What's ethics got to do with it?

A nuanced look at safety and security in drone-enabled healthcare logistics in Africa

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December 2022

FRONTIER TECHNOLOGIES

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DRONES DOING GOOD ALLIANCE

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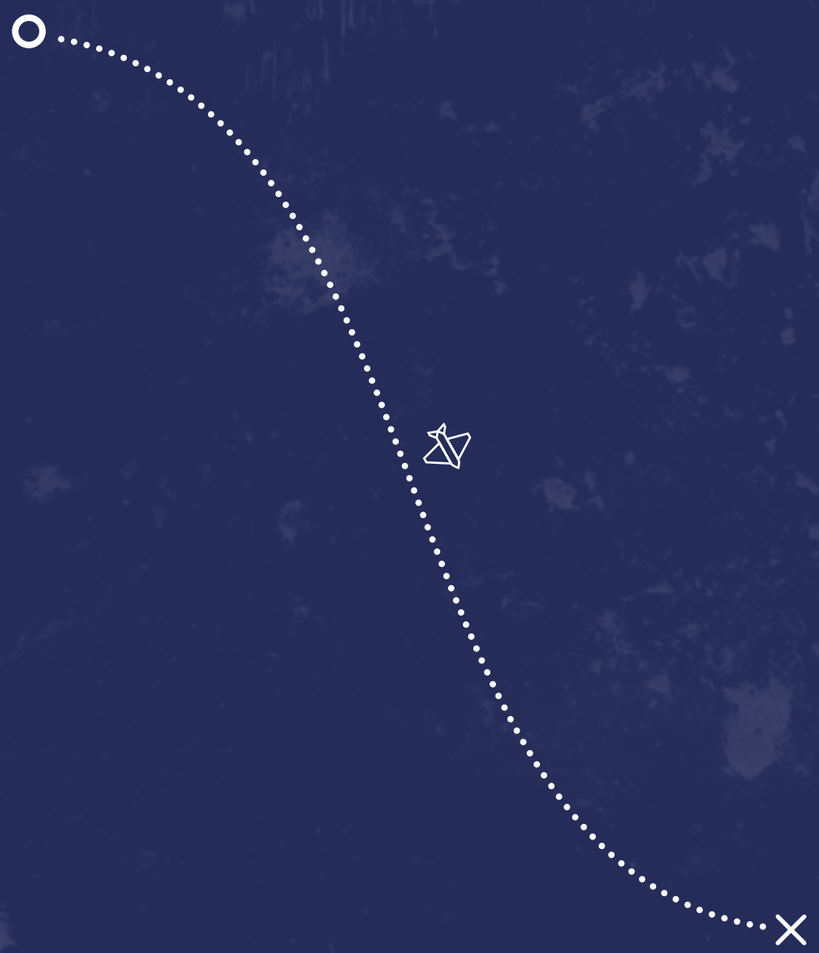
Contents



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Acknowledgements

The authors would like to thank Sarah Pannell, Technology and Innovation Policy Adviser, FCDO, Ruth McPake, Principal Consultant, DT Global and Olivia Elson, Senior Program Officer - Innovation, Results for Development (R4D) for their guidance, direction and editorial support in writing this paper.

This paper has benefited substantially from the input provided by a wide range of stakeholders who have given generously of their time and thoughts in a series of one-on-one interviews.

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Abbreviations

Abbreviation	Definition
AI	Artificial Intelligence
ASRP	Aviation Safety Reporting Program
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
DDG	Drones Doing Good (DDG) Alliance
DJI	Da-Jiang Innovations
DRC	Democratic Republic of the Congo
E-waste	Electronic Waste
EID	Early Infant Diagnosis
FT Hub	Frontier Technologies Hub
GDP	Gross Domestic Product
GPS	Global Positioning System
ICAO	International Civil Aviation Organisation
ICT	Information and Communication Technologies
IoT	Internet of Things
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
MHz	Megahertz
MoH	Ministry of Health
MoHP	Ministry of Health and Population
PPH	Postpartum haemorrhage
R&D	Research and Development
ROC	Remote Aircraft Operators Certificate
RPA	Remotely Piloted Aircraft
RPATWG	Remotely Piloted Aircraft Technical Working Group
SADA	Smart Africa Digital Academy
SDGs	Sustainable Development Goals
SIM	Subscriber Identification Module
SORA	Specific Operations Risk Assessment
UAVs	Unmanned Aerial Vehicles
UNICEF	United Nations Children's Fund
UPDWG	UAV for Payload Delivery Working Group
USAID	United States Agency for International Development
USD	United States Dollars
UTM	Unmanned Aircraft System Traffic Management
VTOL	Vertical Takeoff and Landing
WEF	World Economic Forum
WFP	World Food Programme

1 about this discussion paper

1. About this discussion paper

This discussion paper offers guidance on how to navigate safety, security and ethical questions related to the sustainable growth and scaling of drone operations in healthcare logistics in Africa.

For the purposes of this paper, safety relates to the possibility of harm being done to people or property while security relates to the possibility of somebody taking control of or disrupting drones and drone services. Ethical considerations include the principles determining the 'right' use of drones, what is appropriate for the sector, and who decides this.

This paper is of use to decision-makers such as civil aviation authorities, ecosystem support actors such as donors, drone manufacturers, drone operators and relevant ministries such as Ministries of Health, Innovation or ICT (Information and Communication Technologies). It offers an overview of critical areas of concern, potential solutions and trade-offs or costs associated with these solutions.

Because different scenarios will call for different solutions, this paper also offers a number of guiding principles and myth busters that will help decison-makers and other ecosystem actors embed safety and security in their efforts to optimise and scale drones for health impact.

This paper focusses specifically on transportation use cases in the African health sector, which includes the delivery of critical healthcare products and the collection of samples.

While some safety and security concerns addressed will have relevance for broader use cases, focussing on transportation use cases allows us to direct attention toward issues that relate to health-sector deliveries using small payload drones (1.5-8 kg), whether they be fixed wing or vertical takeoff and landing (VTOL) drones that fly beyond the visual line of site (BVLOS) for distances of 20 to 200 kilometres.

Nevertheless, many, perhaps most, safety and security concerns addressed will have relevance to a broad range of other use cases.

Drones are known by a number of names. These include UAV (Unmanned Aerial Vehicle) or UAS (Unmanned Aerial Systems), which are commonly used terms in the aerospace industry, and RPA (Remotely Piloted Aircraft), which is a term used by officials in some countries. The more commonly used term 'drone' will be used throughout this paper.

This paper has been authored by the Drones Doing Good (DDG) Alliance in partnership with Endeva e.V. and the UKaid funded Frontier Technologies Hub (FT Hub). It draws on desktop research and insights from over 20 interviews with a range of experts including regulators, relevant ministries, local and foreign manufacturers and operators. See full list on page 6.

WHY THIS PAPER IS NEEDED

Drones bear great potential for accelerating health impact. Pioneering African countries are now looking to scale and sustain operations.

Drone technologies have the potential to save lives and play a key role in bridging logistical gaps. They can help reduce deaths due to postpartum haemorrhage (PPH), the leading cause of pregnancy-related deaths in Africa, provide hard-to-reach areas with vaccines and collect samples to enable timely diagnoses and treatment.[1, 2]

A wide range of local and foreign actors have been actively pursuing the use of drones in ways that help achieve the UN Sustainable Development Goals. Drone operations for healthcare logistics have been pioneered in Africa where countries like Malawi and Rwanda have enabled testing and scaling of operations. Their work is now focussed on enabling sustained operations, while other countries are looking to further test and integrate drone operations.

Despite their clear value, drones are dual-purpose machines and the further scaling of the technology raises a range of ethical, safety and security issues.[3]

For all parties involved, any negative incident caused by a drone or drone operation poses a huge reputational risk to the sector, with the potential to set back progress. It is important that all stakeholders remain aware of ethical considerations as well as the safety and security risks involved while having access to the resources to mitigate and respond to them.

This will contribute to all stakeholders doing their part to ensure that we harness the maximum benefits of drones and minimise any harm or damage they might cause.

This requires finding the right balance between regulating and restricting drone operations on the one hand, and allowing the safe and secure use of drones for good on the other.

Keeping in mind that there is a clear cost in lives lost by not effectively leveraging this technology in Africa, it is important for authorities to take safe-as-possible steps toward creating an enabling environment for drones.

For drone logistics to scale sustainably and to prevent African countries from becoming passive recipients of technology, a localisation of technology, skills, and decision-making is essential.

In the vast majority of use cases recorded to date, drone technology has been developed and manufactured outside of Africa, with many experts coming from abroad to implement operations. As discussed further below, localisation is critical for countries to scale sustainably. There may be concerns among funders that localisation could raise different risks, as knowledge may be acquired by those with potentially ill intent.

However, as one of the interviewees for this paper pointed out: "Why should a locally designed, manufactured, operated drone capacity care any less about the safety, security and ethical issues than a foreign operator or expert?"[4] Localisation goes beyond the transfer of technology and is part of an important shift "towards a more equal, diverse and inclusive power balance in the international aid and development sectors".[5]

LOCALISATION IS CRITICAL FOR SUSTAINABLE OPERATIONS

Localisation is the next critical step in promoting drones for good on the continent. This includes increasing the participation of qualified African operators, manufacturers and software engineers in these impactful use cases.

The central challenge today is that drone operations in healthcare logistics are too expensive for local governments to finance without donor assistance and therefore it is unclear how they can be sustained over a long period of time.

Drones are designed and manufactured abroad, their operations are led by foreign teams and companies, and many of the job opportunities in the sector remain abroad or are filled by foreign experts. Sunganani Kalilangwe, Principal Airworthiness Surveyor at Malawi's Department of Civil Aviation, identified that: "Currently the biggest hurdle is the high cost of operations of drones because we don't have local drone operators".[6]

Currently, transferring a pint of blood can easily cost between 400 to 800 euros a pint.[7] A substantial part of this cost is due to the price of the drones: a long-range drone that can do both drop-offs and collections (i.e., VTOL drone) costs between 50,000 euros and 200,000 euros to purchase. Travel and accommodation costs for pilots and others involved in operations adds to the hefty price tag, while drone maintenance and repairs, which tend to be numerous, add further cost and complexity as there is typically no or only limited local servicing.

Furthermore, costs are driven up by duty fees paid when importing drones as they are often classified as luxury items, contributing to the expense and short life of many projects. Innocent Mainjeni, Supply Chain Programs Manager for VillageReach in Malawi commented that: "Most operations in drones for health have been short stints because operations look expensive and duty charges add to this".[8]

Localisation is key to making the drone sector more sustainable, impactful, affordable and resilient.

Having more well-trained and competent local actors involved means there is increased knowledge of the local context, local networks can be activated and there is more insight into which additional solutions could benefit from the use of drones. Integrating drones as part of already existing healthcare logistics solutions can ensure drones are only used where they are needed and cheaper options such as bikes or boats are used where possible, making better use of health facilities' limited budgets.[9]

Integrating local manufacturers will help reduce the cost and complexity of operations, reduce the time to import drones and clear customs, reduce down time when replacement drones are imported and help produce improved designs specifically adapted to the local context and suitable for local manufacturing, maintenance and repairs.

Rumbani Sidira, Drones Desk Officer in the Ministry of Health (MoH) in Malawi is the main liaison between drone operators and the MoH. His extensive experience in the ministry has shown him the reality that projects can end when donor funding dries out. Having seen the impact drones can have, he is vocal about the need to sustain these operations:

"Our current challenge is the possibility of sustaining the program. If the project doesn't continue then we have given hope to communities and healthcare workers by solving problems by bringing in this technology that is faster than other methods and then all of a sudden it closes down and can't continue".[10]

Several actors are actively supporting localisation efforts. These include WeRobotics, UNICEF African Drone and Data Academy and the Drones Doing Good Alliance. However, much more needs to be done to enable local actors to meet demand and compete with foreign companies.

"We believe strongly that if we can manufacture the drones locally, the cost of the drones will go down to the extent that the government would be able to run these programs.

We want to see a scale-up of the transfer of skills from foreign operators to local teams. More Malawians should be able to fly the drones and to maintain the drones. At the end of the day, when those who came here to help leave, we should be able to take over".

- Rumbani Sidira, Ministry of Health, Malawi

Local actors are well positioned to take advantage of the opportunities that drones offer.

From the perspective of the Malawian Ministry of Health, the sustainability of operations in the long run is critical: drones are high tech, but they can be relatively easily built in a low-resource setting. Startups like MicroMek in Malawi, Swift Labs in Kenya, Charis in Rwanda and many others are showing the way forward. Africa also has the youngest population in the world, a generation that is tech-savvy and driven to solve urgent problems they see in their everyday lives.

The continent is thus well positioned to continue to lead the implementation of innovative drone use cases that solve real problems. However, there is still a lot to be done to ensure local players can compete and reap the benefits of this fast-paced sector.

This will require supporting local innovators with the financing, knowledge and opportunities they need provide their services.

The localisation of technology, skills, and decision-making is part of a wider systems change that addresses ethical questions around who is using drones for good and who defines what good is.

Patrick Meier of WeRobotics makes a compelling case for localisation that focuses on the underlying power dynamic of technological solutions driven by actors from the Global North. As Meier states on his blog, "Too many social good projects are foreign-led, top-down and techno-centric, which scales inequality, discrimination and dependency".[11] His organisation instead promotes a locally-led, collaborative, pluralistic model that is inclusive, just and sustainable.[12]

Practically, localisation means increasing the use of drones that are locally designed, built, maintained, and operated by local actors in African countries. It also means that choices around which solutions are appropriate for local problems are made primarily by local actors.

According to Dumisani Kaliati, founder of MicroMek in Malawi, a startup that builds drones locally with 3D-printed parts and recycled materials, important decisions regarding the drone ecosystem should be made by people that are involved in the drone industry from the ground up.[13] Doing so will ensure that the regulation, funding and deployment of the technology is in line with local needs.

THE COST OF INACTION

It is important to note that *not* taking action to shape the drone ecosystem in a way that enables safe and secure localisation involves significant risks.

Clearly here to stay, drones are a key sector in the fourth industrial revolution shaping today's world.[14] If the African drone sector is not localised, this will cost the continent jobs, business opportunities and control over solutions that can be applied to local problems.

Drones will still be used, and the sector will be highly valuable, but the many benefits will flow out of the continent.

A failure to take action today and enable the drone sector means that those decisions will be made by others, leaving African actors to be passive recipients of technology in the future. That is a mistake of the past that should and need not be repeated.

As Kenyan drone manufacturer James Munyoki says: "Waiting just makes you play catch up to big countries later. Countries we call developed are also in trial mode so everyone should be at the table".[15]

Munezero Angelos from the Rwanda Ministry of ICT and Innovation stresses the need for governments to invest in local research and development: "We don't always have to be recipients where everyone is making and throwing everything to us, why can't we now do R&D activities and come up with our own drones to address African issues. Most of the time we have different challenges and to address our challenges we have to work on our solutions".[16]

He adds how important it is to be innovative to stay ahead of the game: "When you are in the comfort zone and not investing in R&D and not interested in new innovations, time is not on your side. Within very few years, you will find yourself out of the game".[17]

"Too many social good projects are foreign-led, top-down and techno-centric, which scales inequality, discrimination and dependency".

- Patrick Meier, WeRobotics

2 the values and opportunities that drones offer

2. The values and opportunities that drones offer

RESPONDING TO CRITICAL INFRASTRUCTURE GAPS

Across Africa, millions of people die each year because hospitals and rural healthcare centres are unable to obtain blood, oxygen, vaccines, test results and other essential medical goods at the right time and in the right condition.

Road networks are poor and inconsistent in many areas creating critical logistical challenges. Even if countries spent 1% of their GDP annually on upgrading rural roads, by 2030, less than 46% of the population in Africa would be living within 2 kilometres of a road usable all year round.[18]

Drones can solve clear bottlenecks in Africa for hard-to-reach health facilities where some critical goods may be unavailable more than 80% of the time.[19] Drones have significant potential to improve the availability of healthcare products in hard-to-reach locations. They can fly over difficult terrain and improve the speed of delivery, thereby offering a reliable last-mile delivery system, highly suitable for time-sensitive products.

