represented and considers how the integration of new technologies into supply chains is done in a cost-effective manner that does not drain investment capital from other parts of the system. Moving from principles to practice, this briefing paper seeks to provide an overview of key issues that must be considered in designing medically oriented drone delivery deployments, including the following:

- Outlining the challenges in medical supply chains that can be addressed by drone delivery
- Developing an initial framework for evaluating potential projects
- Highlighting the trade-offs between different system designs and technologies

Public health cost-benefit analysis can be tough when considering any implementation decision. Important questions such as “How do we compare a scenario that costs more but has a higher social benefit with a scenario that costs less but has a lower social benefit?” and “How do we value improvements in health outcomes relative to the cost of a project?” are vital in understanding the trade-offs for policy-

makers. By examining how these universal concerns have been addressed by others, decision-makers can move on more quickly to considering other challenges. Drone use has additional challenges that go beyond the medical industry; namely, those presented by a lack of regulatory clarity. What's most important is to recognize the clear benefits that drones can provide, once the policies are put in place to protect those on the ground and in the air.

To conduct this analysis, the World Economic Forum brings together a multistakeholder group of government officials, companies and civil society organizations to share their experiences and insights from real-world drone delivery deployments. This briefing paper represents an initial overview of their findings. A more detailed toolkit designed to serve the needs of government and corporate executives considering the use of these technologies is under development and will be released in early 2020.

Health system supply chain challenges in India

India provides an excellent example of a large healthcare system experiencing the challenges felt by myriad other emerging economies around the world and currently considering drone delivery solutions. Operating within one of the fastest-growing economies in the world, India's healthcare industry is huge, approaching \$300 billion. The healthcare market is led by the private sector, which manages more than 80% of outpatient care and more than 50% of inpatient care.² The government provides free or subsidized health services to low-income households but struggles to deliver consistently high-quality care, especially in rural communities where stockouts and lower-quality supplies are frequent.³

More than 80% of the country's doctors work in the private sector and nearly as many are concentrated in urban areas. In rural areas, where lower-income households are concentrated, a lack of skilled human resources and reliable channels for medical supplies inhibit the capacity of public facilities to treat patients. Many patients are referred to better-staffed, better-supplied hospitals in urban or peri-urban areas, at their own expense. Alleviating supply chain challenges can ensure that patients are able to access the medicines and treatments they need at public facilities closer to home. Increasing access to quality care across public facilities will also lower patients' out-of-pocket spending, enabling households to save or invest their income more productively.

Medical supply chain challenges are often related to public infrastructure gaps.⁵ Poor roads over difficult terrain, supply routes that are washed out during monsoons and lack of electricity in many areas directly relate to supply chain shortcomings. Medical commodities are distributed from state stores to district stores, in some cases with a regional store in between. In the case of pharmaceuticals, health subcentres (SCs), primary health centres (PHCs) and community health centres (CHCs) submit bulk orders as "blocks" grouped geographically. Blocks pick up orders from district stores, often on no routine schedule. PHCs and CHCs then pick up from the blocks, and SCs pick up from PHCs. Forecasting demand and managing inventory is difficult, with no set schedule for restocking any given commodity. When a facility is stocked out, it procures needed products from local pharmacies where possible, or refers patients elsewhere.

By ensuring that all public facilities are equipped with the blood, medicines and vaccines needed to deliver the highest level of care, the government of India can dramatically improve

the quality of care in the country's most remote and rural areas. If the government does this, public confidence in government facilities will increase, reducing the population's reliance on private healthcare and lowering the proportion of household income spent on expensive health services.

Blood logistics is a universal challenge faced by developing countries worldwide. When a patient needs blood or a blood product, the situation is often urgent, and predicting emergency demand is extremely difficult. In many states in India, low access to blood and a tenuous cold chain (the system used for storing and transporting blood under the correct conditions) has weakened the health system, caused countless preventable deaths and disabilities and heaped sizeable undue costs on both the government and patients.

The top three challenges facing the management of blood in the supply chain are: low and irregular access to blood; low blood componentization; and the low quality of the blood present. While 68% of the country's population is rural, most of its blood banks and testing facilities are in urban areas, and many rural blood banks operate at a low efficiency rate. Undersupplied facilities request access to blood from other clinics, but one-off trips for emergency deliveries are expensive, and poor road conditions, extreme weather and heavy traffic often prevent the emergency movement of blood within the clinically required time frame. An estimated 10–11% of the blood collected in 2014–17 was wasted as a result of logistical and process inefficiencies and because of reactivity for transfusion transmitted infections (TTI) driven up by poor quality.

