Unlocking the Lower Skies
The Costs and Benefits of Deploying Drones across Use Cases in East Africa

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INTRODUCTION

The current gaps in road transport infrastructure in East Africa and Sub-Saharan Africa more broadly are vast, amounting to billions of dollars annually. These gaps present enormous challenges to meeting the Sustainable Development Goals, from health to agricultural productivity to food security, and can only be expected to be magnified by the consequences of climate change.

As demonstrated by the global economic and health crisis unfolding in 2020 and 2021, essential goods supply chains across Sub-Saharan Africa as well as in many developed countries are highly vulnerable to both climatic events and health pandemics. The COVID-19 (coronavirus) experience shows that traditional supply chains can be substantially disrupted by a pandemic, creating scarcity of medical products, food, hospital beds, and personnel. Although the key disruptions in health supply chains caused by COVID-19 have mostly resulted from factors such as increased global demand, restrictions on manufacturing and support industries, and bans on exporting selected essential health commodities by some source countries—rather than from constraints on the physical delivery of health commodities from warehouses and depots to facilities—unmanned aerial vehicle (UAV) technology has a growing role to play in more effectively managing inventories, protecting people from contamination, and delivering critical goods such as medical products, lab samples, vaccines, and food in a way that minimizes person-to-person contact. This realization provides additional strong impetus for seeking complementary transport solutions that can fill in the gaps and build more resilient supply chains.

This report explores the economic and broader societal rationale for introducing UAV, or “drone,” technologies to complement current transport and logistics systems in several use cases in the context of East Africa. The specific use cases examined include medical goods deliveries, food aid delivery, land mapping and risk assessment, agriculture, and transport and energy infrastructure inspection. The first two of these correspond to cases in which physical deliveries of goods are performed using UAVs; the latter three focus on the role of UAVs mostly as a technology for image and information gathering and as an assessment tool. Across these applications, the case for using UAVs is examined
within the context of the so-called logistics objectives—total operating costs, speed, availability, and flexibility—as well as the human, or societal, objectives, which may include increased access to health care, lives saved, and increased environmental sustainability, among others.

**MEDICAL USE CASE**

As more low- and middle-income countries explore opportunities to improve efficiency and performance in their public health supply chains and diagnostics networks, they face myriad choices about how best to use UAVs to improve product availability, public health outcomes, and reaching the last mile. UAVs have been implemented in several different contexts, proving that they can certainly reach the last mile with urgent health commodities. As public health supply chain managers move beyond pilots and toward implementation, incorporating UAVs as one type of vehicle in their overall fleet, it is important to identify which product groups or flows may be the best candidates for UAVs, and to compare the cost of UAVs with the cost of current transport modes.

The high-level findings from this analysis are that, if examining commodity categories individually, and looking exclusively at costs, delivery with UAVs in general is still more expensive. However, the value of drones tends to increase with higher density of health facilities within the range of unmanned aircraft systems (UASs); greater difficulty of accessing the facilities by road; higher financial value, scarcity, or health value (lifesaving nature) of the medical goods; unpredictability of demand at the level of individual facilities; and shorter shelf life and greater difficulty of storing the medical goods at health facilities. As part of this study, in-depth data collection and interviews with health sector workers were conducted in Ukerewe District, including the district’s islands in Lake Victoria, which forms part of the Mwanza region of Tanzania, to identify optimal use cases in the medical goods delivery space to demonstrate the specific logistical challenges and problems in the current system to which a UAS could effectively respond. Categories with very high quantities of products result in relatively low costs per flight, but significantly more flights and UAVs are required to deliver the same quantities as the current delivery system; the net result is higher costs. Small volumes (such as in the case of lifesaving items) and infrequent demand result in few flights with high costs per flight. Public transport is widely used for medical goods transport and is relatively inexpensive, keeping current delivery costs low.

Although still higher cost than current delivery systems, the most cost-effective use case examples include the transport of laboratory samples to selected destinations (associated with the lowest percentage increase in transport costs compared with the present) and delivery of lifesaving items and blood to selected destinations (associated with the lowest dollar amount increase in transport costs). UAVs are most cost-effective on routes to distant facilities on the small islands and between the District Hospital in Nansio (on the main island) and Mwanza.