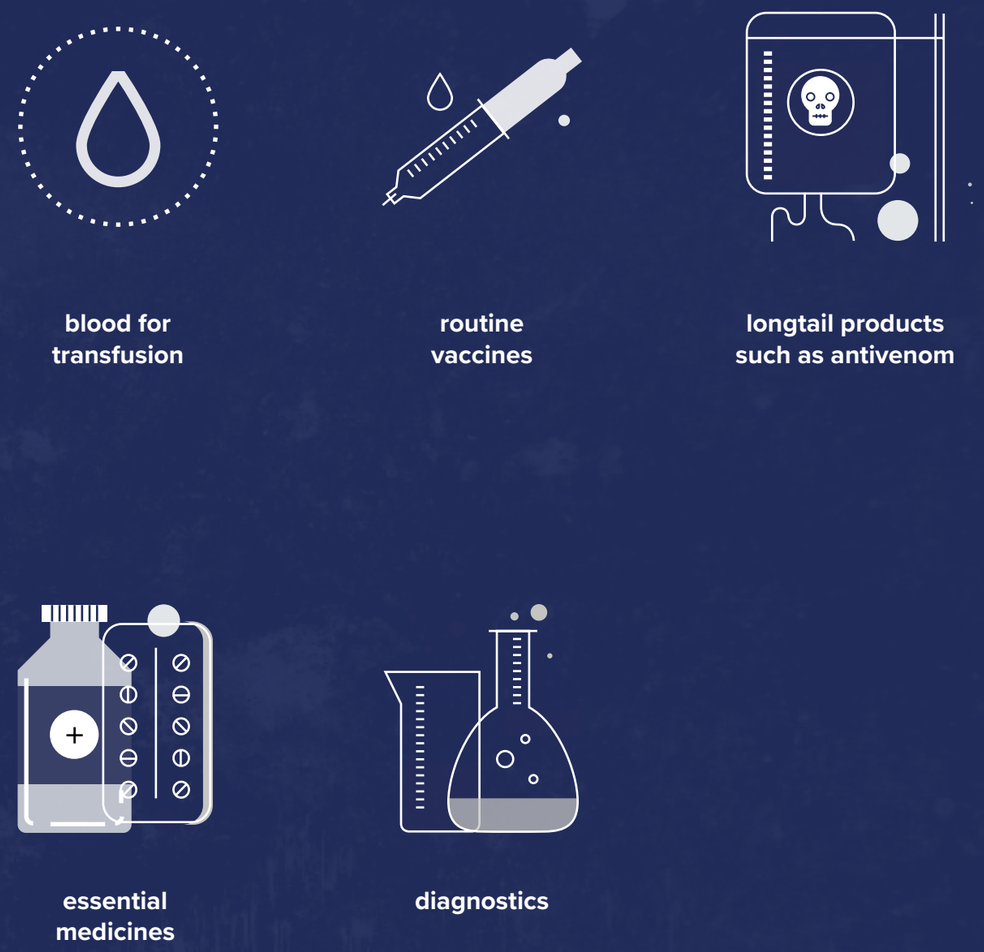
As Sunganani Kalilangwe of the Malawian Department of Civil Aviation explains, “In Malawi it is easy for everyone to understand the benefit of drones because of how bad the roads are. During the rainy season most of the roads in Malawi are washed out, there are no tarmac roads. It can take three to four days for a car to deliver samples from a rural health clinic to a district hospital”.[20]

There is potential to create essential infrastructures, such as drone corridors,[21] which are not commonly found in high-income countries.

The term drone corridors is used in two ways. Some people use it to refer to any tube of airspace that has been specifically assigned to drone operations.[22] Others use it to refer to a dedicated area for *testing* drone operations.[23]

In this paper, we refer to the former as drone corridors and the latter as drone testing corridors or testing corridors. Malawi was the first country in Africa and one of the first in the world to have a drone testing corridor.[24] The Malawian authorities now allow drone operations in a number of districts to address the need for last-mile logistics for medical goods.

Figure 1. What healthcare products can drones carry?



IMPROVING HEALTH OUTCOMES

Drone technology has the potential to create significant impact value by improving health outcomes in African countries.

Currently, drones can carry products that are small and light. Five types of healthcare products have been identified as suitable for delivery by drone: safe blood for transfusion, routine vaccines, long-tail products (products entailing small quantities and unpredictable demands such as antivenom), programme and essential medicines (stockout response), and diagnostic specimens such as COVID-19 test samples.[25]

Drones have the potential to reduce postpartum haemorrhage (PPH), one of the leading causes of maternal death.

PPH is a leading cause of maternal death with approximately 225 women, particularly in low-income countries, dying as a result of it each day.[26] The timely delivery of blood can significantly contribute to reducing these deaths. Indeed, one of the more widely documented use cases of drones in healthcare is the emergency delivery of blood, where multiple players are active in at least five African countries.[27]

When a woman starts losing blood due to PPH, she has between 30 minutes to four hours to receive a transfusion.[28] In Rwanda, drones deliver up to 75% of blood outside the capital and an estimated 30% of these deliveries are for emergencies.[29]

Between March 2017 and December 2019, the average delivery time was 50 minutes, this is 79 minutes faster on average than existing road delivery methods.[30] Other conditions that can require emergency blood transfusions are malaria, hookworm infections, haemoglobinopathies, and accidents.[31]

Drones can play a critical role in increasing safety and reducing hardship and danger for health workers in remote areas.[32]

The personal risk to health workers who have to deliver vaccines and other goods over the last mile can be high and even life threatening. Madagascar health workers at times have to walk several hours, and risk being attacked by bandits. At times, transporting products from a district pharmacy to where it is needed can take up to 70 hours.[33] Drones are relieving health workers of the burden of last mile delivery

Drones are reducing stockouts and increasing the availability of products in a timely and predictable manner.[34]

There is encouraging evidence to support this. For example, according to an evaluation of drone deliveries in DRC, positive trends can be observed after 3-5 months of deliveries to sites directly served by the drone. Availability rate increased from 78% to 102%, the trend towards the elimination of stock-outs was seen in all 12 sites and no health facility experienced antigen stockouts (except for BCG, which was on back order at the national level).[35]

Drones have played an important role during the COVID-19 pandemic.

In Ghana, 11,000 doses of COVID-19 vaccines were delivered by drones in three days.[36] Additionally, drones contributed to faster testing by collecting test samples from health facilities in rural areas in Ghana and Rwanda and delivering them to medical laboratories in the countries' larger cities.[37]

Drones are being used in Malawi across multiple use cases.

The first use case in the Malawian health sector explored the use of drones as a potential solution for diagnosing HIV infections in children in hard to reach areas. This use case is shared in Box 1.

Box 1:
How a step-by-step approach led to scaled drone operations for last-mile delivery of health products in Malawi

In 2014, UNICEF approached the government of Malawi about piloting the use of drones for last-mile delivery of blood samples for Early Infant Diagnosis (EID) of HIV.[38] In Malawi, around 8,000 babies a year are born with HIV, but only 5% of paediatric cases are diagnosed through EID, which requires blood samples to be sent to a central laboratory within eight weeks of birth.[39]

Early detection allows children to receive treatment that enables them to live normal, healthy lives. However, without treatment, 30 percent of HIV-infected children will die before their first birthday, and 50 percent will die before the age of two.[40] Due to an expensive and slow system of transportation, the time it takes for lab samples to be analysed and returned to the child's caregiver is 36 days on average. An initial feasibility study took place in 2016 with last-mile delivery organisation VillageReach leading drone operations in partnership with SwoopAero. This was the first use case of government-approved drones in the country.

In 2017, Malawi's Ministry of Health and Population (MoHP) and the Department of Civil Aviation established a drone testing corridor in the Kasungu district together with the several partners incuding UNICEF, USAID and Chemonics. This corridor allowed for expansion to other use cases of drones, from crop surveillance and soil nutrition to collecting imagery of mosquito larvae for malaria vector control.[41]

Extensive efforts to sensitise local communities are ongoing. They provide continuous feedback and growing acceptance of and support for the impactful use of drones.[42] Once operators had shown their ability to conduct safe operations in the corridor, they were allowed to start servicing rural areas in selected districts.

Now, multiple operators are engaged in last-mile delivery of health products in different regions of the county and those operations are being scaled to more districts.

What started as an exploratory zone for drones testing in Malawi transformed into a major part of the country's medical delivery ecosystem. Innocent Mainjeni, VillageReach's Lead for Drones for Health in Malawi, states that the organisation had "transported over 100 different types of products".[43] The extensive list of products includes COVID-19 vaccines, lab samples and results, obstetrical medicine such as oxytocin, antibiotics, and various blood samples.

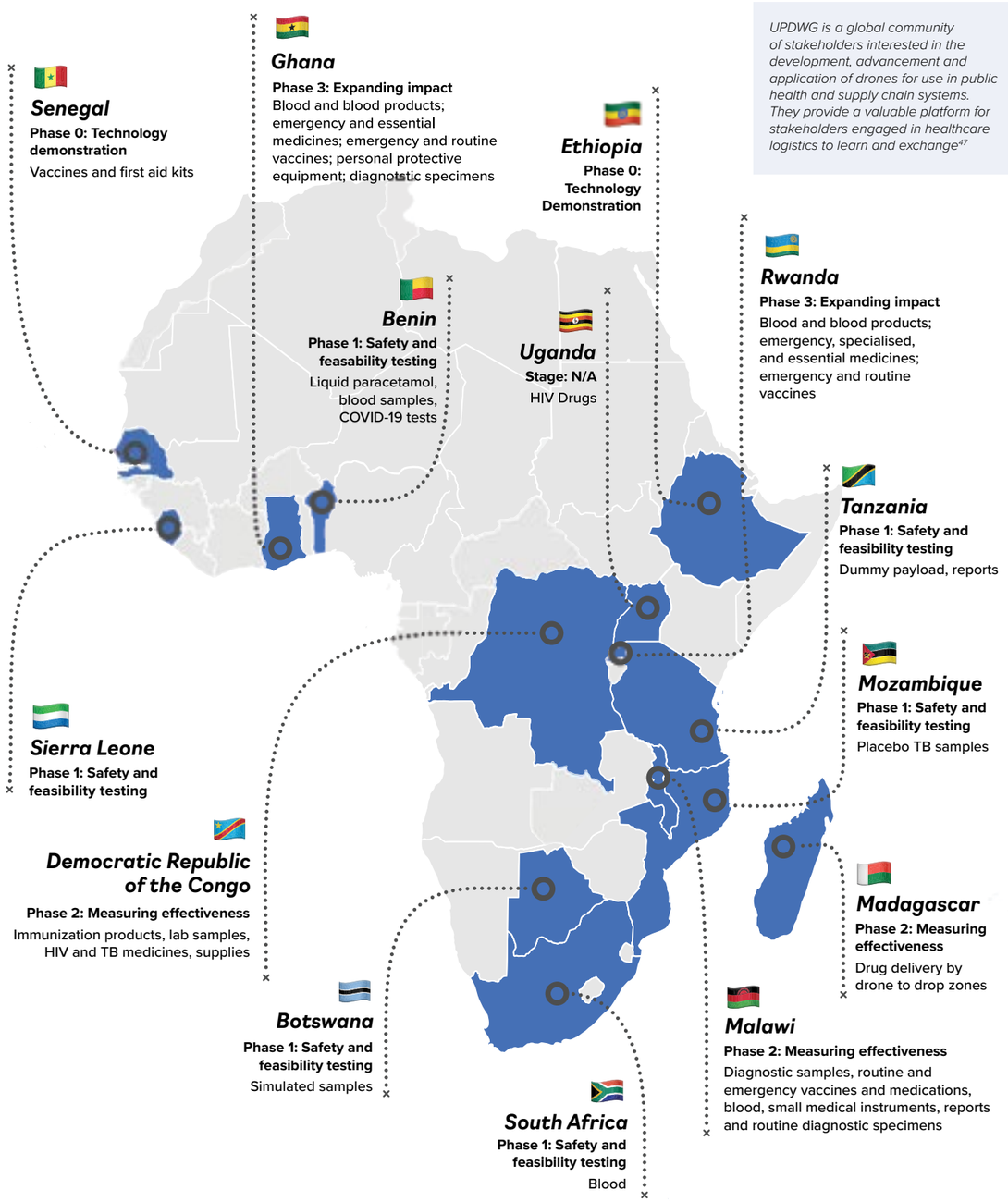
An USAID analysis of operations in the Nkhata Bay and Likoma Island districts of Malawi showed that from June 2019 to January 2020, for HIV Viral Load and EID test results alone, the drones carried results for 225 patients, delivering diagnosis and treatment up to eight weeks earlier than in the past.[44] All stakeholders, including authorities, are continuously learning as this new technology develops.

The Department of Civil Aviation has taken the lead on creating the Remotely Piloted Aircraft Technical Working Group (RPATWG) for all drone operators and stakeholders to exchange experiences and learnings and to inform new operators about previous lessons learned in the drone sector in Malawi.

As Sunganani Kalilangwe of the Department of Civil Aviation in Malawi puts it: "Drones coming in created an opportunity for the country, and it has been accepted as a technology that we have to embrace and improve as we move forward. [...] It's not about the drone. It's about saving the child's life".[45]

Figure 2. Examples of drones being used for medical deliveries in Africa

This map shows some examples of where drones are currently being used in Africa for medical deliveries and for which purposes. This is a visual summary of the information provided by UAV for Payload Delivery Working Group's (UPDWG) Medical Drone Delivery Database.[46]



DRIVING ECONOMIC GROWTH AND CREATING JOBS

In less than a decade, drone technology and use in Africa has gone from barely emergent, with a handful of pioneers testing innovative use cases, to steadily maturing.

In the words of the World Economic Forum (WEF) and Deloitte, the drone ecosystem in Africa is "a proof-of-concept for a successful drone delivery environment".[48] Globally, there are active impact use cases in sectors as diverse as health, agriculture, reforestation, wildlife conservation and disaster response.[49] Other key sectors where drones are used include infrastructure, delivery, mobility, logistics, energy, public safety and security, entertainment, insurance, mining, construction, and telecommunications.[50, 51]

Alongside the impact value, the drone sector can create significant economic opportunities both globally and on the African continent.

According to the World Bank, the value of prospective drone applications for global infrastructure projects is estimated at US $44.2 billion, and prospective drone industry applications globally are valued at about US $127 billion, measured by cost of labour and services that have high potential for replacement by drones.[52] Drone technology has been identified as one of the driving forces of the fourth industrial revolution in Africa.

Globally, the monetary value of drone investments was almost US $7 billion in 2021, which was close to triple the amount of investment in the previous year.[53] In Africa and the Middle East, the drone economy is forecast to grow from US $602 million in 2021 to US $1.06 billion in 2026.[54] In 2019, US $7.9 million was injected into start-ups developing drone applications in Africa, showing that the economic value is clear and investors are paying attention.[55]

The drone sector is set to create a wealth of decent and future-fit jobs, including jobs for youth and women, especially when the sector is localised.[56]

While job forecasting data for African countries is not yet available, reports from the USA estimate that by 2025 the drone sector will have created 103,776 additional jobs, including 34,000 highly paid manufacturing jobs.[57] Manufacturing drones in Africa creates jobs for engineers, designers, mechanics and craftspeople.

The types of jobs needed in a growing localised drone sector range from entry-level to highly-skilled, with additional jobs created indirectly.

As an extension of local manufacturing, jobs arise from locally sourcing and repurposing materials and inputs. Having local supply chains creates additional jobs in logistics and when drone operations are locally owned, pilots, spotters, ground control, project management and administrators are needed.

Finally, drone operations require a range of software solutions that create jobs designing, programming, and analysing data collected by drones. Taking the current aerospace sector as an example, in South Africa, the sector directly employed around 15,000 highly-skilled engineers in 2018 and was estimated to support at least another 60,000 skilled jobs. This is a multiplier effect of roughly 1:4.[58]

GATEWAY TO OTHER SECTORS AND OPPORTUNITIES

Drones are just one piece in a larger picture of the fourth industrial revolution that includes the internet of things (IoT), artificial intelligence (AI), 3-D printing, and big data.[59]

These technologies are changing the way we interact with each other and our environments. They come with a whole new set of required skills and areas of expertise, and the drone sector brings many of these skills and areas together.