Issues with vaccine supply are similar to those with the blood chain. India has 28,863 primary healthcare centres providing vaccines, each covering 44.46 square miles (115.15 square kilometres) on average and with similar challenges. Rural facilities' coverage areas can be much larger, limiting health workers' capacity for last-mile distribution. Many are located in difficult terrain – mountains, jungles and vast, sparsely populated deserts and plains – and populations in some areas are seasonally mobile. A rural health worker may routinely transport vaccine boxes from the nearest cold-chain point to application sites that are two to six hours away by foot or bike. Many patients travel greater distances to reach application sites – a particularly difficult trip for families with multiple children and localized livelihoods. It is not surprising that rural children are the least likely to receive complete vaccinations.

As with blood, vaccine stockout remains a significant challenge, with more than a quarter of facilities experiencing stockouts on a regular basis nationwide, though the rate is significantly higher in many states. As an example, in Himachal Pradesh, hilly terrain results in an overall smaller vaccine supply and there are stockouts at nearly 83% of facilities over any given six-month period, with the average stockout lasting more than 37 days. Low availability of vaccines, particularly in rural areas, has led to a high number of “dropouts” following a first dose. Inaccessible or difficult terrain is one situation in which drones can provide significant benefit.

A related problem to stockouts, system wastage remains a significant problem in the vaccine supply chain. Electrical grid and storage equipment failures, coupled with multiple handoffs along the supply chain and long periods of transport, lead to high wastage rates and increase the likelihood that some vaccines are no longer potent when administered. In addition, because the number of children receiving vaccines varies at each application session and forecasts are rarely accurate, vaccine vial quantities make it nearly impossible to match the number of doses available to the number of patients in need on a given day.

Vaccines follow a similar supply chain to blood, except that blocks do not submit orders; rather, vaccines are “pushed” to blocks based on population data. In addition, while vaccines are administered at PHCs, CHCs and SCs, they are also delivered at more than 9 million application sites across the country. This

entails further transport from the health facility to one or more session sites, often by foot, bike or motorcycle, using cold boxes. Facilities are routinely stocked out of vaccines and are unable to procure them ad hoc from local vendors.

While today’s commercial drones will not replace bulk delivery of all medical commodities in the near term, they can help eliminate stockouts by resupplying products on an on-demand basis as facilities request exactly what they need and receive deliveries quickly. For instance, Zipline claims that its service has increased the use of blood products by 175% in Rwanda while reducing wastage and spoilage of medical products by 95%.⁶ By shortening transport times and delivering inventory that is managed from centralized locations, drones also reduce the variability in quality control along the supply chain, guaranteeing the quality of all products delivered, including cold-chain products. Improved quality control will in turn reduce waste due to expiry, mishandling of a product or inadequate storage conditions. Other models of drone delivery – specifically, point-to-point or clinic-to-clinic connective models – provide an alternative to the centralized model described above. The point-to-point model allows clinics to deliver goods to one another and to be more responsive to local needs – and may provide a greater opportunity for community engagement. This employs analytics that enable specialized ordering, with flexibility for on-demand needs between community members and less infrastructure investment in a central hub, which in the long run may reduce congestion in the airspace from a more centralized hub.

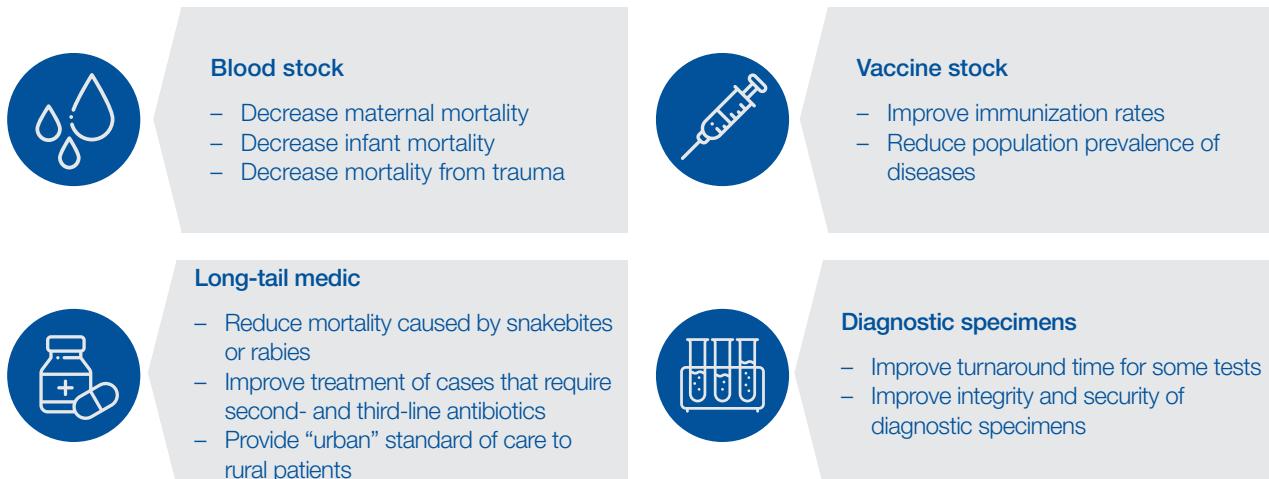
Where to begin in evaluating drone logistics