However, layering use cases can provide efficiencies and cost savings by allocating fixed costs across a greater number of flights and maximizing drone capacity and time utilization. The base case absorbs fixed costs and start-up capital costs, and additional layered use cases incur incremental operations costs. Increasing the number of flights per UAV reduces overall per flight costs,
and combining products per flight maximizes capacity usage (in liters or kilograms) of the vehicle. The cost-effectiveness of a UAV can be increased by maximizing the cargo capacity and time utilization in all directions, which case layering contributes to. For routine deliveries, cost-effectiveness can also be increased by using “milk runs” (visiting multiple facilities in one outing) instead of hub-and-spoke routes (going out and back between Nansio District Hospital and each facility) because excess capacity is used by including cargo for more than one facility, and total mileage traveled is reduced. In the Ukerewe context, opportunities for UAV transport cost reduction lie in layering lifesaving item and rabies vaccine deliveries on top of laboratory sample and blood deliveries that make up the base cases. As a result of such layering, the time utilization of a given UAV could be increased by 60–80 percent, leading to average transport cost savings per flight of about 30–40 percent. It should be noted, however, that, given the estimated time required to complete one flight, including preparation, packing, unpacking, and flying, a single UAV can be expected to perform no more than 1,200–1,600 flights per year; thus, the layering of use cases only provides cost efficiencies up to this ceiling; additional flights above the ceiling would require capital investment in additional UAVs.

Cost sensitivity analysis for a hypothetical “East Africa base case” demonstrates that any savings in transport costs for medical goods using UAVs as compared with traditional transport modes are mostly driven by drone vendor pricing structures and drone costs, ground transportation costs, and the level of demand:

- **Drone vendors vary greatly in their pricing and drone capabilities.** The capital cost of one drone may be nearly 10 times the price of another, so to be cost competitive, the cheapest vendor that meets the required specifications should be chosen.
- **Leasing (that is, the drones-as-a-service model) provides a much more cost-competitive option compared with buying.** Leasing not only often results in lower overall costs, but large capital investment requirements are avoided and cost stability is increased compared with owning drones. In the hypothetical East Africa case analysis, leasing is the only cost-competitive option across all scenarios.
- **Because drones cannot compete on price with cheap or free transportation (including public transit), site selection is critical to a cost-effective drone program; drones must be used where ground transportation is currently expensive.**
- **Drones scale well because savings add up faster than costs.** When the population of the area to be served increases by a factor of 10, traditional ground transport costs of medical goods (by truck or motorcycle) increase by roughly six times, whereas drone costs only double. This relationship enables large savings to be realized from not using ground transportation, thereby offsetting the costs of the drones. However, having a prohibitively expensive drone or cheap or free ground transportation will prevent drones from ever reaching a cost-competitive scale, no matter how many trips the drones travel.
- **Costs for the infrastructure necessary to support drones, such as the costs of a drone port, can easily prevent drone programs from becoming cost competitive, regardless of demand levels or drone vendor specifications.** Offsetting high infrastructure costs by either leasing the drone or selecting the drone with the cheapest capital investment is critical to being cost competitive.
The Ukerewe case study suggests that the capital cost of a UAV that would bring drone usage to cost parity with current road- and boat-based transport is approximately $19,000. This estimate is significantly less than the $75,000 capital cost per UAV assumed throughout the baseline scenario cost analysis, but it is not impossible to reach given the speed with which the technology is developing, including in research and development facilities in emerging markets such as China. However, it should be noted that the estimated capital cost parity assumes several specific UAV technical capabilities, such as vertical takeoff, cargo capacity of at least 12 liters (4 kilograms), and a range of 100 kilometers (km), which the cheaper UAV would also have to meet. The estimated operating cost parity is extremely low for vaccine deliveries, at less than $0.01 per liter per km, regardless of the destination type. The estimated parity is by far the highest for lab sample pickup from the small island facilities and the distant big island facilities, at about $0.68 per liter per km. The scenarios modeled in this analysis did not include the up-front costs of procuring, importing, and setting up the UAS. These fixed costs should be taken into account if budgets are developed for UAS deployment.