Drone manufacturing involves the use of 3-D printing, and IoT sensors placed in drones are used to monitor component parts. AI combined with IoT sensors is used in predictive health monitoring systems to improve drone failsafe mechanisms, object recognition in mapping, and sense and avoid technology, thereby optimising low-risk flight paths, local weather prediction and much more.[60, 61, 62]

Drones offer a range of opportunities for the continent's growing talent pool of software engineers.

Software used in the technical operation of drones themselves guides a drone, tells it where to go, and how to respond. Further, sensors used in drones collect vast amounts of real-time data that help people make decisions and generate usable insights. Software can also greatly improve operations from dispatching to air traffic management.

There are a multitude of valuable opportunities to be unlocked by increasing the awareness of gaps and needs in the drone sector amongst local software engineers as well as increasing their exposure to the drone sector.

This drone-related software can catalyse virtuous cycles of skills and software development, thus creating resilient career paths and generating additional value.

Part of the additional value that the drone sector can create lies in the strengthening of the ecosystem that enables drone operations.

A stronger ecosystem means improved linkages between universities and companies that provide more relevant education that can build capacity in various fields such as aviation, design, innovation, manufacturing, programming and commerce.

It means providing more appropriate and innovative financing tools that can better fund African innovators in this sector. It means participatory regulations for drone-based deliveries, which can attract investment. And it means better access to and training in information technology which improves digital inclusion and literacy.

The positive spillover effects of a strong drone sector are tangible, diverse and far-reaching.

3 fallacies, myths and flawed logic

It is important to remain aware of the fact that technologies and regulations are not developed in a cultural and moral vacuum. Rather, they are influenced by the societies and people developing them and their underlying ethical positions.

At times, these ethical positions may be consciously taken and at other times they may be based on assumptions, ideas and concepts that may prove problematic.

The following two chapters explore the ethical considerations that have been brought to light in the interviews conducted for this paper.

This chapter identifies and challenges several such assumptions with the aim of helping to add nuance and alternative ideas to the discussion that support more holistic discussions on safety, security and ethics in healthcare logistics.

ONE DEATH IS TOO MANY, IF YOU BAN DRONES YOU WON'T HAVE A PROBLEM

One line of thinking about new technologies in general - and drones in particular - is that one death caused by these drones is one too many, leading to the conclusion that the use of the technology is unacceptable or must be heavily restricted.

The issue with this conclusion is that it does not consider the balance of potential benefits alongside the potential harm. Indeed, many other tools that we have accepted into our daily lives also present a degree of risk, but have nonetheless been accepted because of their perceived benefits - consider for example cars on the road, or household gas appliances such as cookers.

Drones can be used to save lives, both through the delivery of life-saving medical goods as well as by doing jobs that are highly dangerous for humans (e.g. transporting medical goods across insecure areas).[63] Denying the use of drones can therefore be more harmful than well-regulated safe use.

A number of interviewees shared the view that this is an ethical decision that must be made on a country level. As drone consultant for BVLOS operations Nigel Breyley stated, “The regulation of what is permissible is not just an aviation issue when it influences health, it becomes an ethical debate for the country and their tolerance of risk versus societal benefit”.[64]

Regarding humanitarian aid and disaster response, David Guerin from the World Bank’s Africa Drone Forum shared this view, saying “It is a question of what risks a country is willing to accept to save people. It comes down to their risk-benefit analysis”.[65]

Indeed, government officials in Malawi were very aware of the wider implications of not using drones or reducing their potential impact. “If a drone has an accident and kills an individual, making a decision to say that this is not a good technology is very wrong. Even though these [safety] challenges might be there, the possibility of saving lives outweighs them. The good outweighs the bad”.[66]

It is worth noting that even those who took a holistic approach, including officials in Malawi, stressed the need to ensure high safety standards.[67] The ethical debate is further discussed in the section Additional Ethical Considerations on page 34.

Some may believe that if you ban drones you won’t have a problem. Indeed, a number of African countries have done exactly that. In the short term, this seems safe. However, as shown in section 2 on the value of drones in healthcare logistics, some lives that could be saved will be lost. In the long run there is also the risk of losing the opportunity to shape this technology as it develops.

Meanwhile, drone applications will be refined, technology improved and adapted, and ecosystems shaped. Drones are part of the future and are set to be further adopted for widespread use.[68] Countries that ban drones now will likely be the last to adopt them.

Consequently, they will have less control over how the technology develops and actors in their countries will have missed opportunities in the commercial drone landscape.

Furthermore, those intent on misusing drones for terrorist or military purposes can still obtain and use them. Such a ban is mostly a challenge for those who want to use drones for good.

Banning drones does not remove the risk of intentional misuse, nor does it reduce the total number of lives lost as drones in healthcare contribute to saving lives.

PREPARE FOR EVERY RISK

It is important to prepare for risk and have regulations in place that mitigate those risks. However, there is a real danger that over-regulation either impedes the implementation of a technology, therefore not maximising its potential benefits, or generates requirements that are burdensome and impractical, which fosters non-compliance and can potentially exacerbate safety issues.

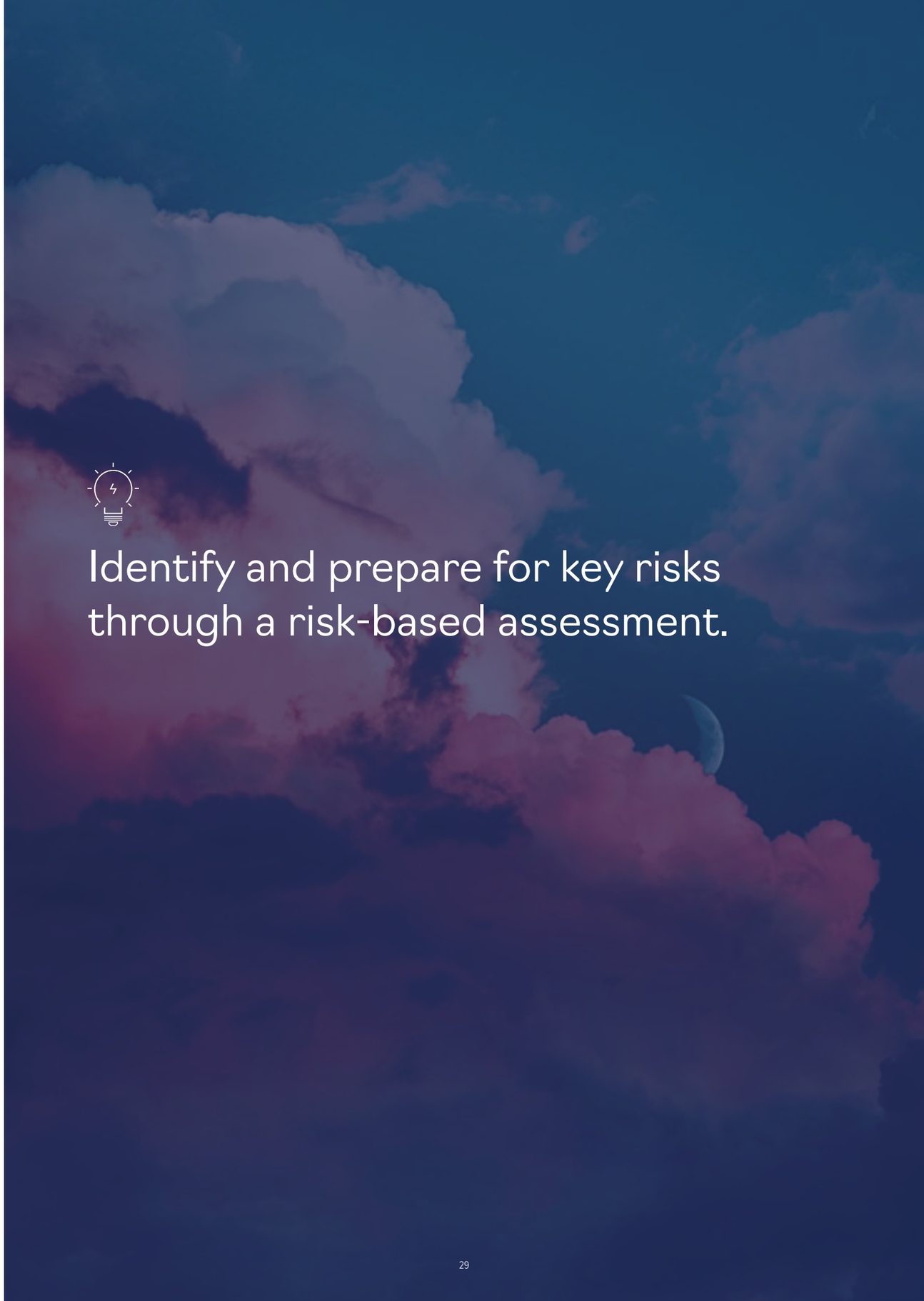
When cars were newly available for consumers in the UK, there was a rule that every car had to have a person walking in front of them waving a red flag.[69] This rule reduced the risk of pedestrians getting hurt, but also removed the benefit of driving a car.

Development and healthcare experts interviewed for a report by Airbus saw the lack of clear regulations or existing cumbersome rules as the main threat to unlocking the commercial and social potential of drone technology in Africa.[70]

All interviewees pointed to the importance of ensuring high safety standards. As voiced by Rumbani Sidira: "We should be serious about all the risks and that is also what we tell operators".[71]

A number of our interviewees pointed out how it can help to use risk analysis methodologies that take the type of operation into account, such as the Specific Operations Risk Assessment (SORA) methodology developed by the Joint Authorities for Rulemaking of Unmanned Systems (JARUS)".[72]

As Oleg Aleksandrov, Aviation Officer at the World Food Programme (WFP), explained, "The general concept of operational risk assessment is that it has to be assessed and calculated at several different layers. For example, the density of population can be the first layer, the location of a highway is the second layer, the location of the local hospital is the third layer, etc. When you make the assessments of those layers you can calculate the risk of operation on the particular route. For each level of risk, you have to define the actions that you will do to prevent or mitigate it".[73]



MAXIMUM REDUNDANCY IS THE BEST APPROACH TO SAFETY

One way to reduce risk is to design for redundancy. Redundancy is an important concept that in modern aviation engineering denotes safety and integrity. Redundancy involves the duplication of critical components or functions within a system, with the aim of increasing reliability in the event of a failure.[74]

For example, a drone may have a backup engine to avoid failure. However, there are cases where redundancy might not increase safety. Zac Kennedy shared that he had recently learned this while discussing a new drone design with a colleague: “Coming from an aviation background I always thought redundancy was the holy grail. I hadn't thought of the complexity of adding that redundancy”.[75] This complexity in turn holds the risk of malfunctioning, potentially cancelling out the safety benefits that the redundancy was trying to achieve.

As explained by Dumisani Kaliati, redundancy works for relatively simple aspects of drone design (e.g. motors) and should be used strategically. “For example, if the specifications of the flight controller and the electronics aboard can only process so much, having redundant sensors doesn't make as much sense as having redundant motors.”[76]

Indeed, systems like motors do not require complex software for their redundancy to function. However, in the case of height sensors that provide flight height information, this becomes more complex.

In this case, you need triple redundancy, where you have three height sensors instead of two. That way, if one height sensor is defective and gives false information, a third sensor shows which of the two is the defective one.

Redundancy in this case however requires very complex software to constantly detect differences and judge which sensors are providing the right data. The challenge is that such complex software is more prone to glitches due to its high complexity.

Redundancy is a valuable safety measure, but it should be wisely applied to ensure it is not counterproductive.

BIG BANG VS 1000 ISLANDS SOLUTIONS

When it comes to software solutions that accompany drone applications, a common tendency is to want a comprehensive solution that includes every necessary aspect (big bang solution).

An example is the set up of a comprehensive air traffic management (ATM) system, with the idea that all air traffic, from large manned aircraft and helicopters to the small manned planes for business or recreation, and all drones which are in the air, are visible in near real-time. All information about every air vehicle (type, owner, properties) and ideally additional information (complete previous flight logs of every air vehicle, state of the maintenance etc.) is included, down to the online availability of these records.

The realisation of such a sophisticated system is very complex and at the moment we do not know of a country in the world with such an ATM system. According to one expert, “We haven't found an integrated ATM system for drones and manned aircraft that works". Munezero Angelos also confirms this adding: “Something we don’t have yet and you can’t find anywhere in the world approved by International Civil Aviation Organization (ICAO) is a unified unmanned air traffic management system (UTM)”.[77] Zac Kennedy added, “if we wait until the dream UTM is built, it will be 2050 and then it becomes a monopoly. That's a problem if it fails. Also if the company decides to charge high fees for using the UTM, it can be a barrier for local operators”.[78]

Experts suggest that it is often more practical to take a modular approach (1000 islands approach), starting with selected aspects of a system, gradually building them out, and eventually integrating them. This enables companies to work on single programs now that can be part of an integrated system in the future.

This can involve enabling the CAA to track all drones in a drone corridor and thereby gain experience that improves the system before adding the next set of functionalities. This enables a quick start for drone operations and the possibility to iterate and refine solutions based on experience. And later, if the single programs from different companies are working well, they can be integrated to form a more complete system, by defining clear interfaces. If interfaces are clearly defined it helps to integrate the single programs into a complete one.

The advantage of this approach is that if one module has an error the whole system will not be compromised; the software is less cumbersome, easier for developers and operators to control and allows for different providers to contribute.

In Malawi, authorities decided to start with what’s currently available to coordinate drones operating in corridors. As Sunganani Kalilangwe reported: “In Malawi we said 'let's get started'. We can't wait for a comprehensive solution, the technology has to catch up. So we used a WhatsApp group. In it, operators share what they are doing and when they stop”.[79]

Aware of the many limitations of this temporary solution, he added that developing a UTM is currently a high priority in Malawi. Since May 2022, Malawi has begun testing an open source UTM solution. As Tautvydas Juskauskas noted: “A good UTM needs to be collaborative. The CAA should take the lead in creating a mandate for all airspace participants to take part. Start with a low-tech solution that seeks to integrate existing separate systems”.[80]

Building a modular system brings a degree of resilience and competitiveness to systems that a single comprehensive solution cannot provide.

4 additional ethical considerations

New technologies come with many unknowns, the same is true for drones. Assumptions surface that may be based on limited, isolated experiences or unsound logic.

This chapter continues the discussion on ethical considerations begun in chapter 3. It looks at additional considerations that must be taken into account. There are no 'right' answers to these ethical questions, however we discuss some of their implications for drone operations in healthcare logistics.

SHOULD THE CAA HAVE A NARROW OR HOLISTIC APPROACH TO SAFETY?

CAAs have the challenging task of dealing with drone technology and finding the balance between maintaining safety while allowing drones to be used for good.

While the safety and security measures described above are all key to mitigating risks, the most risk-averse option would be to not use drones. However, in the case of healthcare logistics, this results in the challenge that fewer lives will be saved through the use of this technology.

One interviewee expressed this as follows: "For many regulators in Europe and increasingly in Africa, the ethical consideration is: 'How can I make sure a drone doesn't harm anybody?' [...] Of course that is something we should all strive for. But I think the other side of the coin is often forgotten: 'Is somebody harmed because I did not employ a drone?'"[81]

This is an important question for the near future as African countries continue to work on their regulations. What is the right balance between mitigating risk and enabling the good use of drones?[82] And who decides the answer to this question.[83] In some countries, CAAs have decided to include the perspectives and needs of other ministries, for example the Ministry of Health in Malawi and the Ministry of ICT and Innovation and the Ministry of Health in Rwanda.[84, 85] This broadens the perspectives that feed into decision-making.

Some countries adopt a narrow approach to safety where the emphasis is narrowly on safety and reducing harm at all costs.

They select to maintain the highest level of security even if this may negatively impact healthcare logistics. This may make sense in cases where alternative transport options offer a satisfactory solution.

Pointing to the challenges involved with making ethical decisions, David Guerrin noted that if we had "a process that understands the benefit of drone operations and therefore could equate what risk would be acceptable, we would be in a much better position. But no one is working on that at the moment".