Though the supply chain needs are many, so, too, are the opportunities for drone delivery. Policy-makers must understand how to assess the various models of delivery systems, and the benefits or risks associated with those models. It is recommended that public health leaders considering the adoption of medical drone technology undertake three important initial steps as part of a drone feasibility study. While these are not the exclusive considerations for any initial proposal, they provide an overview of how the supply chain mission will be handled. In addition to these three steps, the mechanism for procurement must also be considered.

Step 1: Select the use case

While many medical use cases have been suggested for drones, and this overview focuses on the use of drones for delivering blood and vaccines, there are five main use cases that have been demonstrated for drones in medical supply chains to-date.

Figure 1: Drone delivery use cases with targeted outcomes



Step 2: Compare available technologies

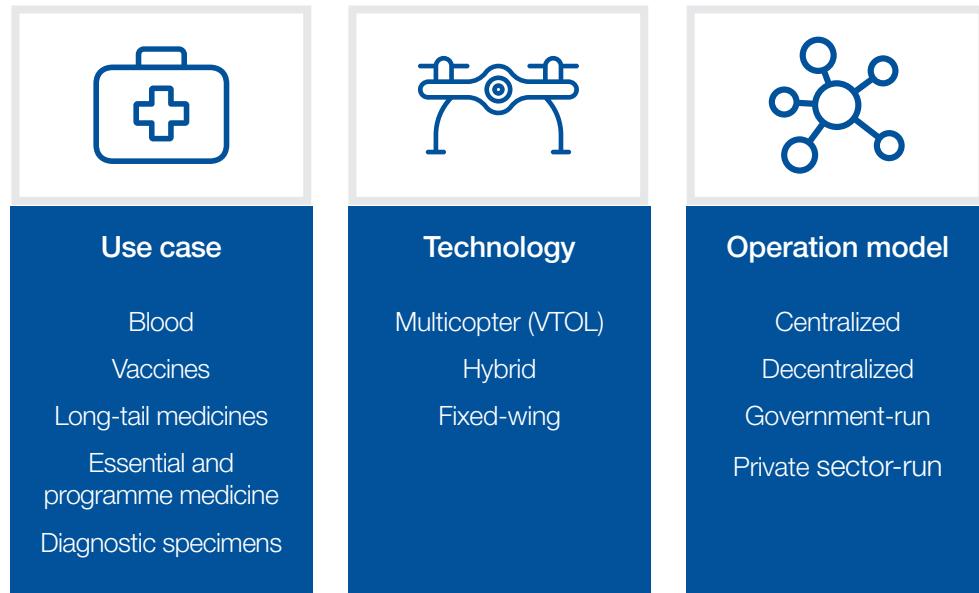
While the technological landscape of delivery drones is diverse and evolving rapidly, most technologies can be divided into three main categories, each of which has relatively well-understood advantages and disadvantages, as shown in Figure 2 below. Where diagnostic specimen collection is a critically important use case, health systems should consider a multicopter or hybrid option. Vertical takeoff and landing (VTOL) multicopter technologies can take off and land easily in confined areas without any specialized or even paved infrastructure. They are well proven and relatively low cost, but tend to have a shorter range than other options, which may make them less useful when there is a need to cover a large geographical area. Hybrid solutions hold out the promise of combining copter-like vertical takeoff and landing capability with the longer range of a fixed-wing aircraft, but are a less-proven technology whose airframe complexity may generate high operations and maintenance expenses and/or make them hard to operate in severe weather.

For the other four “delivery-only” use cases, health systems also have the option of using fixed-wing delivery drones. These airplane-like technologies tend to fly longer distances with the same amount of energy. They also tend to be more resistant to weather than multicopter solutions and are often more cost-effective to operate and maintain. However, they are limited in their mission opportunities because they are often unidirectional in nature, require significantly more infrastructure for launch and recovery and are more difficult to fly remotely.