The drone-as-a-service model, albeit still relatively new, provides complementary insights into cost parity results. The Malawi-focused cost model examining scenarios assuming the drone-as-a-service model finds that cost parity—or maximum cost-competitive monthly all-in drone-as-a-service price—is approximately $2,000, equivalent to the savings obtained from not using ground transportation. The case study also highlights the importance of the level of demand in determining the maximum price at which UAV services would be cost competitive with ground transportation. When using the Malawi data to calibrate the hypothetical East Africa base case model, it can be observed that if the number of monthly cases of an illness that requires lifesaving medicines, blood transfusion, or a similarly urgent intervention were to quadruple, the parity monthly drone-as-a-service cost would more than double, to $5,000.

Across most of the existing analyses, the main drivers influencing the relative cost advantages of UAV-based versus road transport-based medical deliveries are found to be vehicle and fuel costs. Other studies of the medical use case that have been implemented in the region report a range of conclusions, with some finding the transportation costs of a UAS higher than those associated with land-based transport and others suggesting that under specific assumptions, UASs are cost competitive.

From the perspective of public decision-makers or international donor organizations, the cost-effectiveness of UAVs cannot be analyzed without looking at the public health benefits, which may be substantial. In Rwanda, where the drone program has been operational for several years, stock-out rates have decreased to zero, and availability of rare blood products is estimated to have increased by 175 percent. In Madagascar, although the tuberculosis-focused drone pilot program was assessed as unaffordable from the government’s perspective, as measured by the incremental transport costs per disability-adjusted life year, the health impacts of the trials were impressive, with tuberculosis diagnosis rates, and, subsequently, enrollment rates in treatment programs, doubling. In Ukerewe, the analysis conducted for this study using a decision-tree model suggests that the deployment of drones to deliver emergency blood for transfusion would reduce the number
of deaths by almost 80 percent compared with traditional transport. Drones would achieve this level of success by reducing the travel time either from nearby health care facilities or from the National Blood Transfusion Services Laboratory Center located in Mwanza as well as by maintaining product quality. Evidence from the study shows that more than 10 percent of blood that is collected by health facilities is currently wasted because of hemolysis of samples that use traditional transport to Mwanza for screening. If drones were used to transport blood samples, wastage would be minimized and the need to borrow from nearby facilities or make requests from the blood center in Mwanza would be reduced.

The use of UAVs can also help reduce the longer-term negative health impacts stemming from the current diversion of health care workers’ time to medical goods transport, although the extent to which health workers are directly involved in the transport of health commodities varies by country. Public transport is an inexpensive mode of transport across Tanzania and is also used widely for transport of public health commodities in other countries in the region, such as Malawi. Thus, from a cost perspective alone, it is difficult for UAVs to compete with public transport. However, public transport schedules can be limited and generally inflexible in meeting urgent needs, limiting the health center’s ability to respond, which may result in significant impacts on patients. Although the Ukerewe analysis includes the cost of salaries and per diem in transport costs where applicable, it does not explicitly quantify the opportunity cost of health care workers’ traveling by public transport to pick up the needed medicines to serve patients. The field research in Ukerewe confirmed that health care workers are tasked with the delivery and collection of goods. For facilities near the collection points the impact is likely negligible, but for distant facilities or for those with limited personnel, travel time requirements can be significant, effectively replacing time serving patients and leading to tangible health impacts over the long term that may or may not be possible to quantify.