In other cases, they adopt a holistic approach to safety. Here the priority is to reap the maximum benefits of this technology while still maintaining a high degree of safety.

The Malawian CAA has taken a holistic approach. As explained by Sunganani Kalilangwe, "Your primary goal is to serve the community you are operating in. Safety is paramount, but you must never forget your role is to use that tool [the drones]".[86] It is important to stress that a holistic approach does not mean you care less about safety. It does mean however, that you focus on ways to enable the safe use of drones while mitigating associated risks.

To further complicate the challenges around this ethical question is the fact that the narrow approach tends to increase cost and reduce health-related operations, especially those led by local actors.

High standards can at times increase costs substantially due to special certification processes, procedures and requirements. This can make it commercially unviable to offer drone-enabled health logistics. This makes low-cost low tech solutions particularly valuable in low and middle-income countries.

Figure 3 explores the possible outcomes in a purely theoretical scenario where the CAA adopts different ethical positions.

Figure 3. Differences in the ethical adoption within CAA

	Closed regulation No drone flights permitted	**Narrow approach to safety** How do we ensure no harm through the use of drones	**Holistic approach to safety** How do we ensure no harm is done both through the use of drones or by preventing the safe use of drones
REGULATION	Wait until the industry is more mature and safety solutions better established	Drone operations permitted based on regulations for manned aircraft	Locally derived, performance-based, appropriate regulation
SAFETY	**HIGHEST** Generally high as there are no flights, although would not necessarily prevent illegal or intential misues	**HIGHER** Potentially high safety as flights are restricted to a smaller group of users	**HIGH** High standards and safety measures in place balanced with need to ensure operations permitted to maximise benefits to a country
COST	**NONE** No costs as no flights permitted	**HIGHER** Low number of flights therefore very high cost per flight hour	**LOWER** Large number of flights reducing the cost per flight
BENEFIT	**NONE** No flights so no benefits realised	**LIMITED** Fewer flights so fewer benefits realised and reduced potential for positive impact	**HIGHER** Increased number of flights resulting in more benefits realised and more quickly

"Your primary goal is to serve the community you are operating in. Safety is paramount, but you must never forget your role is to use that tool [the drones]"

- Sunganani Kalilangwe, Malawi Department of Civil Aviation

HOW CAN WE AVOID RAISING FALSE HOPE THAT RESULTS FROM INSUFFICIENT FOLLOW-UP FUNDING?

Far too often, health workers face dashed hopes when it comes to implementing a technological solution with promising deliverables.

Some interviewees raised the issue that it can be harmful to a community when drone projects successfully proceed beyond their proof of concept or pilot stages, but cannot be continued due to a lack of funding.[87]

Community members learn about and experience the benefits of being able to get critical healthcare products on time. If this comes to a halt, people have been given false hope.[88]

On the other hand, the point was also raised that more experimentation is needed to accelerate learning and that therefore: "a greater number of smaller projects and programs should be encouraged in different settings and different countries".[89]

HOW CAN WE ENSURE THAT AFRICAN COUNTRIES ARE NOT JUST BEING USED AS A TESTBED?

There is a concern that African countries may once again be passive recipients of foreign technology and not sufficiently use the opportunity to gain meaningful local ownership of the design, manufacture and operation of drones.

The use of African countries as a testbed raises ethical questions. It is possible that foreign operators will gain experience in Africa until regulations ease up in their more lucrative home countries.

At this point, they may abandon the African health sector. Several African countries are proactively supporting local entrepreneurs, innovators and youth to take advantage of this space.

This involves building training academies and encouraging foreign companies to hire and train local actors as well as pushing for local manufacturing, assembly and repair.

Indeed, for African countries to fully benefit from the technology, localisation is key as explained in section 1. Supporting localisation requires a conscious, strategic and well-resourced effort as the playing field is tilted in favour of better-resourced foreign companies. [90, 91]

5 overview of potential risks

Risks

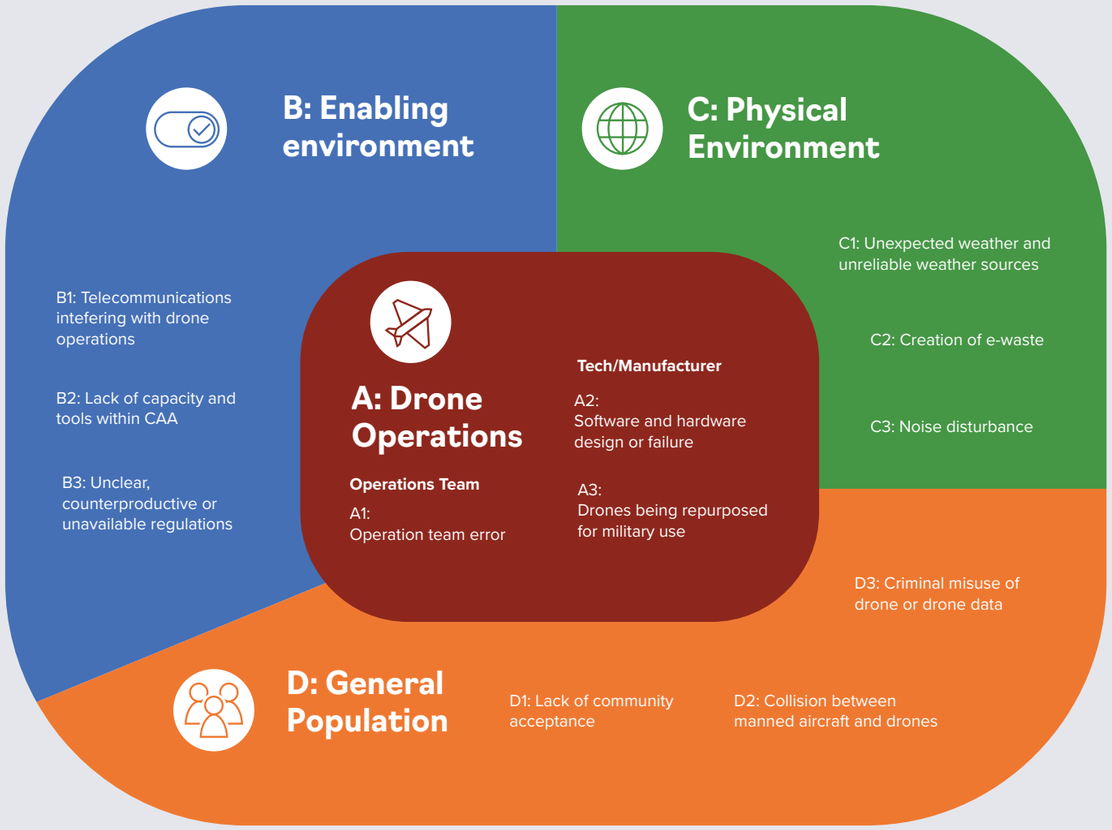
With the wide array of opportunities drones have to offer comes a responsibility to minimise any harm they might cause. As the sector grows and scales, there are various factors that cause safety and security risks and there are important ethical considerations to be aware of.

This section provides an overview of potential risks raised by the use of drones in healthcare logistics. The main underlying risks are that drones could potentially harm people, property or planet.

An overview of the main sources of these underlying risks is illustrated in figure 3. We will discuss these below in the following four categories: risks related to drone operations, the enabling environment, the physical environment and the general population.

Due to the focus on last-mile delivery of critical healthcare products, issues such as privacy concerns that are related to cameras on drones used to map, survey and take aerial photography work are not addressed in this paper.

Figure 4. Overview of safety and security risks



A. Drone operations risks

When it comes to the potential to harm people or property, drone operations can bear risks involving operational team or manufacturer errors.

A1. Operations team error

Once a drone has completed the prototype and development phase, the majority of safety incidents in drone operations are caused by human error.[92] "Whether drones do good or harm depends on who is handling them. People need to be trained".[93]

If pilots and other operator personnel are not informed and well-trained they may not be aware of the technical capabilities of the drones they are using, the drone's maintenance needs, or important aviation principles related to drones using airspace. People may also be unaware of the risks involved in flying over crowds in shared airspace.[94, 95]

Even with training, people may fail to follow protocol. For example, when doing routine pre-flight checks, people may think they do not need to follow a checklist because they do it often. They then forget a step, which results in failure during the flight.[96]

If the operations team fails to provide appropriate crowd control measures, people from the general public could get hurt if they get too close to take-off or landing sites, especially when the launch of a technology attracts crowds.[97]

A2. Software and hardware design failure

Hardware issues can occur for a variety of reasons from the drone being poorly designed to parts being of a low quality. The drone design can be inappropriate for the context, for example when a drone is prone to overheating. Drones can also suffer technical failure due to software issues.[98]

Drones may also pose a safety risk due to the lack of failsafe features that ensure they do not operate if certain safety measures have not been respected. For example, if the battery capacity is insufficient to complete the mission, a failsafe feature could be that it makes an emergency landing at a predefined emergency landing site or as a last resort it can release its parachute.

A3. Drones being repurposed for military uses

This risk raises ethical concerns because of the mandate of many organisations that fund and execute operations for drones doing good.

Regardless of the sector in which drones are deployed to save and improve lives, the possibility remains that they are eventually used for military purposes, which poses a risk to their outcomes and reputation.

B. Enabling environment risks

Drones operate within existing infrastructure and regulations, which can be a source of risk when infrastructure interferes with operations or regulations that do not enable a safe environment due to a lack of capacity or a lack of clarity on where to find regulations.

B1. Telecommunications interfering with drone operations

Drone operators need to maintain communication with their drones. In some cases, interference happens due to telecommunications being on the same frequency as the drones.[99, 100] When operators are not aware of this and therefore have not taken necessary precautions like frequency hopping, the drone can crash.

B2. Lack of capacity and tools within Civil Aviation Authorities (CAAs)

Drone operations in African countries and beyond are currently advancing faster than CAAs can keep up with.[101] There are no functioning comprehensive UTM solutions available that can fully integrate drones and manned aircraft.[102]

Furthermore, navigating the sector demands acquiring considerable knowledge and experience. Regulators themselves are learning as they go, which makes it hard for them to put the appropriate safety and security measures in place.[103, 104, 105]

B3. Unclear and hard to locate regulations or a lack of regulations.

Linked to the above issue of a lack of capacity within CAAs is the challenge that in many countries, regulations are unclear or hard to locate. This poses a risk because it means that it is harder for operators to know what the safety requirements are and what they need to do to fulfil them.

C. Physical environment risks

The physical environment in which drones operate both affects and is affected by the use of drones. Drone operations are largely influenced by weather and a lack of information poses a risk to them. Drones themselves pose risks to the physical environment, in the form of e-waste at the end of their lifetime and in the form of noise disturbance while in operation.

C1. Unexpected weather and unreliable weather sources

To assess the safety of a drone operation before it starts, operators need to know what the weather will be like. This tells them whether they will be flying the drone within its specified parameters regarding temperature, rain and wind.

In many African countries, operators cannot access reliable weather data for the locations in which they operate.[106] In certain geographical areas, there are microclimates that are not picked up in the national weather data and weather forecast models.[107]

C2. Creation of e-waste

When taking into account the growth of the sector and the lifetime of a drone, there is also a challenge around e-waste to be considered as it poses a risk to the health of the environment.[108]

While some parts might be suitable for repurposing or recycling, that process needs to be put into place and those facilities may not be available in the countries the drones are decommissioned in.

While significant research is underway, there is not yet any system operating at scale for recycling the types of lithium batteries that power most drones used for last-mile delivery.

C3. Noise disturbance

Drones can be rather noisy which might be experienced as a nuisance to people or animals.

While this risk was hardly raised in interviews, research indicates that noise pollution negatively impacts biodiversity and wildlife.[109, 110]

The degree to which wildlife react to drones depends on the attributes of the drone and the characteristics of the animals.[111] Animals react more strongly when targeted directly, when drones are large, and when engines are fuel powered (making them more noisy).[112]

D. General population risks

The general population can be at risk from drones as collisions and criminal misuse may jeopardise public safety. Drones and drone operations can also be at risk if they are not accepted by the broader public.

D1. Collision between manned aircraft and drones

The risk that a drone and a manned aircraft may collide is especially high when there is no physical separation between the airspaces for manned aircraft and drones or when aircraft are not electronically conspicuous. This is a safety risk for people in the manned aircraft, for the drone, and for people or property on the ground that could get hurt by a crash.

As a consequence of this safety risk, a collision between a drone and an aircraft poses a reputational risk to the entire drone industry.[113] While nearly all modern drones have the capability to hold a pre-defined flight height to a good degree of precision, at times manned aircraft may pose a risk by flying lower than their permitted airspace.[114]

D2. Lack of community acceptance

When communities are insufficiently engaged, drones may be rejected by a community or viewed with suspicion. There are cases where communities have seen drones as a threat because they believe the drones are powered by witchcraft.[115, 116]

Communities that are unaware of what drones are, how they work, safety measures in place and the benefits of their operations can pose an indirect reputational risk to the sector; if anything negative were to happen, people would be less tolerant of a failure as they are not aware of the good or value the drones are bringing.[117, 118]

D3. Criminal misuse of drones, drone operations or data

Drones could potentially be used maliciously by criminals or terrorists in a number of ways. For example, drones could be stolen from storage, or people may take control of the drone while it is flying and disrupt services or intentionally crash it for terrorist or criminal purposes.[119, 120, 121, 122]

Drones could also be used for illegal transportation of goods such as drugs, weapons and rare minerals, including cross-border transportation.

Finally, there is a risk that is not necessarily a security risk, but does fall under criminal activity, which is the risk of government officials or others within the drone ecosystem obtaining sensitive data about drone operations or derived from drone operations and selling this for their private benefit.

6 guiding principles

Guiding Principles

When making decisions about when, where and how to use drones, issues of safety, security and ethics will arise. The types of concerns and their solutions will differ based on the context.

This section provides some guiding principles to advance the safe and secure use of drones.

These principles, summarised on the right, reinforce each other as is well-illustrated by the Malawi use case shown in Box 1.

1.

Be proactive: start safe and small and work your way up.

It is important to find ways to start with small-scale, low-risk and safe operations with low risk, learn from those experiences and steadily scale.

2.

Don't cut and paste; develop, test and refine appropriate and safe regulations instead.

If harnessing the potential of drones to achieve the Sustainable Development Goals (SDGs) is of value to a country, simply cutting and pasting regulations from high-income countries will not support this objective.

3.

Adopt a participatory approach to developing regulations.

There is great value in understanding the co-dependence and interaction of different actions in the ecosystem and establishing co-creative processes when developing regulations.

4.

Inform and educate to better contextualise risks and acceptance.

Meaningful community engagement is a valuable approach to increasing acceptance and risk tolerance through a more complete understanding of the benefits of drone operations.

5.

Train to mitigate risk and unlock potential

The more everyone in the ecosystem is trained, the more competence there will be to collaboratively develop a safe and impactful drone sector.

1.

Be proactive: start safe and small and work your way up

It is important to find ways to start with small-scale, low-risk operations, learn from those experiences and steadily scale. The drone sector is evolving rapidly. The technology is new to many people, including decision-makers. Complete and comprehensive information is hard to obtain as new findings, technical developments, and practical needs keep changing.

If countries wait until the technology is fully matured, they run the risk of becoming passive recipients of the technology and lose out on part of the impact it could offer. It is better to be proactive, to take the steps you safely can now rather than wait on the sidelines.

As Munezero Angelos said: "Being proactive means not being reactive to new technologies coming out. When you are reactive, technology will always be ahead of you and you will be trying to catch up, but you will not be in front leading and paving the way".[123]

The experience in Malawi provides a clear example of how this approach can be beneficial. Authorities in Malawi chose to start because there was a need specifically for children under 5. Sunganani Kalilangwe explains: "We started with community sensitisation. Then we set up a drone corridor to start testing operations.