Step 3: Consider the operational model

The medical drone delivery sector is young and evolving rapidly, with little consensus established as to best practices, and it has therefore not yet settled on a dominant service model. While early leaders have demonstrated success in centralized nodes aligned with urban core logistics warehousing, dispersed peer-to-peer models may provide different benefits, especially when considering the need for bidirectional deliveries of goods. Public health systems interested in drone technology must carefully examine the potential operational models for their project in order to engage effectively with the private sector. Where local infrastructure is well developed, drones may not be the right solution and it is important to recognize when, where and how the use of these new technologies will be implemented. Whether the drone delivery operation is managed as a public-private partnership, owned completely by a multinational organization or domestic company, or driven locally by community health clinics, there will be different values returned to the local population and therefore the tradeoffs in ownership models must be considered thoroughly before investing in long-term services.

Figure 2: Three steps for proposal evaluation

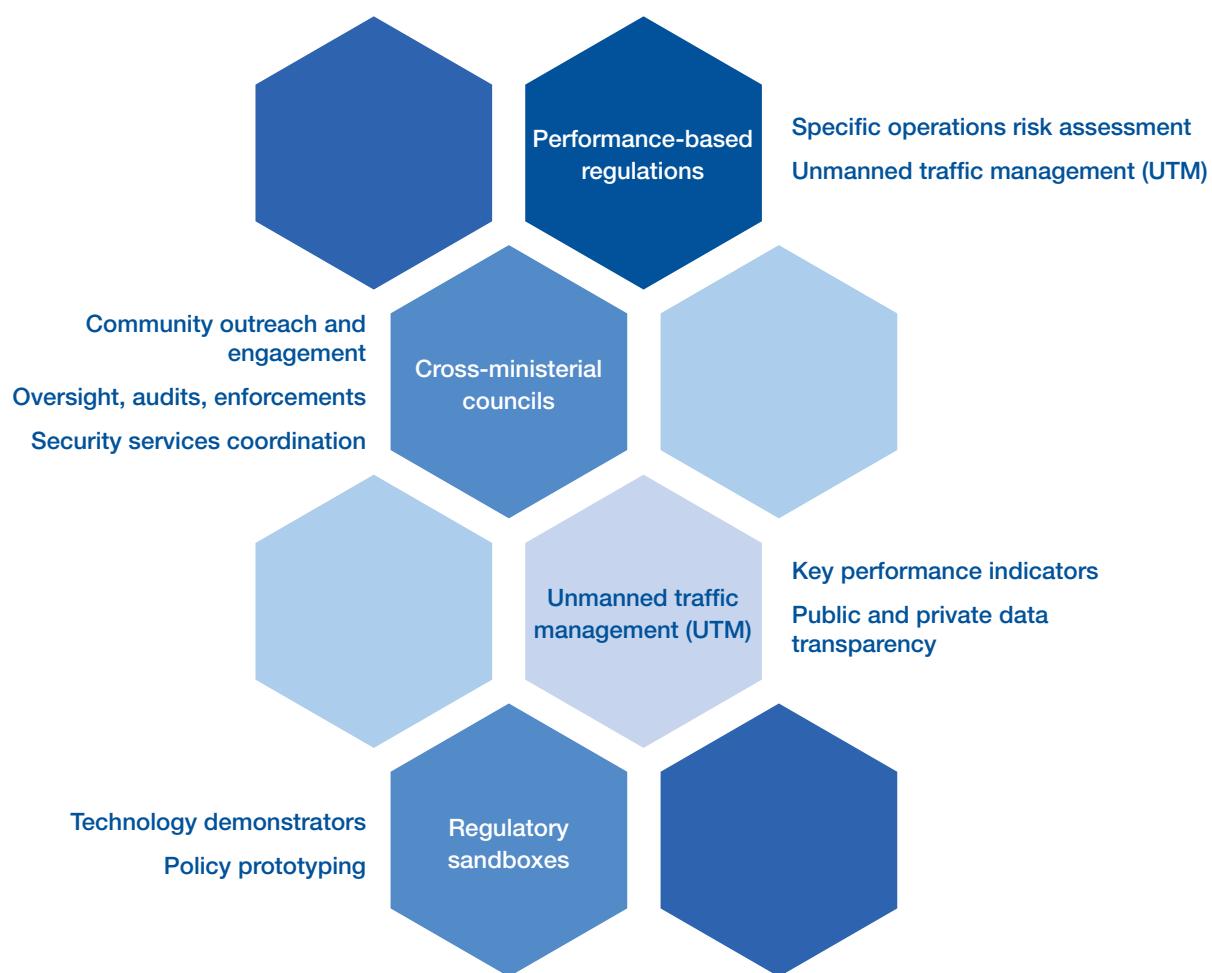


Policy development considerations

In December 2018, India's Ministry of Civil Aviation released a comprehensive framework for the operation of unmanned aerial systems (UAS), also known as drones, in the region. This would permit the use of drones for commercial purposes within visual line of sight (VLOS). Based on weight, drones have been classified into five sections: nano, micro, small, medium and large. Flying a drone would require manual controls with a valid unique identification number tagged to each drone and an operator permit for licensed operations. Further, technical guidelines were released for policy-compliant manufacturing.