Existing UAV impact assessments suggest the need to mix and match modes to serve needs; the trade-offs are going to be positive only in particular niches. In other words, the transport technology needs to be matched with system characteristics: accessibility and distance, product weight and volume, product value, and urgency of need. Despite some encouraging results from the existing efforts to quantify the advantages of UAVs through pilot operations in the medical goods delivery use case, there is still insufficient long-term, ex post data with which to accurately assess the comparative advantage of UAVs, either from the cost or the health impacts perspective. More in-depth research is needed on how transportation systems could include both land transport and UAVs to best take advantage of the benefits of each transport mode. Additional scenarios should focus on overall system optimization to define concrete implementation plans. Other specific areas for further research, in the Ukerewe context and elsewhere in the East Africa region, include a cost comparison between current transport modes and the use of UAV transport as a service (rather than purchasing UAVs); an assessment of how the current modes would compare with heavy-lift UAVs; and the potential advantages of a truck-UAV hybrid distribution model for routine products. Finally, future research could expand the health-impacts assessment of UAVs by studying health-seeking behavior resulting from increased availability of health products.
OTHER USE CASES

In the food aid delivery use case, large cargo drones may already be able to offer cost advantages on a per ton per km basis compared with regular manned aircraft, as illustrated by the analysis of data pertaining to the World Food Programme’s (WFP’s) operations in South Sudan. The most feasible scenarios in which drones may provide overall cost advantages compared with manned airplanes, however, could be in those cases, such as during true emergency conditions, when relatively small quantities of food would need to be delivered to individual destinations and therefore a small cargo plane would be the real counterfactual to drones. Moreover, drones may provide a practical advantage—or be the only practically feasible solution—in scenarios in which, because of climate or security conditions, a manned cargo plane would not be able to physically reach its airdrop destination and safely return. In the case study of food deliveries to hard-to-reach districts in Rwanda as part of the WFP–managed Home-Grown School Feeding program, where trucking is the counterfactual, drones do not appear to provide advantages in direct up-front transport costs, even for last-mile deliveries. However, drones can be a solution for ensuring timely delivery of the much-needed food items to the target schools and potentially reduce the delivery time uncertainty–related food inventory costs at the school level. Overall, in East Africa and elsewhere, there are still few cases of actual, even pilot-based, delivery trials in the cargo sector, and it should be expected that the costs of the vehicles and equipment will decrease significantly in the future.

Drone use in use cases such as mapping, risk assessment, and agriculture in East Africa is relatively more common than cargo drone operations, and existing pilot initiatives have delivered impressive results for speed and quality (precision). Drones have also been shown to be cost competitive with traditional aircraft, even if not with very low-cost, crowdsourcing-based data-collection methods, and offer practical advantages in conditions after natural disasters such as cyclones when traditional manned aircraft are not able to capture high-quality imagery because of the cloud cover. Compared with satellite imagery–based data-collection methods, drones appear cost competitive in contexts in which high-precision maps need to be produced on short notice. However, the use of drones in the mapping and risk and postdisaster needs assessment use cases remains only partially, or not at all, integrated into government systems, which to some extent is a function of the funding of the programs by external organizations. At least partly because of the significant know-how and skills requirements, which in some cases may be an even greater barrier to drone adoption in the disaster risk management space than their cost, across East Africa, the mapping and risk assessment initiatives that have used drone technology have tended to be contracted to private firms. An exception is the Zanzibar Mapping Initiative in which significant investment was made to build local technical capacity to ensure continuity. Most companies operating in the region that integrate drone imagery with other data sources to develop and disseminate data to farmers are in the early stages of testing and developing their farmer advisory services into products, as well as developing viable business models. Nonetheless, the region’s experience in the precision agriculture use case suggests that drones can be a relatively low-cost solution for significantly increasing production volumes and can also deliver large environmental sustainability benefits through reduced water and fertilizer consumption.
Including in developed countries, drone technology has shown promising results in civilian infrastructure applications, with numerous successful feasibility studies and experiments performed to demonstrate the cost, time, and quality advantages versus traditional infrastructure inspection and monitoring methods. Many of these studies, as well as actual experience in Rwanda and Zanzibar, have found that drone technology can help deliver less time-consuming detection and inspection of power transmission and distribution infrastructure, road and bridge infrastructure inspection, and infrastructure construction management. However, cost and time savings may not materialize in all situations and will depend on the complexity and quality of the desired outcome and the regulatory context (for example, the ability to fly the inspection drones over live traffic), among other factors. Thus, in this use case, as in others, a more appropriate approach to analyzing the economic rationale for drones—and one that is more likely to be used by public and private sector decision-makers—would be to select the approach that achieves the required level of service or quality at the lowest cost. South Africa’s experience also demonstrates that there are still obstacles to be overcome for local drone companies to readily engage with the power utility in providing inspection services over the long term.