By the time this technology is quite mature, I would say we will be almost self-sustaining as a country in terms of the technology and last-mile transportation".[124] Rumbani Sidira explains part of the step by step process taken in Malawi: "When we have our technical working group meetings, we discuss how we can scale up operations in the country. Who will take which role and how we can work together to scale successfully. Success is measured by the impact the program is having on the population".[125]

Munezero Angelos of the Rwanda Ministry of ICT and Technology explains how Rwanda took a very proactive stance towards drone technology: "So you find that most regulators tend not to open up to these new technologies and they await for example for international regulatory organisations to publish regulations on how drones can be monitored, controlled and integrated, to avoid any risk that might be associated. [...] Our country sees itself as a Proof of Concept nation, where different technologies are tested before they are deployed in other countries. [...] We work together [with the regulators and other players] so that as long as we are mitigating risks, we ensure that we also have a way to promote innovations in the drone ecosystem to continue leading this development on the African continent".[126]

2.

Don't cut and paste; develop, test and refine appropriate and safe regulations instead

There is a reason why companies from Europe, America and Australia are coming to Africa to conduct drone operations. Many of these companies, which include Zipline, Wingcopter and Swoop Aero have their most extensive and impactful operations in African countries and not in their home countries.

More permissive regulations in African countries have played a critical role here. For example, it is easier for Wingcopter to fly BVLOS in Malawi than in Germany as there is no testing drone corridor in Germany. It is interesting and important to note that the more permissive regulations have not been accompanied by any 'horror stories' of major drone failures. More than 20,000 drone flights have taken place in Rwanda since 2016 without there being any major incidents.[127] Instead there are a great deal of cases that show drones are saving lives.

If harnessing the potential of drones to achieve the Sustainable Development Goals (SDGs) is of value to a country, simply cutting and pasting regulations from high income countries will not support this objective. It may simply replicate the barriers that prevent foreign companies from operating in their home countries. Instead, this is an opportunity to leapfrog.

African countries can lead the way in developing regulations that will offer a very high degree of safety but at the same time, allowing and enabling the use of drones for good at scale.

According to Munezero Angelos, Rwanda's success is a direct result of the performance based regulations that they pro-actively and collaboratively developed in partnership. For more on performance-based regulations, see the solutions section on page 71.

3.

Adopt a deeply participatory approach to developing regulations

Going beyond engagement and co-designing local ecosystems together with local players through a deeply participatory approach ensures that rules and regulations fit the local context and enable the solutions and outcomes people are aiming to achieve. A participatory approach is recommended in which regulators can work closely, through a process of co-creation, with key stakeholders in the drone ecosystem to avoid unnecessarily disrupting much-needed investments into the sector.

As Munezero Angelos puts it: "Since you are designing regulations and policies to develop that [drone] ecosystem you have to involve everyone in that ecosystem to understand their view and to understand what technologies they are working on to ensure that there is synergy".[128]

Israel Bimpe from Zipline confirmed that the open dialogue amongst stakeholders was critical: "an open dialogue between operators, airspace users, regulators and other people; I think that is one thing Rwanda has done really well. The Civil Aviation Authority has what they call a Technical Working Group of Civil Aviation For Drones it has all the regulators, it has the air navigation service provider, it has the military, it has all the drone operators in the country, we come together we talk about what is too restrictive, what is too lax and how best we can develop. [...]it is a nice open platform where there is a good exchange between the industry and the regulators, which also allows us to understand where they [the regulators] are coming from".[129]

Additionally, communicating long-term goals, visions, and strategy for the sector builds clarity and enables investor confidence. Innocent Mainjeni from VillageReach agrees: "This is critical in my opinion, because one of the key questions in Malawi is around sustainability and how we transition this technology. The earlier these conversations start, the better, because you need to understand who the interested players are".[130]

There is great value in understanding the co-dependence and interaction of different actions in the ecosystem. For example, certain regulations can have the unintended consequence of stopping the flow of investments required by the private sector to grow. If regulations suddenly change in a way that makes companies' business cases unviable, or if there is perceived unpredictability in the sector, investors will hesitate to dedicate funds or pull out of investments.

However, by virtue of the sector being new and evolving rapidly, changes to regulations can be made as regulators adapt to new realities; this is where in-depth engagement and processes of co-creation are critical as explained above.

4.

Inform and educate to better contextualise risks and acceptance

Meaningful community engagement is an essential approach to increase acceptance and increase risk tolerance. It's important to keep in mind that the use of drones takes place within existing complex and dynamic contexts. Some regions may have recently seen conflict, making the airspace something frightening. Other regions may have sacred sites that need to be respected. As new technologies enter people's lives, community engagement can shed light on context-specific concerns to consider.[131]

Innocent Mainjeni who is strongly involved in community sensitisation in Malawi illustrated: "Although drones have been around for a long time, their usage in the health space in low and middle income countries is quite recent. That brings in perspectives of cultural connotations of what people believe drones are all about. One thing that has been critical over the years is to try and help people understand how the drone is a helpful innovation also for them, and how they can co-exist with this technology".[132]

How people respond to drones depends on their views and beliefs. The more people know about the use of commercial drones and the positive impact they can have, the more they can engage constructively. Innocent Mianjeni shared from his experience in Malawi: "Once you are able to convince people that you are ready to take in their input from the word go, it helps ensure local ownership of the drone ecosystem and the collaboration as you move through the steps is great. Engaging local community leaders helps to create trust that the use of drones will serve the community".[133]

Besides the benefits of community engagement, it is also seen as an ethical requirement by many. One operator shared that: "In regards to ethics, it is very important to always do enough community sensitisation. This is especially important in areas where people are less familiar with this technology. The Humanitarian UAV Code of Conduct places ethical guidelines for drone operations in a humanitarian context that include considering and engaging local communities.[134] As Innocent Mainjeni from Village Reach pointed out, "Community engagement is a continuous process. I believe you never reach a saturation point".[135]

Strong engagement pays off in cases where things don't go as planned. Israel Bimpe Director of Africa Go-To Markets at Zipline mentioned the value of community engagement in the case of an incident. "Even when the innovation is still at a young age, when it's still being developed, the community is really understanding and wants to accompany the innovators because they see the value and the impact".[136]

This was echoed by Lyela Mutisya, Drone Lead at LifeBank, "When I tell people what we do [..] they are fascinated. They want to learn more about the company and stay up to date about what the company is doing. The more the public is aware of the good drones can do, the more receptive they will be, and the more they will weigh the pros and cons. If anything [bad] were to happen, they will know that this doesn't always happen and it shouldn't stop something good."[137]

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- Lyela Mutisya, Drone Lead, Lifebank

5.

Train to mitigate risk and unlock potential

The higher the level of training throughout the ecosystem, the more competence there will be to collaboratively develop a safe and impactful drone sector. This goes beyond training pilots and operators and includes training regulators and other government stakeholders that are involved in drone operations. Rwanda strives to be a leader in the drone space and speaking with Munezero Angelos the use of training to unlock potential came to the forefront: "We need facilities such as the Drone Operations Centre where drone technologists, enthusiasts, developers, and researchers can meet and work together to be sure that we unlock our space. There is a lot of potential to be unlocked by training and upskilling our future drone pilots and drone innovators in general."[138]

Thus, besides the safety benefits addressed below, upskilling is essential for job creation and long-lasting impact as it enables more local teams to lead the way, designing, building and operating drones and co-creating the surrounding ecosystem.

Training pilots and operators strongly mitigates safety risks as the majority of drone failures are due to human error.[139, 140] "The more educated and informed pilots are, the more they will be able to recognise hazards and risks and be able to mitigate those risks",[141] shared Lyela Mutisya. Innocent Mainjeni pointed out that in last-mile deliveries of samples that need to be picked up from rural health clinics, the health staff also need some training so that they can ensure the take-off and landing area is cleared, there are no people or animals around it, and how to load the payload safely.[142] One operator we spoke to added to this the importance of continuous training saying, "Make sure that you don't just train once, people also need refreshers."

As the use of drones is still new in most contexts, regulators are also on a learning journey: "A lot of people come in from experience operating or regulating Da-Jiang Innovations (DJI) type drones [quadcopters] and then go into conducting BVLOS, not recognising that there is a gap between the two. And I don't think that a manned regulator is going to know everything that it should do in order to become an effective regulator of drone operations," shared Nigel Breyley, saying it comes down to having a mindset of readiness to find out and learn about things.[143]

The need to train and support regulators and policymakers is precisely why the Smart Africa Digital Academy (SADA) was created. It provides courses, webinars and opportunities for exchange to policymakers and regulators to promote the digital transformation in Africa. SADA partnered with the DDG Alliance to offer an introductory training on the drone sector to 89 participants from 22 African governments. As explained by Dr. Ralph Oyini, Director of Digital Transformation and Servicies at Smart Africa: "We are working to future-proof our decision and policy makers with the necessary skills that will enable them to provide the right and safe environment for this dynamic industry".

Thus, besides the technical training of operators discussed in solutions, essential training topics for everyone involved include knowledge of what is needed for operators to conduct safe BVLOS operations, knowledge of the types of drones used in health logistics, and ongoing learning around how regulations impact operations and how best to find appropriate solutions together.

7 solutions

Solutions

There are a variety of solutions that can make it safer and more secure to operate drones. The range of solutions mapped in Figure 4 based on whether they are related to drone operations, the enabling environment, the physical environment or the general population.

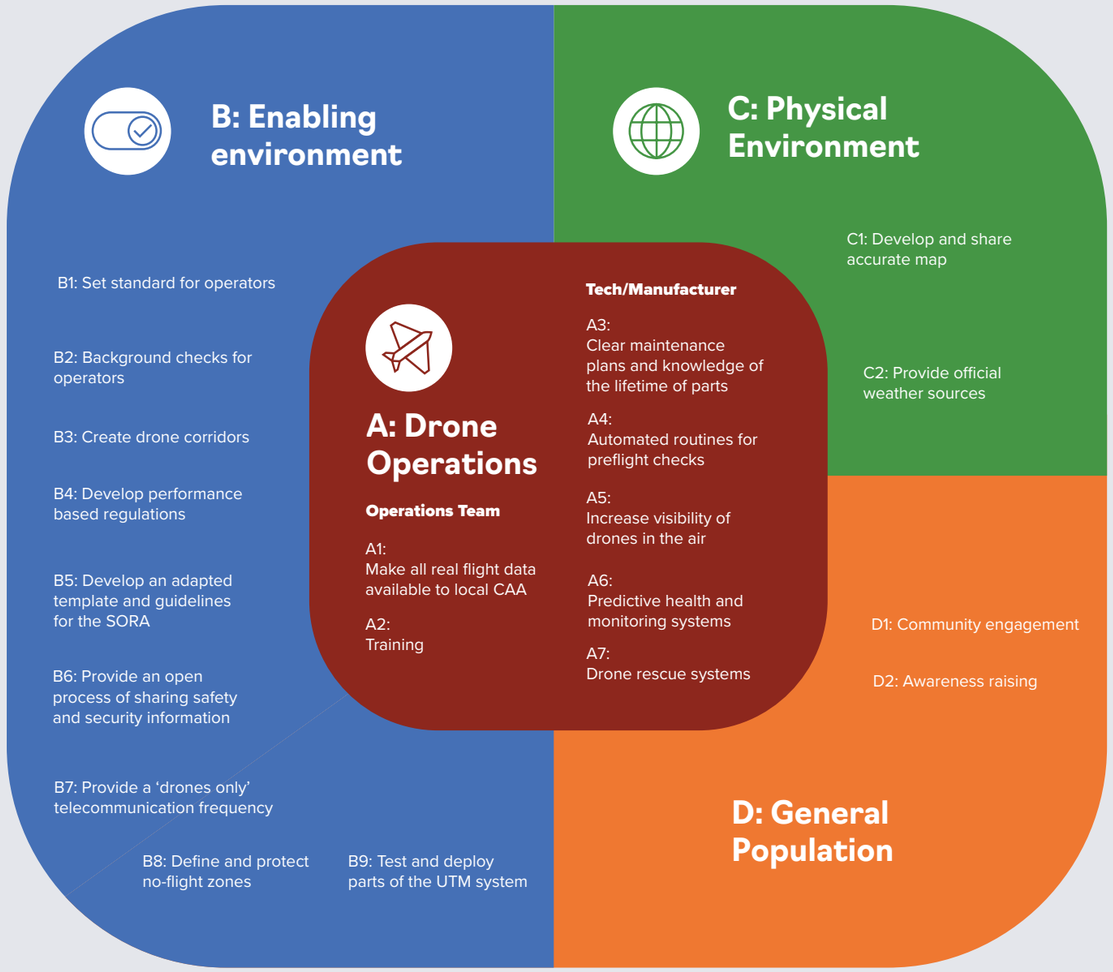
These solutions are at different levels of accessibility. Some are low-cost, low-tech solutions (e.g. physical separation of drones). Others are high-cost solutions that may not be quite ready at the moment such as UTM. This is discussed further on page 74.

We have purposely left out solutions that come with significant negative side effects including digital turnkeys and forced landings.[144]

The solutions that follow are derived from a combination of literature research and interviews from professionals covering decades of experience developing and operating commercial drones in over 40 countries.

These solutions offer countries a menu of options to increase safety and security. They are suggested in the spirit of agile systems change. In line with guiding principle 1, they can be tested in a small and safe space and, if appropriate and satisfactory, they can be rolled out or replaced with a better solution.

Figure 5. Overview of solutions



A. Drone operations solutions

The solutions in this section are related to drone operations, with the first two focusing on the operators themselves and the following four on the drone technology being used in operations. Drone failures are frequently caused by human error when operators do not follow the checklists and procedures accurately.

As David Guerin put it regarding incidents and accidents, "The biggest [safety] issue is human error. How do you prevent this: through a combination of automation and training".[145] Accordingly, most, though not all of the solutions provided in this subsection are a mix of training and automation.

A1. Make all real flight data available to local CAA

Operators can be required to make flight data available to the local civil aviation authorities. This can be done in two ways: by sending all flight logs daily, weekly or monthly, or through near real-time transmission of flight parameters.

This is done, for example, by Swoop Aero in Malawi and by Zipline in Rwanda.[146, 147] In both cases, data should be in an encrypted and standardised format to enhance security. Real-time data can be transferred from either the drone directly or a ground station. This would include data on the drone's position, height, speed over ground, and airspeed. Transmitting flight parameters in near real-time has limitations today.

The transmitters themselves are affordable, light, and work with a SIM Card but they need an uninterrupted data link between the CAA and the drone.

This solution also requires a fairly high level of organisation from the CAA in terms of reliable information technology (IT), suitable software for display of the flights, and power supply, however these may not be technically available in all cases. See Big Bang vs 1000 Islands Approach on page 32 for recommendations on the long integration and use of open source interfaces.

The main benefit of making flight logs available to local civil aviation authorities is that it enables data-driven decision making. The records show how precise the real flight path is within the flight corridors. Additionally, they reveal insights into problems, the frequency of dangerous situations, and the influence of weather on the drone flights.

Gaining these insights requires the technical know-how and ability to analyse the data, which can be supported. This is possible with available open-source tools. This solution requires a motivated CAA that is able to ensure data security for companies to protect their commercially sensitive flight data.

The CAA would have full overview over flights within their region of authority. This can show them how the potential of drones is being fulfilled and provide them insight into the real probabilities of risks.

A2. Training

Training people to become excellent operators requires equipping them in all the different fields necessary for the safe operations of drones. This includes knowledge and understanding of the surroundings that the drones operate in, both physical (meteorology, geography) and regulatory (air space regulations).

Operational staff must also have comprehensive knowledge of the drones and equipment they are operating: their components, failsafe measures, and maintenance requirements.

Further, operational procedures must be thoroughly understood and practised, these include creating safe flight plans, pre-flight checks, conducting flights, after flight checks, and keeping proper flight logs.

Training of operational staff should also cover personal health and fitness, the responsibilities of operators, ethical considerations, and interaction with members of the general public. In addition as further discussed on page 61, training should also be extended to regulators and policymakers.

A3. Clear maintenance plans and knowledge of the lifetime of parts

Timely maintenance of drones prevents technical failure, thereby increasing safety. Zac Kennedy shared how proactive maintenance from operators results in tangible safety improvements: "In the Democratic Republic of the Congo (DRC) we had fewer defects than in Malawi. When we looked into why, we found out that our team in DRC had taken the initiative to perform more preventative maintenance".[148]

For operators to perform timely maintenance, they require information from manufacturers on when to maintain certain parts. For example, propellers may require maintenance after a certain amount of flight hours. Manufacturers must also provide the estimated lifespan of components so that replacement can happen on time.