In February 2019, the Drone Ecosystem Policy Roadmap was issued by the Ministry of Civil Aviation proposing carriage of new forms of air freight, recognition of services providers for airspace deconfliction and permission (Digital Sky) and the ability to fly drones beyond visual line of sight (BVLOS).⁷ These policy evolutions are needed to implement drone delivery solutions for medical and other applications, as BVLOS flight is required to make drone delivery economically justifiable. Under the current regulations, drone delivery is not possible, although companies may file for an exception with the Directorate General of Civil Aviation (DGCA). A more robust national regulation, similar in nature to Rwanda's Part 27 or the Drone Regulations of the European Union Aviation Safety Agency (EASA), could open additional opportunities in this space.

Figure 3: Policy priorities for UAS activity⁸



There is an increasing opportunity for countries to benefit from advanced drone operations as associated technologies rapidly improve and evolve. Providing a planned revision of the policy or a continuous process for evaluating the implementation policies for drone technologies according to key performance indicators (KPIs) is a new approach to governance requisite to meet the challenges of the Fourth Industrial Revolution.⁹

Conclusion

The World Economic Forum's Medicine from the Sky project aims to answer one important question: How can we accelerate the transformation from analogue and inefficient health supply chains to digital, resilient infrastructure that reduces wastage and improves health outcomes? At its core, this project focuses on multistakeholder engagement that drives meaningful conversations about methodology, explores challenges to current systems and unlocks opportunities for collaboration leadership between the public and private sectors alongside civil society.

Drones present a tremendous opportunity to address supply chain shortcomings in the healthcare sector, reducing stockouts and wastage. Deaths due to diseases such as dengue, conditions like postpartum haemorrhage, loss of blood due to accidents and even races against time in cases of organ grafting can be addressed through faster responses, higher-quality products and better availability. Health system shortcomings, especially those felt in rural communities suffering from a lack of infrastructure and forecasted growth that outpaces investment, can be addressed and lives saved by adopting advanced logistics systems in the sky.

A performance-based regulatory approach, as modelled in Rwanda and adopted by the European Union, could help solve the problem of access by opening the sky to more participants and ensuring safety-focused approvals even with a security-focused process. As access to healthcare becomes an increasing focus in emerging economies, the increasing needs of society will continue to strain the system.

Most importantly, this high-level overview of the health system in India proposed the introduction of drones into the delivery of medical supplies. The operational model of choice, or the companies seeking approval, should be evaluated in a process-focused way that maximizes the benefits while mitigating the risks to society. It should be done in a way that empowers local populations and addresses the needs of society on the ground by using the sky. Many rapidly evolving approaches – local, national and international in origin – are being tested globally. It is important for each country and society to develop its own expertise, oversight and approach to these technologies.

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Sunder Akunuri, Program Manager Innovation, Cyient

Pavan Ananth, Business Development, Zipline

Siddharth Balachandran, BizLab Leader India, Airbus

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K Hariprasad, President, Apollo Group – Hospitals, Apollo Hospitals

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Vinod Kamat, Head, Technology, Tata Trusts, Tata Trusts

Bhrigu Kapuria, Health Specialist (Immunization), UNICEF

Srinivas Kollipara, Chief Executive Officer, GEN India

Rama Devi Lanka, Director, Emerging Technologies, OSD, Government of Telangana

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Jessie Mooberry, Head of Deployment, Airbus UTM, Airbus

Nilesh Modi, Chairman's Office, RIL

Gaurav Mundra, Lead, Strategic Initiatives, Chairman's Office, RIL

Aditi Namdeo, Head of Operations and Business Engagement, World Economic Forum

Jayant Narayan, C4IR Government Affairs, World Economic Forum

Pradeep Palleli, Founder, Thanos Technologies

Devansh Pathak, Business Analyst, Government of Telangana

Neelima Ramaraju, Senior Director, Global Impact, Llamasoft

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Endnotes

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