Across the use cases, drone costs per kilometer or per other metric can be reduced, sometimes significantly, by improving the time utilization for each UAV; however, such efficiency will necessarily entail collaboration among different sectoral agencies or even actors managing supply chains in different sectors, such as health and agriculture. Another key consideration in the economics of future drone operations in the region relates to the need for regulatory support, or at least clarity, regarding the ability of UAVs to operate in the shared civilian air space, including beyond line of sight. In the absence of such clarity, UAV initiatives are bound to remain at the scale of donor-funded pilots, and investment in local technical capacity and necessary infrastructure—including infrastructure in ancillary services such as reliable internet and electricity connectivity services that enable UAV operations to run smoothly—will be discouraged.

Drone applications are rapidly evolving, and several use cases could grow in impact and scale over the coming years. In addition to the applications reviewed in this report, other less-well-documented use cases are emerging. Applications in disease monitoring and prevention have seen success in Ethiopia and Malawi. The COVID-19 pandemic has shown that countries with drone distribution networks in place, such as Ghana and Rwanda, could more easily scale up a drone-based pandemic response. In the field of conservation, UAVs hold much promise, particularly in monitoring illegal poaching and deforestation. Drones have the potential to transform business models, serve communities that are digitally online but physically isolated, and help society tackle some of the most pressing development challenges.

**POLICY AND OPERATIONAL IMPLICATIONS**

- Drones can solve critical issues in supply chains but need to be integrated as much as possible into existing systems rather than being developed as an entirely parallel system. Even if not directly integrated into existing public systems, donor-funded drone initiatives in the region should ensure technical capacity transfer to local stakeholders.
The number and scale of UAV pilot projects must be significantly expanded to demonstrate a sustainable long-term business case.

Cost-effectiveness of drone operations is critical in Africa; resources are scarce not only in public health systems but also in the private sector. The health pandemic of 2020 and 2021 and the resulting economic recession in many countries, with a projected decline in economic growth of between 2.1 percent and 5.1 percent in 2020 following positive growth of 2.4 percent in 2019 (Zeufack et al. 2020), mean that governments will have even fewer resources, rendering cost-effectiveness yet more critical.

As suggested by examples in several countries in Sub-Saharan Africa, drone-based transport can effectively fill supply gaps in transportation services that arise in emergency situations such as COVID-19, for example, critical goods deliveries avoiding human interaction, aerial-image-based quarantine compliance monitoring, and others.

Although drone initiatives in the region have mostly been donor funded or remain small scale, the private sector—drone manufacturers, operators, consultants, and commercial banks that can finance large UAS operations—is expected to play a much more prominent role in the future.

Across the potential UAV use cases, the regulatory enabling environment—both support and predictability—is key. Regulations need to be harmonized across government entities in each country and across countries in the region; drone companies need to work closely with civil aviation authorities. The COVID-19 health pandemic has demonstrated that in most countries the enabling environment for quickly launching drones, including human resources with the right knowledge and skills to facilitate drone integration into the response, regulations, and air traffic management procedures, is not there yet.

Developing the data ecosystem is important for both drone operators and public entities to understand what gaps drones are filling, what their impact on costs and societal outcomes may be, and what new UAV-based use cases might be viable as the context changes (for example, with the onset of widespread restrictions on in-person mobility and goods delivery systems).

The World Bank can help governments define their national strategies for drone development. The African Drone Forum community could play a similar role at the regional level.

NOTES

1. A UAS consists of one or more UAVs, the associated equipment (launch and landing stations, batteries and charging equipment, flight control software, and so forth) as well as the software and personnel needed to control the UAV.

2. In the drones-as-a-service model, drones are provided and operated for a flat monthly fee, which removes all other cost components.

REFERENCE