The example from the DRC also illustrates the value of having competent local teams that limit down time as they replace the need for specialists coming in from abroad and enable preventative maintenance as a part of normal operations.

Software solutions are available that inform operators on when maintenance should take place, as illustrated by Tawanda Chihambakwe: "We are onboarding fleet management software to keep track of maintenance so that we do not operate beyond what is prescribed by manufacturers and beyond the limits of what batteries can do".[149]

A4. Automated routines for pre-flight checks

Automation is a valuable tool for reducing error on the part of the operations team. As Lyela Mutisya has observed: "Some people feel they don't need to follow a checklist because they are used to doing something, they feel they won't forget anything, but they do. So having an automated checklist where they have no choice but to go through the necessary steps is one way to make sure they will be able to take off and fly safely".[150]

Such checks can detect a lot of potential problems for air security. This involves checking the servos,[151] engines, propellers, point of gravity, and battery. If any of these systems are not responding correctly, the automated system sends information on which system is failing and how to correct it to the operator, who can then adjust it and recheck the systems.

Nicolas Brieger confirms the importance of this solution based on his experience: "All the problems I have witnessed have been caused by human error, whether not responding to different weather conditions, forgetting to check batteries, or loading a payload that is too heavy. Automatic pre-flight checks should be heavily encouraged. Everything that can be checked programmatically should be".[152]

Automated pre-flight checks must be well programmed to ensure that they properly identify errors in a system. It is important to note that this solution does not replace the role of human pre-flight checks. There are some checks that cannot be automated such as a visual check for slight cracks on propellers or the frame. Encouraging the sharing of tests and algorithms through the use of open-source software would help to normalise and improve automated routines for pre-flight checks.

A5. Increase visibility of drones in the air

A good, practical and cheap solution to increase the visibility of drones for manned aircraft is to attach position lights to all drones operating in the corridor. These low-weight lights can be easily mounted and are also available in air traffic certified quality. They can be seen over several kilometers even in bright daylight.

A6. Predictive health monitoring systems

Predictive health monitoring systems can predict when parts need replacement before they fail, thus reducing the chance of drone failure. They do this by constantly observing parameters that provide information on the state of parts like servos, engines, flight controllers, and batteries.

For example, to monitor the servos the system measures energy consumption as well as time needed to get into position. If the servos are worn out, more energy is needed, and the response time increases. A predictive health monitoring system substantially increases safety even for drones with relatively cheap parts.

This system requires sound programming and should not replace careful checks from operators. As with pre-flight checks, open-source solutions have the benefit that they can be shared and improved upon.

This solution has a high impact on safety. It can also facilitate controlled and safe use of lower cost parts since a fault can be detected at an early stage and the part can be replaced before a problem arises.

A7. Drone rescue systems

Drones can be equipped with parachutes as a last resort in case of battery, propeller, flight controller or other failures. For this to work well, the drone must be at least eight metres high. The parachute causes the drone to fall slowly, substantially reducing its impact.

There may still be an impact when the drone hits the ground, potentially damaging the drone, but the risk to people, animals or property is largely reduced.

Adding a parachute rescue system to a drone does add some weight, complexity, and therefore cost to the drone. However, operators are interested in this safety feature: "I believe a parachute is important. It's a good way to have that extra safety measure. More companies should have the option of including a parachute when you're purchasing a drone", said Lyela Mutsiya.[153]

One challenge with this solution however is that the parachute can be set off by a false alarm. According to some industry experts this issue was more of a problem in earlier models and reliability of these systems is now improved.[154] Furthermore, it must be considered that once the parachute is open, the drone can no longer be controlled.

"The biggest [safety] issue is human error. How do you prevent this? Through a combination of automation and training".

- David Guerin, World Bank Group

B. Enabling environment solutions

The solutions in this section are measures that governments can take the lead on to create a safe and secure enabling environment for drone operations. They range from requirements for operators, to the use of airspace, to the provision of telecommunication channels.

While governments can take the lead, there are also roles to play for other actors including donors, operators and manufacturers. Strong collaboration is essential for certain solutions such as the sharing of safety and security information.

B1. Set standards for operators

Competent operators contribute significantly to safe drone operations. Governments can set standards for operators to ensure they have the right level of expertise for the type of drone and operation they are engaged with. "Educating pilots is critical and key. When I was recruiting pilots in Ethiopia, I could not find any that didn't need further training", shared Lyela Mutisya from her experience as Lead Pilot for Lifebank's operations in Ethiopia and Kenya.[155]

There are several guidelines in existence that are relevant and can be applied. However, it is especially important that there are no high financial barriers to get certified. In Malawi, as Tautvydas Juskauskas shared: "We have less and less drone incidents because the capacity of the pilots is being improved. Huge emphasis is being put on training and licensing of pilots through the African Drone and Data Academy".[156]

Well-trained pilots are just one part of the standards required for safe operations. In the future, drones are likely to become increasingly autonomous and less reliant on pilots. There is value in thinking more broadly of the various fields of expertise of the operations team including creating flight paths, maintaining the drone, flight weather, handling the batteries, fail safe measures, documenting the flights, and air space regulations.

B2. Background checks for operators

Authorities can run background checks on companies wishing to operate drones to mitigate the security risk of intentional misuse. This could also include signing a legal agreement about the persons intentions, similar to agreements signed when entering a country that one is not a terrorist and has no criminal intentions.

The background check would include information on the company's goals regarding drone operations, their motivations, the profile and background of founders and funders and insurance. It would also include company history.

In Kenya, where security risks are prevalent due to terrorist activity, the goverment has such a background check process in place, shared Lyela Mutsisya: "Before going through the ROC (Remote Aircraft Operators Certificate) process, every company goes through a rigorous background and security check to make sure that the company would be more likely to do good than harm once they receive their ROC".[157]

Acknowledging that users with ill intentions may not register their drone(s) and submit themselves to background checks, authorities could require companies to report the sale and/or border forces to report the import of any drone, including contact details and business registration of the purchaser, to the government. This could either enable authorities to follow up on use or serve as pre-approval to buy or import.

This process should be fast and simple so it doesn't stall operations. Once an operator has completed their background check, they could receive an operator ID number. This number should be listed on every drone they own. It should be non-removable and made from an inflammable material. In the future, every drone can have a licence plate similar to cars. This would allow the government to know precisely how many and which types of drones are being operated.

Background checks can have some limitations. It is important that options are available for new companies as they have no track record. Another point to consider from an ethical perspective is that the background check does not include any generally discriminating processes. For example, it should not single out people based on their identity, whether ethnic, religious or otherwise, to be generally untrustworthy.

B3. Create drone corridors

In the places without heavy air traffic, Nicolas Brieger pointed out that, "Physical separation is a quick and easy way to avoid errors [...]. Safety by default is a good way to do some things the low tech way. If every helicopter pilot in the country knows to avoid specific lanes in the air you can greatly reduce the chance of collisions".[158]

Drone corridors are a way to create physical separation. Corridors are placed in lower airspace, typically under 300ft, which is below the level most aircraft operate. Testing corridors are placed in especially safe areas where there is little risk for a crash to harm people or property (e.g. above waterways, forests, disused runways and uninhabited areas).

In addition to carefully selecting corridors so they lie above low-risk areas, corridors can be further secured by having only one- way drone traffic, where each drone has a delayed start, if there are higher volumes of flights. Furthermore, different types of drones can be assigned different heights within the corridor. For example, lower heights can be assigned to copters while fixed-wing drones and VTOLs can be assigned higher levels within the drone corridor. Finally, it is important to designate emergency landing spots as well as areas where the drones can circle and stall when necessary.[159]

There are multiple practical examples of successful implementation of drone corridors in Rwanda, Malawi, and Ghana.[160, 161] Moreover, testing corridors are highly valuable to commercial drone development. They stimulate new concepts and drone design by offering a safe place for testing: "Those companies that have been operating in Malawi are getting a lot of data which also helps them improve their systems. They can go back to their flight logs and investigate the reasons for any incidents".[162]

B4. Develop performance-based regulations

A number of countries including Malawi and Rwanda have developed performance-based regulations to enable the safe use of drones. Performance-based regulations make it possible for unmanned aircraft to access airspace on a mission-specific basis. How it works is that the government specifies the safety standard of the mission, and drone operators specify how they will meet it.[163] By doing this, governments can give operators timely access to airspace and expand the range of possible applications. This is a very different approach than using certification to ensure safety. Whereas certification takes time, performance-based regulations are agile and therefore a good match for new and rapidly developing technologies like drones.[164]

The experience in Rwanda forms a clear example of how the performance-based regulations can be developed collaboratively. The government started by identifying sectors with clear use cases for drones and informing themselves on the availability of operators able to provide the services needed.

They then set up a drone steering committee in 2015 that progressed with a participatory approach, conducting meetings with operators, other government departments, security units and end users.[165] Regulations were revised through a process of collaborative decision-making and testing. Seven years later, there have been over 20,000 flights and not a single serious incident or accident, showing that when

properly and collaboratively managed, drones can operate safely in an environment with performance-based regulations.[166, 167]

Having performance-based regulations has enabled Rwanda and other African countries to remove the limitations that many drone operators experience in the US and Europe. These agile regulations have put Rwanda on the map as a world leader in creating an enabling environment for drones: "The performance-based regulations that we have are the primary solution. If we hadn't developed that we wouldn't have Zipline flying today. Having an enabling environment is key. For us, the enabling environment is created through the performance based regulations. Many countries are coming to learn from us to see how this is being implemented".[168]

B5. Develop an adapted template and guidelines for the Specific Operation Risk Assessment (SORA)

The purpose of a SORA (Specific Operation Risk Assessment) is to identify potential risks and problems and answer how they are addressed through operational procedures. This can involve determining what happens when wind conditions change and become too strong or when the drone malfunctions. It is very important that drone operators develop their SORA - and that they have the relevant procedures in place.

They must describe what they want to do in a given situation, clarify their operational process, and define the safety measures they have in place. Developing a SORA increases the likelihood that operators implement relevant safety procedures.

A SORA that identifies every single possible risk, even a highly unlikely one, becomes very expensive for operators to create and the resulting document is too long to practically implement. Instead, it should focus on the most important issues. For it to be most effective as a safety tool for operators, the SORA should be a living document that is mastered by operators rather than a bureaucratic exercise completed by consultants.

The need for consultants also raises the cost of entering into operations, which some see as disadvantageous to local players.[169] It should include risk minimised flight paths, establish emergency landing solutions where relevant, and identify procedures in place for when telecommunication is lost.[170]

Nigel Breyley added the need for regulators to be clear on which risks need to be accounted for: "set some baseline levels of requirements and then set some guidelines around what are the important issues to think about".[171] One way to ensure that an adapted SORA handles the most important risks is to create a template with guidelines for what to do in common situations. For this, a SORA adapted to the context in low and middle income countries or low resource remote settings is critical.

As David Guerin explained on the SORA methodology, "There is not one that suits [...] the limited resource settings with remote locations where the connectivity is low or not available. Where surveillance on where aircraft are is poor or very expensive and there is no infrastructure to support it and the mapping data quality is poor or not existent. [...] So how do we solve that? We have to come up with a methodology that suits".[172]

Developing and testing such an adapted SORA as well as developing detailed guidelines and templates should be a participatory approach and include local operators and local manufacturers. Underscoring the need for better guidance, Zac Kennedy stated "There is wildly insufficient information on what is expected in each part of the SORA. I think we have to make it easier to comply, without the need of consultants, by publishing an enormous amount of guidance material on the requirements of each section".[173]

B6. Provide an open process of sharing safety and security information

The government can support open communication about safe drone operations, best practices, challenges, and failures. In Malawi, the Department of Civil Aviation established the RPATWG: "To ensure all stakeholders in Malawi have a common platform to share experiences and learn from each other", shared Innocent Mainjeni.[174]

Beyond sharing with each other, the members of this group also create information products for new operators to learn from as they start out: "We [RPATWG] created a toolkit for any new operators coming into Malawi. In it, we share the technical challenges we are having and some of the solutions we have created".[175]

"The performance-based regulations that we have are the primary solution. If we hadn't developed that we wouldn't have Zipline flying today. Having an enabling environment is key. For us, the enabling environment is created through the performance based regulations. Many countries are coming to learn from us to see how this is being implemented".

- Munzero Angelos, Ministry of ICT, Rwanda

A digital information platform, where drone operators can report their problems anonymously, can significantly increase safety and security. Anonymous reporting makes it easier for people to report errors who might otherwise fear repercussions involving the loss of a licence or a damaged reputation.

The Aviation Safety Reporting Program (ASRP) in the US provides an example of enabling anonymous reporting for the benefit of the drone community.[176]

In this example, reporting is incentivised by offering protection to those who have reported a failure, meaning that if a safety violation is discovered it will not be penalised if the incident has been reported and their requirements fulfilled.

B7. Provide a 'drones only' telecommunication frequency

To prevent interference and potential crashes due to telecommunications being on the same frequency as drones, governments can provide a 'drones only' telecommunication frequency in a long band width of around 900MHz.

This solution requires transmission stations that can be provided by the government, by private actors, or by the drone operators themselves. While this frequency has the advantage of a long range, it has the disadvantage of a small bandwith, which makes it suitable for the transmission of flight logs, but not for video transmissions.

For large countries in which drone operations are widespread, this solution can become costly. A government may choose to only set up transmission stations where they have approved drone flight areas.

Despite the cost involved, this measure provides a high impact on safety because it provides safe communication between drones and operators, which is a common challenge: "[A lack of coverage] is definitely a complication we've had in the past in Kenya. Together with other drone operators we have been trying to figure out the best way to make sure we have coverage the entire time".[177]

B8. Define and protect no-flight zones

No-flight zones are areas that drones should not fly over. These can include large airports, hospitals, schools, government buildings, universities, markets, and police stations. Where deliveries are made to hospitals, safe landing sites on or near hospital grounds can be identified. It is important that, once defined, these no-flight zones are clearly communicated and placed on digital mapping programs used by drone operators.

No-flight zones can be intentionally or accidentally violated. Therefore, it is necessary to protect them. There should be penalties for violations to ensure operators strictly avoid accidental incursions. In addition, they can be electronically protected by jamming or spoofing the GPS signal of drones that enter no-flight zones.

Alternatively, the telecommunication between the drone and the ground station can be interrupted. If these measures fail, drones can be fired upon with lasers or bullets, or captured with nets. Guaranteed protection is not possible, but a high level of effectiveness can be achieved with well-planned measures. It should be noted that these are quite expensive and require a high degree of training and organisation.

B9. Test and deploy parts of a UTM system

Air traffic authorities are keen to have a UTM system which is able to see, manage and control all drone flights and even all aircraft in a country in near real time. In some countries, the drone regulations state that a UTM is mandatory for drone operations or at least for BVLOS flights.

In theory, this sounds commendable and it can increase the safety and security of drone operations. However, the topic of a UTM solution is challenging at the moment. To begin with, regulations rarely clearly define UTM solutions. For example, does it just need to show where drones are operating, or should it have additional features?

To further complicate things, in reality, there is currently no fully operational comprehensive UTM solution in the world.

This was echoed by a number of the experts interviewed. In fact, it will still take many years of development before a UTM will work for every drone for a whole country. There are factors to define such as the required functionality. There are also prerequisites that need to be in place for such a system to function. For example, reliable telecommunication for every drone, even the very small ones, reduced delays in communication speed, all drones should be electronically conspicuous, there should be unique identifiers for every drone, etc.

Because of these issues, simply stating that a UTM is mandatory for a flight to take place may be of limited value. In some cases, such regulations are hindering the development of a drone industry and the provision of critical healthcare logistics.

There is, however, another way to begin using UTM that is in line with guiding principle 1: be proactive, start safe and small and work your way up (see page 56), and it applies the "thousand islands" approach (see page 32).

In Malawi, the DCA in cooperation with UNICEF and various operators recently started to implement a basic UTM based on open software programs, which are able to deal with already defined standards (e.g. for geo-fencing, identification numbers for drones, etc.).

They began by testing the software as is, then based on the lessons learned and the requirements on the ground, they will tailor the software to meet their needs by adding, for example, specific functionalities. They have now defined a roadmap of the future development in detail. This is an interesting approach and because they are using open-source software it can be shared with other countries.

C. Physical environment solutions

The solutions in this section focus on the physical environment that impacts drone operations, namely the weather and geography. They relate to the opportunity to acquire local data sources.

C1. Develop and share accurate maps

Operators use maps to plan their flights. The more accurate the maps, the better operators can plan safe flight plans. Operators need insight into surfaces, no-flights zones and other obstacles. Governments can provide these maps themselves, or private companies can take the initiative to develop them themselves.

This solution may sound extremely simple but because maps are in some regions updated only every few years, operators may not be able to use them without on-site visits. Older maps may not capture changes such as settlements and telecommunication transmission towers, which will affect the planning of corridors and flight paths.

As explained by one operator, “We use Google Maps Pro for an initial route planning but when we arrive on site we still have to check whether there is a new house or road and often have to change our flight plans again”.

The benefits to flight safety are quite concrete because accurate maps enable flight plans that correspond with the reality on the ground. If the geographic data is not already present, it can be quite costly to create and update these maps. However, once created, these maps can have positive spillover effects for other sectors and businesses.

C2. Provide official weather sources

Drone flights can be strongly impacted by weather. The more relevant meteorological information operators can obtain, the better they can respond. Global sources often don’t pick up weather variances of local microclimates.

A government, university, or private company providing more detail on local weather patterns can improve flight safety and increase the speed of operations. Lyela Mutisya shared how this solution is particularly relevant in an African context: “Especially coming from America where getting that information is really easy, I’ve been struggling to get it in African countries. If the government could make it a lot easier for us to access accurate weather information it would definitely be extremely helpful for safe operations”.[178]

Zac Kennedy from Swoop Aero shared a similar experience: “One risk for us is that in some countries like the DRC the weather sources are not as reliable or frequently updated as in other countries.”[179] Another operator added that they use a combination of different software solutions and that: “it takes a while when you go into a different country to understand which software works best in that country. It would make sense to have better information available here”.

Israel Bimpe noted the added complexity of micro weather events caused by the hilly nature of Rwanda. He explained that this is not something that can be predicted by any mini weather station. Instead, Zipline drones have sensors that collect weather data. They are using this to build models to help guide and better understand patterns. He also stressed that innovators should not wait for the government, but be proactive in contributing to their solution.[180]

D. General population solutions

The solutions in this section are about engaging with and raising awareness among the broader population as the drone sector develops.

D1. Community engagement

Community engagement is important to increase the safety of communities and operations in areas where drones are being used. Methods may differ per context, but there are general practices that can be helpful.

The communities engaged with should be those that are directly affected by drone operations. Find a suitable point of contact, someone or organisation with standing in the community, and tell people about the drones, what they are, what they do, and how they work.

"We have strong engagement with the communities, we teach them about drones and show them how they function. We take the drones into the villages and communities and make sure that there is that acceptance and they turn into your champion", said Israel Bimpe.[181]

Having developed a relationship with local communities also provides a pathway to receive feedback when incidents happen, as Israel Bimpe explains, "Here in Rwanda it's amazing that when our drone pulls a parachute and lands, the community picks it up and takes it to the hospital. It's written on the drone 'Don't move, don't touch', but the people say that 'these people told us it is an ambulance in the sky so we would rather take it to the hospital, maybe there is blood in there'".[182]

He added that when asked whether they were annoyed about their crops being damaged, they replied yes but it's good because it's saving lives.[183] This solution relates closely to guiding principle four: Inform and educate, to better contextualise risks and acceptance.

D2. Awareness-raising

Awareness-raising is closely related to community engagement, but broader as it addresses the entire general public, not just the communities directly affected.

This solution also aims to increase the acceptance of drone operations and ensure that people understand how and why drones are used. This can be done through communication campaigns that use videos on television and social media and radio broadcasts.

These can be about case studies of drone operations and their impact, illustrating the benefits for health outcomes as well as for job creation. They can showcase local entrepreneurs and how they use drones to serve the country while creating jobs for others in this sector.

8 the way forward

This is an exciting time on the African continent. Countries like Rwanda and Malawi have taken a lead in enabling the use of drones and their citizens reap the benefits by gaining access to health products and services in previously underserved areas.

Both countries are now making strides to advance the localisation of manufacturing, maintenance, and logistical expertise to generate a wide range of jobs, stay ahead of the game, and have tangible and diverse positive spillover effects.

The good news is that much can be done today by applying simple low-tech solutions that come at a low cost but offer high impact by significantly reducing the risk of harm.

Below is a road map for countries on how they can steadily increase safety and security in the short term and over time further strengthen it with more complex solutions in the mid and long term.

CAAs will be major actors in implementing these solutions, but there is plenty of space for other actors to take action and collaboration will be essential to long term success.

Short-term, low cost, low complexity solutions

Be proactive and start small by creating physical separation and testing corridors so that your local drone community can start testing their technology safely in your context.

- Set up a simple, straightforward online system for drones and operators to be registered.
- Run background checks on all operators.
- Ensure all drones have an operator ID and position lights.
- Establish corridors above low-risk areas
- Ensure that corridors are reserved for drones and that if other aircraft need to use the space a NOTAM is issued to warn operators.

Start a deeply participatory approach of co-designing regulations, policies and tools

- Engage with different actors (local innovators, manufacturers, operators, relevant government departments) to explore appropriate ways to ensure safety while enabling innovation and operations.
- Co-create an appropriate SORA with templates and guidelines, as well as exchange safety and security relevant learnings, this can be done by creating a working group.
- Consider adopting a holistic approach to safety together with stakeholders.

Develop performance-based regulations that enable drone operations

- As part of the co-creative process, develop regulations that allow operators to progress through different stages of activity based on their performance. Operators can start in the drone testing corridor, where they can gather data on their drone's performance and refine their technology and processes in a safe space. Once they prove they can operate safely, they can graduate into corridors outside the testing area and start operations serving local communities.
- Create an anonymous platform to report errors so the CAA and other stakeholders can continuously learn from the data and make informed decisions.

Provide ongoing training, community sensitisation and awareness raising to build capacity and create widespread support to sustain drone operations

- Identify areas where it is appropriate to set standards, for example for operators, together with the stakeholders in your working group.
- Start community sensitisation in the communities that drones are going to operate in so that they understand what drones are and how they work as well as how they can serve the community.
- Work to raise awareness in the general population by communicating case studies through local media.

What happens after that? Below are solutions that are appropriate for the mid term and long term. They are of medium and high level cost and complexity.

Mid-term and medium cost and higher complexity solutions

- Set standards and improve training for operators and the CAA.
- Provide a "drones only" frequency to prevent interference in drone communications.
- Enable automated transmission of flight logs from operators to the CAA.
- Identify, test and improve parts of a UTM solution.
- Provide accurate local maps with information on land use, geographical features and obstacles.

Future solutions

- Provide accurate and detailed local weather data that includes data on local microclimates.
- Enable the real-time transmission of flight data from operators to the CAA.
- Complete ATM with UTM integration through clearly defined interfaces.
- Enable automated pre-flight checks on all drones in health logistics.
- Enable predictive health monitoring on all drones operating in health logistics.
- Enable failsafe features on all drones operating in health logistics.

Figure 6 below offers a visual summary of some of the key ways that safety and security can be ensured in areas that do not have a crowded airspace. Nevertheless, each country will need to address the ethical considerations and decide what are the appropriate solutions for their country. We hope the publication can help shed light on the various options at hand and their possible consequences.

A. Drone Operations

TODAY

- Ensure clear maintenance plans and knowledge of the lifetime of parts
- Increase visibility of drones in the air e.g. with position lights

TOMORROW

- Enable automated transmission of flights logs from operators to the CAA

FUTURE

- Enable automated pre-flight checks on all drones in health logisitics
- Enable predictive health monitoring on all health logisitics

B. Enabling Environment

TODAY

- Set up a simple and straight forward online system for drones and operators to be registered.
- Run background checks on all operators.
- Ensure all drones have an operator ID and position lights.
- Establish corridors above low-risk areas
- Ensure that corridors are reserved for drones and that if other aircraft need to use the space a NOTAM is issued to warn operators.
- Develop performance based regulations that enable drone operations.
- Create an anonymous platform to report errors so the CAA.
- Identify areas where it is appropriate to set standards.

TOMORROW

- Set standards and improve training for operators and the CAA.
- Provide a 'drones only' frequency to prevent interference in drone communications.
- Identify, test and improve parts of a UTM solution.

FUTURE

- Enable the real-time transmission of flight data from operators to the CAA.
- Complete ATM with UTM integration through clearly defined interfaces.

C. Physical Environment

TOMORROW

- Provide accurate local maps with information on land use, geographical features and obstacles.

FUTURE

- Provide accurate and detailed local weather data that includes data on local microclimates.

D. General Population

TODAY

- Community sensitisation
- General awareness in population

Figure 7: Key takeaways

Enabling drone operations can have an immense positive impact on the local economy – a field of high tech where African countries can play an important role by enabling operations.

For more on the value of drones see page 16

Not enabling drone operations for medical issues **can harm and prevent positive health outcomes and improve mortality rates,** which poses an ethical dilemma for many. What is needed is permissive and appropriately high safety standards.

See chapters 3 and 4

A great deal can be done to decrease safety and security risks and a number of these measures are low-tech and low-cost operations. There is value in striving to minimise the risk that a failure can do harm.

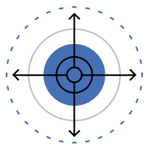
See page 85 for list of solutions

Regulations found in most high-income countries should not be the role model for Africa. Africa has safe BVLOS drone operations unlike high-income countries where there are only a few. African countries must lead the way in developing regulations through a participatory approach that will enable Africa to continue to allow innovation to thrive while maintaining high safety standards.

Create practical and doable performance-based regulations developed in a participatory manner – foster good dialogue with operators, manufacturers and communities, where the impact of regulations can be discussed, tested and refined to ensure both safety and enabling objectives are met.

This will allow regulators to understand and evaluate the effects of your decision on all actors.

See page 52 for more guiding principles

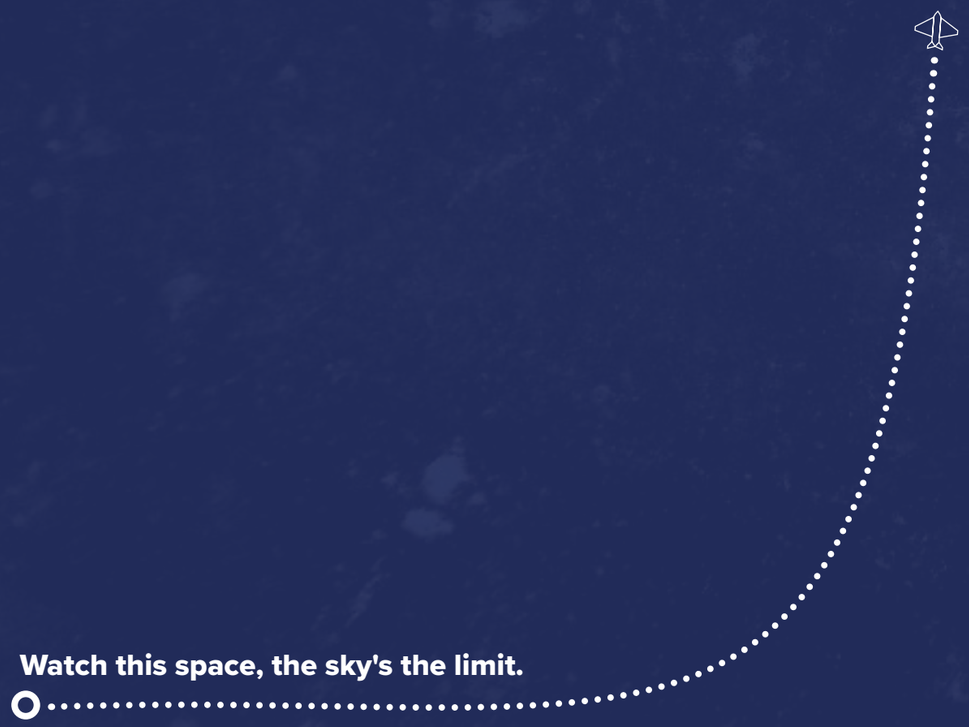


Do not wait till a perfect solution is available – start fast, small and safe, and expand as you learn by experience.

See page 56 for more guiding principles

In conclusion one of the main messages of this paper is to start small and safe. Malawi started by setting up a drone corridor as a testing space. Rwanda dedicated flight paths that reduced the risk of drones causing harm to people and property.

Both countries have become examples and places of learning. Authorities from across the world are coming to learn from their progress. Meanwhile, both Malawi and Rwanda are looking ahead and making concrete steps towards creating drone hubs where people can learn, design, manufacture, train and innovate.[184, 185]



Watch this space, the sky's the limit.

Endnotes

1. WEF (2021) Medicine from the Sky: Opportunities and Lessons from Drones in Africa, http://www3.weforum.org/docs/WEF_Medicine_from_the_Sky_2021.pdf
2. European Investment Bank (2020) Africa's digital solutions to tackle covid-19, https://www.eib.org/attachments/country/africa_s_digital_solutions_to_tackle_covid_19_en.pdf
3. Dual-purpose machines are machines that can be used for both civil and military applications.
4. Interview with David Sarley, Senior Program Officer, Bill & Melinda Gates Foundation, 2022.
5. WeRobotics, (2021) Shift the Power, https://werobotics.org/shiftthepower/
6. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
7. DDG Alliance (2019) When to use drones? https://endeva.org/wp-content/uploads/2019/11/ddg_alliance_report_digi.pdf
8. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
9. Drones Doing Good Alliance/UKaid, "When to use drones." uploaded by Endeva, November 16, 2019, https://vimeo.com/373596106
10. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
11. WeRobotics (2020) Technology for good is broken. Here's how we're trying to fix it, https://blog.werobotics.org/2020/02/13/technology-for-good-is-broken-heres-how-were-trying-to-fix-it/
12. WeRobotics and FlyingLabs (2022) The majority of localisation efforts have failed. This one continues to shine, https://werobotics.org/wp-content/uploads/2022/03/Localization-A-Success-Story.pdf
13. Interview with Dumisani Kaliati, Founder and CEO, MicroMek, 2022.
14. Droneii (2022) Drone investments continue to break records, https://droneii.com/drone-investments-in-2021-break-records
15. Interview with James Munyoki Kiua, Founder and CEO, Swift Lab Limited, 2022.
16. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
17. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
18. WorldBank (2021) Unlocking the Lower Skies: The Costs and Benefits of Deploying Drones across Use Cases in East Africa, https://openknowledge.worldbank.org/handle/10986/35593
19. WEF (2021) Medicine from the Sky: Opportunities and Lessons from Drones in Africa, http://www3.weforum.org/docs/WEF_Medicine_from_the_Sky_2021.pdf
20. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
21. Drone corridors are tubes of airspace that have been specifically assigned to drone operations.
22. Interview with Nicolas Brieger, Head of FIA / TCS Drone & Vertical Mobility Academy, Touring Club Scweiz TCS, 2022.
23. Sopfie Henwood and Navpreet Atwal (2021) How will drone corridors revolutionise industrial estates? https://www.boodlehatfield.com/articles/how-will-drone-corridors- revolutionise-industrial-estates/
24. UNICEF (2017) Africa's first humanitarian drone testing corridor, https://www.unicef.org/innovation/drones/africa-first-humanitarian-drone-corridor-malawi
25. JSI Research & Training Institute (2018) What should you deliver by unmanned aerial systems? The role of geography, product and UAS type in prioritising UAS deliveries, https://publications.jsi.com/JSIInternet/Inc/Common/_download_pub.cfm?id=19145&lid=3
26. Carroll, M., Daly, D. & Begley, C.M. The prevalence of women's emotional and physical health problems following a postpartum haemorrhage: a systematic review. BMC Pregnancy Childbirth 16, 261 (2016). https://doi.org/10.1186/s12884-016-1054-1
27. European Investment Bank (2020) Africa's digital solutions to tackle covid-19, https://www.eib.org/attachments/country/africa_s_digital_solutions_to_tackle_covid_19_en.pdf
28. WEF (2021) Medicine from the Sky: Opportunities and Lessons from Drones in Africa, http://www3.weforum.org/docs/WEF_Medicine_from_the_Sky_2021.pdf
29. Reach Alliance (2021) From A to O-positive: Blood delivery via drones in Rwanda, https://reachalliance.org/wp-content/uploads/2021/03/Zipline-Rwanda-Final-April19.pdf
30. Nisingizwe et.al., (2022). Effect of unmanned aerial vehicle (drone) delivery on blood product delivery time and wastage in Rwanda: a retrospective, cross-sectional study and time series analysis. https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(22)00048-1/fulltext
31. Barro, L., Drew, V.J., Poda, G.G., Tagny, C.T., El-Ekiaby, M., Owusu-Ofori, S. and Burnouf, T. (2018), Blood transfusion in sub-Saharan Africa: understanding the missing gap and responding to present and future challenges. Vox Sang, 113: 726-736. https://doi.org/10.1111/vox.12705
32. Gabriella Ailstock, Manager, Health Systems, Village Reach
33. UAV for Payload Delivery Working Group webinar, featuring PSI Madagascar, on May 6, 2021
34. Gabriella Ailstock, Manager, Health Systems, Village Reach
35. Université de Kinsasha, Ecole de Santé Publique, en collaborations avec VillageReach,Évaluation des performances des drones pour le transport des vaccins et autres produits de santé vers les formations sanitaires éloignées. Province de l'Equateur, République Démocratique du Congo,Rapport de l'enquête à mi-parcours, page 17, retrieved from https://www.updwg.org/wp-content/uploads/2022/04/Evaluation_Performances_Projet-Drones-Resultats_Enquete-a-mi-parcours-2.pdf
36. WEF (2021) 5 Lessons from Africa on how drones could transform medical supply chains, https://www.weforum.org/agenda/2021/04/5-lessons-from-africa-on-how-drones-could-transform-medical-supply-chains/
37. European Investment Bank (2020) Africa's digital solutions to tackle covid-19, https://www.eib.org/attachments/country/africa_s_digital_solutions_to_tackle_covid_19_en.pdf
38. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
39. Singer et.al., (2016). Cost Analysis and Feasibility of Using Unmanned Aerial Vehicles to Transport Laboratory Samples for Early Infant Diagnosis of HIV in Malawi, http://docplayer.net/17711108-Cost-analysis-and-feasibility-of-using-unmanned-aerial-vehicles-to-transport-laboratory-samples-for-early-infant-diagnosis-of-hiv-in-malawi.html
40. Ghadrshenas A, Ben Amor Y, Chang J, Dale H, Sherman G, Vojnov L, Young P, Yogev R; Child Survival Working Group of the Interagency Task Team on the Prevention and Treatment of HIV infection in Pregnant Women, Mothers and Children. Improved access to early infant diagnosis is a critical part of a child-centric prevention of mother-to-child transmission agenda. AIDS. 2013 Nov;27 Suppl 2:S197-205.
41. The Department of Civil Aviation, MACRA, VillageReach, GIZ and UNICEF (2019), Malawi Remotely Piloted Aircraft (RPA) toolkit.
42. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
43. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
44. USAID. Drones in International Development. Innovating the supply chain to reach patients in remote areas. https://www.usaid.gov/sites/default/files/documents/Drones_in_International_Development_Innovating_the_Supply_Chain_to_Reach_Patients_in_Remote_Areas_2_1.pdf
45. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
46. UPDWG (2022), MD3 Medical drone delivery database, https://www.updwg.org/md3/
47. www.updwg.org
48. WEF (2021) Medicine from the Sky: Opportunities and Lessons from Drones in Africa, http://www3.weforum.org/docs/WEF_Medicine_from_the_Sky_2021.pdf
49. World Economic Forum, 5 ways drones are saving lives and the planet, https://www.weforum.org/agenda/2021/09/drones-reforesting-restore-conservation-disease/
50. Unlocking the Lower Skies: The Costs and Benefits of Deploying Drones across Use Cases in East Africa, World Bank (2021), https://openknowledge.worldbank.org/handle/10986/35593
51. PWC (2016) Clarity from above. PWC global report on the commercial applications of drone technology, https://www.pwc.com/kz/en/services/drones-technologies/clarity-from-above-eng.pdf
52. Unlocking the Lower Skies: The Costs and Benefits of Deploying Drones across Use Cases in East Africa, World Bank (2021), https://openknowledge.worldbank.org/handle/10986/35593
53. Droneii (2022) Drone investments continue to break records, https://droneii.com/drone-investments-in-2021-break-records
54. Drone Industry Insights. 2021. This CAGR (Compound Annual Growth Rate) 15,5% is a conservative forecast, given the anticipated regulatory progress. If there will be strong changes in the near future, the number will be much higher, http://www.droneii.com/
55. AfDB (2019) Potential of the fourth industrial revolution in Africa https://4irpotential.africa/wp-content/uploads/2019/10/AFDB_4IRreport_Main.pdf
56. Droneii (2022) Drone investments continue to break records, https://droneii.com/drone-investments-in-2021-break-records
57. AUVSI (2013) The Economic Impact of Unmanned Aircraft Integration in the United States, https://cms.qz.com/wp-content/uploads/2013/03/econ_report_full2.pdf
58. Airbus (2017) The Great Enabler: Aerospace in Africa, https://www.airbus.com/content/dam/corporate-topics/publications/brochures/TheGreatEnable_AerospaceinAfrica.pdf
59. AfDB (2019) Potential of the fourth industrial revolution in Africa https://4irpotential.africa/wp-content/uploads/2019/10/AFDB_4IRreport_Main.pdf
60. Interview with Dumisani Kaliati, Founder and CEO, MicroMek, 2022.
61. Interview with James Munyoki Kiua, Founder and CEO, Swift Lab Limited, 2022.
62. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
63. Drones Doing Good Alliance (2019), When to use drones in critical healthcare logistics, https://2020.endeva.org/publication/ddg-alliance-when-to-use-drones
64. Interview with Nigel Breyley, Founder and CEO, Cyclops Air, 2022.
65. Interview with David Guerin, Consultant, World Bank Group, 2022.
66. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
67. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
68. WEF (2021) Medicine from the Sky: Opportunities and Lessons from Drones in Africa, http://www3.weforum.org/docs/WEF_Medicine_from_the_Sky_2021.pdf
69. Britannica, Locomotives on Highways Act, 1865, United Kingdom, https://www.britannica.com/topic/Locomotives-on-Highways-Act
70. Airbus (2017) The Great Enabler: Aerospace in Africa, https://www.airbus.com/content/dam/corporate-topics/publications/brochures/TheGreatEnable_AerospaceinAfrica.pdf
71. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
72. JARUS (Joint Authorities for Rulemaking of Unmanned Systems), (2019), JARUS Guidelines on Specific Operations Risk Assessment, http://jarus-rpas.org/sites/jarus-rpas.org/files/jar_doc_06_jarus_sora_v2.0.pdf
73. Interview with Oleg Aleksandrov, Aviation Officer, Head of RPAS-UAS unit, World Food Programme, 2022.
74. Downer, John. When failure is an option: Redundancy, reliability and regulation in complex technical systems. Centre for Analysis of Risk and Regulation, London School of Economics and Political Science, 2009
75. Interview with Zac Kennedy, Chief Regulatory Officer, Swoop Aero, 2022.
76. Interview with Dumisani Kaliati, Founder and CEO, MicroMe, 2022.
77. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
78. Interview with Zac Kennedy, Chief Regulatory Officer, Swoop Aero, 2022.
79. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022..
80. Interview with Tautvydas Juskauskas, Innovation Consultant, UNICEF Malawi, 2022.
81. Interview with Nicolas Brieger, Head of FIA / TCS Drone & Vertical Mobility Academy, Touring Club Schweiz TCS, 2022.
82. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
83. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
84. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
85. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
86. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.

87. Interview with David Sarley, Senior Program Officer, Bill & Melinda Gates Foundation, 2022
88. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
89. Interview with Daniel Ronen, Co-Founder, UAVAID, 2022.
90. Larry Madowo (2020),Silicon Valley has deep pockets for African startups – if you're not African, The Guardian, https://www.theguardian.com/business/2020/jul/17/african-businesses-black-entrepreneurs-us-investors
91. Friederici, N., Wahome, M., & Graham, M. (2020). Digital Entrepreneurship in Africa: How a Continent Is Escaping Silicon Valley's Long Shadow. The MIT Press. https://doi.org/10.7551/mitpress/12453.001.0001
92. Interview with Nicolas Brieger, Head of FIA / TCS Drone & Vertical Mobility Academy, Touring Club Schweiz TCS, 2022.
93. Interview with Tawanda Chihambakwe, Director, Precision Aerial, 2022.
94. Interview with Dumisani Kaliati, Founder and CEO, MicroMek, 2022.
95. Interview with Zac Kennedy, Chief Regulatory Officer, Swoop Aero, 2022.
96. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
97. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
98. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
99. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
100. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
101. Interview with Tautvydas Juskauskas, Innovation Consultant, UNICEF Malawi, 2022.
102. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
103. Interview with David Guerin, Consultant, World Bank Group, 2022.
104. Interview with Nigel Breyley, Founder and CEO, Cyclops Air, 2022.
105. Interview with Tautvydas Juskauskas, Innovation Consultant, UNICEF Malawi, 2022.
106. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
107. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
108. Interview with Jonty Slater, CEO - Head of Ideas and Challenges, Blue Globe Innovation, 2022.
109. Shannon G, McKenna MF, Angeloni LM, Crooks KR, Fristrup KM, Brown E, Warner KA et al. (2016) A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews 91:982–1005
110. Sordello, R., Ratel, O., Flamerie De Lachapelle, F. et al. Evidence of the impact of noise pollution on biodiversity: a systematic map. Environ Evid 9, 20 (2020). https://doi.org/10.1186/s13750-020-00202-y
111. Mulero-Pázmány M, Jenni-Eiermann S, Strebel N, Sattler T, Negro JJ, Tablado Z (2017) Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review. PLoS ONE 12(6): e0178448. https://doi.org/10.1371/journal.pone.0178448
112. Mulero-Pázmány M, Jenni-Eiermann S, Strebel N, Sattler T, Negro JJ, Tablado Z (2017) Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review. PLoS ONE 12(6): e0178448. https://doi.org/10.1371/journal.pone.0178448
113. Interview with David Guerin, Consultant, World Bank Group, 2022.
114. Interview with James Munyoki Kiua, Founder and CEO, Swift Lab Limited, 2022.
115. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
116. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
117. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
118. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
119. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
120. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
121. Interview with David Guerin, Consultant, World Bank Group, 2022.
122. Interview with Oleg Aleksandrov, Aviation Officer, Head of RPAS-UAS Unit, World Food Programme, 2022.
123. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
124. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
125. Interview with Rumbani Sidira, Chief Biomedical Engineer, Health, Technical Support Services (HTSS) department, Physical Assets Management (PAM) division, Malawi's Ministry of Health, 2022.
126. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
127. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
128. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
129. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
130. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
131. Jeyabalan, V., Nouvet, E., Meier, P., & Donelle, L. (2020). Context-Specific Challenges, Opportunities, and Ethics of Drones for Healthcare Delivery in the Eyes of Program Managers and Field Staff: A Multi-Site Qualitative Study. Drones, 4(3), 44. MDPI AG. Retrieved from http://dx.doi.org/10.3390/drones4030044
132. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
133. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
134. Humanitarian Code of Conduct, https://uavcode.org/code-of-conduct/
135. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
136. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
137. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
138. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
139. Interview with Nicolas Brieger, Head of FIA / TCS Drone & Vertical Mobility Academy, Touring Club Schweiz TCS, 2022.
140. Interview with Tawanda Chihambakwe, Director, Precision Aerial Group, 2022.

141. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
142. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
143. Interview with Nigel Breyley, Founder and CEO, Cyclops Air, 2022.
144. A digital turnkey is a device that prevents a drone from taking off without the approval of the CAA. This can potentially increase security, however, it can also cause delays and disruptions if the CAA does not approve flights in a timely manner. In addition, there is a risk that the CAA could be the target of intentional misuse and that an ill-intentioned party successfully hacks the CAA and can prevent operations from taking place. Similarly, forced landings involve the government forcing a return to launch or an emergency landing, however, this too opens a backdoor through which drones, including entire fleets, can be hacked and hijacked.
145. Interview with David Guerin, Consultant, World Bank Group, 2022.
146. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
147. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
148. Interview with Zac Kennedy, Chief Regulatory Officer, Swoop Aero, 2022.
149. Interview with Tawanda Chihambakwe, Director, Precision Aerial Group, 2022.
150. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
151. Servos are motorized gearboxes that are rotary or linear actuators that rotate and push parts of a machine with precision. In avionics they are often used to move the flaps and rudders.
152. Interview with Nicolas Brieger, Head of FIA / TCS Drone & Vertical Mobility Academy, Touring Club Scweiz TCS, 2022.
153. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
154. Seidenberger A. (2022), Drone Parachutes: A Reasonable Safety Feature? Global Aerospace Aviation Insurance, https://www.global-aero.com/drone-parachutes-a-reasonable-safety-feature/
155. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
156. Interview with Tautvydas Juskauskas, Innovation Consultant, UNICEF Malawi, 2022.
157. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
158. Interview with Nicolas Brieger, Head of FIA / TCS Drone & Vertical Mobility Academy, Touring Club Schweiz TCS, 2022..
159. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
160. UNICEF (2017) Africa's first humanitarian drone testing corridor, https://www.unicef.org/innovation/drones/africa-first-humanitarian-drone-corridor-malawi
161. ICT Works (2021) Why Rwanda beat Tanzania in UAV Drone Regulation and Experimentation, https://www.ictworks.org/tanzania-rwanda-uav-drone-regulation/#.Yir5fBBBzMI
162. Interview with Tautvydas Juskauskas, Innovation Consultant, UNICEF Malawi, 2022.
163. WEF (2019) What the world can learn from Rwanda's approach to drones, https://www.weforum.org/agenda/2019/01/what-the-world-can-learn-from-rwandas-approach-to-drones/
164. WEF (2019) What the world can learn from Rwanda's approach to drones, https://www.weforum.org/agenda/2019/01/what-the-world-can-learn-from-rwandas-approach-to-drones/
165. ICAO (2019) Development and Promulgation of Performance-based Regulations for Unmanned Aircraft Systems (drones), https://www.icao.int/Meetings/a40/Documents/WP/wp_518_en.pdf
166. ICAO (2019) Development and Promulgation of Performance-based Regulations for Unmanned Aircraft Systems (drones), https://www.icao.int/Meetings/a40/Documents/WP/wp_518_en.pdf
167. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
168. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.
169. Interview with Dumisani Kaliati, Founder and CEO, MicroMek, 2022.
170. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
171. Interview with Nigel Breyley, Founder and CEO, Cyclops Air, 2022.
172. Interview with David Guerin, Consultant, World Bank Group, 2022.
173. Interview with Zac Kennedy, Chief Regulatory Officer, Swoop Aero, 2022.
174. Interview with Innocent Mainjeni, Lead for Drones for Health in Malawi, VillageReach, 2022.
175. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
176. Federal Aviation Administration (2022) Aviation Safety Reporting Program (ASRP), https://www.faa.gov/uas/getting_started/asrp/
177. Interview with Lyela Mutisya, Drone Pilot Lead, and Sodiq Oloko, Director of Operations, LifeBank, 2022.
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180. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
181. Interview with Israel Bimpe, Director of Africa Go-To-Market, Zipline, 2022.
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184. Interview with Sunganani Kalilangwe, Principal Airworthiness Surveyor, Malawian Department of Civil Aviation, 2022.
185. Interview with Munezero Angelos, Public Sector Digitization Analyst, Rwandan Ministry of ICT and Innovation, 2022.

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December 2022

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